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La coordination des politiques budgétaires dans une union monétaire au taux plancher zéro

Résumé

Suite à la Grande Récession, les gouvernements de la zone Euro furent confrontés à des environnements économiques dégradés : de forts ratios de dette publique, des PIB en-deçà de leur tendance pré-crise et la possibilité d'une politique monétaire limitée par la contrainte de positivité des taux d'intérêt (Zero-Lower-Bound, ou ZLB). L'objectif de cette étude est d'évaluer dans quelle mesure les effets d'une politique budgétaire dans une région de la zone Euro affectent le reste de l'union monétaire, pourquoi ce phénomène est plus important en ZLB, et comment ce fait affecte les comportements des gouvernements à travers leurs interactions stratégiques.

A partir du modèle Mélèze, modèle DSGE budgétaire à deux zones développé au sein de l'Insee, et en estimant les chocs structurels sur la période 2004-2015, il est possible de répliquer les conditions où, en l'absence de chocs additionnels, la zone Euro aurait été contrainte par la ZLB de 2013 à 2015. En simulant les effets de divers chocs budgétaires, nous montrons que les externalités de la politique budgétaire d'une zone sur l'autre sont substantiellement plus importantes en l'absence de réponse de la politique monétaire. Elles croissent avec l'ampleur de la consolidation budgétaire, et peuvent atteindre un sixième de l'effet domestique dans le cas de mesure de réduction de la dépense, voire la moitié de l'effet domestique dans le cas de hausses de TVA.

En absence de ZLB, la zone dans son ensemble bénéficie de la coordination budgétaire dans la mesure où une expansion dans une région nuit au reste de l'union, en raison de la réponse de la politique monétaire. La coordination tend ainsi à limiter les mesures expansionnistes, même en l'absence de considérations dynamiques telles que la crédibilité de la politique monétaire. En ZLB, les objectifs nationaux sont plus alignés, et la politique coordonnée optimale est plus expansionniste. Enfin, la coordination encourage des politiques budgétaires symétriques plutôt qu'asymétriques (document en anglais).

Mots-clés : modèle DSGE, union monétaire, trappe à liquidité, politique budgétaire, coordination

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Fiscal Policy Coordination in a Monetary Union at the Zero-Lower-Bound

Abstract

Following the Great Recession, Eurozone governments faced adverse economic environments: high public debt to GDP ratios, depressed outputs and the prospect of monetary policy hitting the zero-lower-bound (ZLB). The goal of this paper is to assess how stronger cross-region fiscal policy spillovers arising from constrained monetary policy may lead to different strategic interactions. This paper also offers a detailed analysis of the fiscal policy trade-offs the Eurozone faced when monetary policy became constrained.

Using the Mélèze fiscal DSGE model developed at the Insee and estimating structural shocks to replicate the conditions where, absent any additional shock, the Eurozone economy would have been stuck at the ZLB for three years starting in 2013, we show that cross-border spillovers from fiscal policy are substantially higher without monetary offset. Increasing with the size of fiscal consolidation measures, they can amount up to a sixth of the domestic impact in the case of spending-based consolidations, and to almost half of the domestic impact in the case of VAT-based consolidations.

Outside the ZLB, there are gains from fiscal coordination across countries as expansion in one region benefits less to the whole union than for the region undergoing expansion due to the reaction of monetary policy. As such, cooperation tends to limit fiscal expansion, even in a static setting that does not take into account issues of rule credibility nor time inconsistency. At the ZLB however, monetary policy being constrained, national objectives tend to be closer and the coordinated policy is less consolidating. Moreover, cooperation encourages symmetric rather than asymmetric policies.

Keywords: DSGE model, monetary union, ZLB, fiscal policy, coordination

Classification JEL : E10, E61, E62, F45

1. Introduction

Following the large increases in public debts across the Euro Area after the 2008 financial crisis, a will to return to lower levels arose, either to reduce actual or perceived default risks that would drive up the cost of public debts, or to enhance future resilience and prepare for potential future shocks. However, fiscal consolidation tends to reduce activity in the short term, therefore creating a trade-off for governments between their willingness to reduce public debt levels and to foster the economy in the short term. Moreover, fiscal policy in one region of the Euro Area may affect the other region, either positively or negatively, notably because of monetary policy reaction. The goal of this paper is to analyze how these trade-offs are affected by the prospect of monetary policy becoming unresponsive to fiscal shocks (i.e. possibility of a *Zero Lower Bound* on interest rates). We use the *Mélèze* model developed at the Insee (Campagne & Poissonnier, 2016a), a state-of-the-art DSGE Model with imperfect trade in assets and two countries in a monetary union calibrated to distinguish two zones: a *North* region including Belgium, France, Germany and the Netherlands, and a *South* region including Greece, Ireland, Italy, Portugal and Spain. These two regions were characterized by different inflation, productivity and hence competitiveness paths in the decade preceding the crisis, and reached different levels of debts and outputs, which may lead to different incentives for fiscal policy. We consider two illustrative fiscal policy instruments, public spending and value-added tax, and consider only temporary shocks.

Our first contribution is methodological. In order to take into account the existence of two monetary policy regimes (constrained and unconstrained), we endogenize the possibility to reach or exit the ZLB and solve the model in a piecewise linear fashion following Guerrieri and Iacoviello (2015). In contrast with most previous analysis, we replicate the initial conditions that Euro Area governments faced when monetary policy reached the ZLB at the end of 2012. We back out structural shocks that replicate observed dynamics in the two regions from 2004 to 2015 and define fiscal policy as a deviation from this baseline scenario, taking the form of a temporary spending or VAT shock expected to last three years from 2013Q1 to 2015Q4. Then we simulate paths along a grid of different shock sizes, with *ex ante* deficit reduction ranging from − 5 % to + 5 % of steady state GDP. We then define a policy objective function for each region assuming the goal of governance is to increase output and reduce deficit, with decreasing marginal gains. We calibrate this policy objective such that inaction is the optimal policy at the steady state. We take a close look at the coordinated fiscal optimum at the ZLB and compare it to the uncoordinated Nash equilibrium. We also define the *sustainability* of the coordinated fiscal optimum as follows: a coordinated optimum is deemed sustainable when both regions are better off than at the Nash equilibrium. Because its implementation crucially depends on the willingness of governments to cooperate, we explore under which conditions the coordinated optimum is sustainable.

Our second contribution is positive and shows that in a monetary union, spillover effects from fiscal policy are substantially higher at the margin when monetary policy is constrained by the ZLB than when it is not: while the literature usually finds effects on foreign output that amount to 5 % to 10 % of the domestic effect outside the ZLB, we find that those can reach 15% for spending-based consolidations, and 50 % for VAT-based consolidations, when monetary policy is constrained. Spillovers are also stronger for consolidation packages than for stimulus packages, since a stimulus package will decrease the duration at the ZLB. The stronger spillovers arising from VAT-based consolidations in case of ZLB translate the fact that VAT hikes are less deflationary than public spending cuts, and have a stronger effect on the external demand of the consolidating country.

Our third contribution is normative. Assuming that policy objectives are to increase activity and primary balance with decreasing returns, we show in that theoretical framework that the optimal coordinated policy is more expansionary at the zero-lower-bound, because fiscal multipliers are higher. We also show that higher spillovers mean that regional and union-wide objectives are closer and thus, coordination by external fiscal rules (such as the Stability and Growth Pact) is less necessary. Finally, we show that absent any default risk or financial constraint, that is if the central bank effectively acts as a lender of last resort, optimal policy is somewhat similar between regions, because imperfect spillovers mean that stimulus in one region benefits that region more, and thus, when both regions are depressed, decreasing returns to activity and primary balance imply that both regions should act in similar ways.

As a result, for our calibrated policy objectives, the optimal coordinated spending policy when monetary policy hit the zero-lower-bound in 2012 would have been to increase spending by 1.3 % of GDP in the *North* and to decrease spending by 0.3 % of GDP in the *South*, which is close to the uncoordinated policy of increasing spending by 0.8 % of GDP in the *North* and increasing spending by 0.3 % in the *South*. Outside the zero-lower-bound, if monetary policy was not constrained, the optimal coordinated spending policy would result in strong consolidations with decreased spending of 2 % of GDP both regions, which is very different from the uncoordinated policy of increasing spending by 1.3 % of GDP in the *North* and no additional action in the *South*. Similar results are found for VAT-based policies. We find that in all cases, while not technically stable, the cooperative equilibrium is sustainable.

2. Literature

Our research question falls within a large body of literature on fiscal reforms, inter-regional spillovers and policy coordination. There are three main axes along which the effects of fiscal policies have been studied: *(i)* sizes of fiscal multipliers, *(ii)* trade-offs between short-term and long-term benefits of fiscal policy, and *(iii)* externalities in a monetary union.

Regarding the two first axis, the effects of fiscal policies are strongly dependent on the context (position in the business cycle, monetary policy stance, etc.) in which such policies are enacted, and on their content (productive/unproductive expenditures, tax composition, etc.). In a standard new Keynesian framework with independent monetary policy, the fiscal multiplier is typically lower than 1 (Coenen et al., 2012). Thus, Coenen et al. (2008), in a two-region DSGE model of the Euro Area and the United States, show that the effect of fiscal consolidation (defined as a decrease in the targeted value of public debt) is negative in the short run regardless of its composition, while it can be positive or negative in the long run, depending on its composition and the variable of interest. Similarly, using a world economy model with six regions and two types of households - liquidity-constrained and overlapping generations households - Clinton et al. (2011) show that short-term pain can be mitigated if the consolidation is permanent and lead to a long-term reduction of distortionary taxes with respect to the baseline case. In a monetary union, Roeger and in't Veld (2010) also show that permanent consolidations lead to less short-term costs, because the decrease in debt service costs in the long run has a strong positive effect on current expectations.

However, for strongly integrated economies, and beyond the domestic scope of fiscal policy, there may be sizable spillover effects on trading partners. Indeed, in a monetary union, fiscal policy not only affects demand addressed to other union members and the real effective exchange rate, but also the union-wide interest rate (Farhi & Werning, 2016). Similarly, Erceg and Lind (2013) study how currency union membership modifies the implication for the optimal composition of a fiscal consolidation package. They show that, at the domestic level, a tax-based fiscal consolidation may be preferable in the short run to a spending-based fiscal consolidation (defined as in Coenen et al. (2008)), in contrast with the standard case of an open economy with independent monetary policy. This stems from the fact that spending cuts are more deflationary, and while independent monetary policy will mitigate their effects, a more distant central bank will react less, which increases their effect on output. They also find that the size of spillovers on foreign activity varies between 1/5th to 1/10th of the domestic impact on activity. This scale of spillovers is in line with in't Veld (2013) or Cwik and Wieland (2011), that also find external spillovers of 1/10th to 1/20th of the domestic impact for transitory consolidation programs in one Eurozone member on its trading partners, and corroborates our results outside the ZLB.

In addition, in't Veld (2013) shows that during a crisis, if the share of liquidity-constrained households is high and monetary policy is at the zero-lower-bound, spillover effects can be even larger: a Euro Area-wide fiscal consolidation nearly doubles the negative effect on any given region, compared to the case where that region is the only one consolidating. Conversely, Cwik and Wieland (2011) argue that the positive effect of the German stimulus plan on other Euro Area economies was offset by the negative effect of a real effective exchange rate appreciation vis-a-vis the rest of the world. Note that, as mentioned above the stance of

monetary policy, and in particular if it is constrained by the zero-lower-bound, affects the fiscal multiplier (Christiano et al., 2011). More generally, and beyond the scope of the present paper, the conduct of fiscal policy (coordinated or uncoordinated) should take the whole economic environment into account. Indeed, Annicchiarico et al. (2013) show for instance, in the specific case of Italy, that fiscal consolidation substantially reduced the benefits of business-friendly reforms after the financial crisis, in part because of the lack of independent monetary policy response to offset the effects of fiscal consolidation. Likewise, Furceri and Mourougane (2010) show that when taking into account the feedback effect of risk premia on government bonds in a monetary union without lender of last resort, short-term effects of stimulus packages are still positive, even more so for spending or wage tax-based policies.

All in all, these papers clearly posit the existence of spillovers in a monetary union. As such, those spillovers need to be taken into account when designing consolidation or stimulus programs. Our paper directly follows this literature and takes a broader normative approach to see how fiscal policies could have been better coordinated post crisis within the Eurozone.

3. Model

Non-technical outline

We use the *Mélèze* DSGE model developed by Campagne and Poissonnier (2016a), derived from two standard models of the euro area, namely Smets and Wouters (2003) and Christiano et al. (2005), and designed to be as parsimonious as possible.[1] The current model consists of two aggregate regions in a monetary union trading partially substitutable goods. In each region, firms and households interact on the goods, labor and capital market. Both firms and households, as well as factors of production are considered immobile across countries, but cross-border financial flows are allowed in the union and with a Rest-of-the-World.

Firms produce partially substitutable goods from a standard constant return to scale production function. Given our short-term - cyclical rather than structural - focus, total factor productivity is exogenous and growing at the same pace across countries. At each period firms optimize their relative demand in capital and labor to minimize their production cost, taking the aggregate wage and gross return on capital as given. Partial substitution allows firms to price a mark-up over their marginal cost. In addition, the existence of price stickiness allows for monetary policy to play a role in our model. At each quarter, each firm can only reset its price with an exogenous probability. This price rigidity leads to a New Keynesian Phillips curve

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[1] A specific focus on fiscal authorities is made below and a detailed outline of complete model is provided in the online Appendix C1. Further robustness tests of both the calibration and the behavior of the model are exposed in Campagne and Poissonnier (2016a) and Campagne and Poissonnier (2016b).

where current inflation depends on past inflation, expected future inflation and the real marginal cost.

Households provide labor on monopolistically competitive markets. Hence, they are paid with a mark-up over their marginal disutility of labor. Each household can only reset its wage each quarter with an exogenous probability. To keep a simple labor market framework, there is no unemployment and labor only adjusts at the intensive margin.

In addition, following Gali et al. (2007), households are distinguished between *Ricardian* and *non-Ricardian*. This distinction enables to replicate credible private consumption behaviors following fiscal policy shocks. Therefore, a fraction of *Ricardian* households is financially unconstrained, hold financial assets (or debt) and own capital which they lend to firms in their region, whereas *non-Ricardian* households consume their full current income, and consequently do not hold any asset.

In each region, the government behaves according to a standard budget rule where public consumption ensures the convergence of the public debt to GDP ratio to its steady state level. Moreover, it collects taxes on wages, consumption and investment, provides lump-sum transfers and borrows on financial markets. Public debt is traded across borders, and we assume that because of incomplete financial markets public debt is the only tradable asset.

The central bank sets the nominal interest rate common to both countries through a Taylor rule (Taylor, 1993), where it reacts to current consumer price inflation. In simulations where we allow for the existence of a Zero-lower-bound, the effective nominal rate on households' wealth cannot fall below a particular level, slightly above zero, to account for liquidity spreads. Financial frictions, in particular debt default and associated feedbacks on the yield curve, are voluntarily left out of the model, where we focus on the case where the central banks effectively act as a lender of last resort. However, to ensure the convergence of our open economy model, financial spreads proportional to aggregate financial assets managed are introduced as in Schmitt-Grohe & Uribe (2003). Those spreads are calibrated to have a negligible impact on the model dynamic. The Rest-of-the-World, with which the currency union trades only in the form of assets, also obeys a budget rule to ensure convergence in the long-run.

Lastly, structural and policy shocks are introduced. Specific to each country, structural shocks hit preferences, productivity, labor supply and investment costs. Also, specific to each country, policy shocks hit public spending, public transfers shocks, cost of public debt and net foreign assets. The union-wide policy shock is a monetary policy shock. In the estimation part of the model, measurement errors are introduced on public assets and inflation.

Fiscal Authorities

Tax rates over consumption and labor are deterministic and arbitrarily chosen by the government. This

choice is consistent with a low variability of apparent tax rates in the data over the calibration period. In the absence of public production or employment in the present model, all dimensions of public expenditures are encompassed through public consumption, which endogenously reacts to economic developments. A noteworthy assumption is that public consumption is fully domestic. In addition, public investment (defined as public expenditures increasing public capital stock) is not considered as an instrument of public policy in the model. We discuss the impact of this simplification in further details in section V.

Lastly, government behavior is modeled through a budget rule inspired by Corsetti et al. (2010). This rule is such that each regional government follows a convergence criterion derived from the Stability and Growth Pact, and therefore adjusts its public expenditures in order to achieve an average yearly convergence ρ_g of 1/20th of the initial deviation from pre-crisis (steady state) debt levels to GDP.

$$G_t^i - \bar{G}^i = \rho_g \left(pa_{t-1}^i - \overline{pa}^i \right)$$

where G_t^i denotes the level of public expenditures in region i and $pa_t^i = PA_t^i / P_t^i \bar{Y}^i$ the public debt to GDP ratio. $\bar{G}$ and $\overline{pa}$ denotes the steady level of each variable.

All in all, the government is budget constrained by:

$$PA_t^i = \left(R_{t-1} - \psi^g \left(\frac{PA_{t-1}^i}{P_{t-1}^i \bar{Y}^i} \right) \right) PA_{t-1}^i + v_t^{c,i} CPI_t^i (C_t^i + I_t^i) + v_t^{w,i} W_t^i L_t^i - P_t^i G_t^i - \Phi_t^i$$

where PA_t^i denotes the nominal public assets of region i at the end of period t. The budget balance includes proceeds from value-added tax (v^c) levied on private consumption and investment valued at consumer prices $CPI_t^i (C_t^i + I_t^i)$, and from labor tax (v^w) levied on the wage bill $W_t^i L_t^i$. Public consumption is denoted G_t and Φ_t^i nominal transfers to households. In addition, R_t denotes the gross nominal interest paid on financial assets reduced/augmented by negligible transaction spreads $\psi^g \left(\frac{PA_{t-1}^i}{P_{t-1}^i \bar{Y}^i} \right)$.

4. Calibration

Structural and non-structural parameters

The model is calibrated to distinguish two regions within the Eurozone and match their pre-crisis situation: a *North* region including Belgium, Germany, France and the Netherlands, facing a *South* region encompassing Ireland, Greece, Spain, Italy and Portugal. *Northern* countries are those with lower inflation and thus higher competitiveness gains before the crisis, while the cut-off point was decided as to make the two zones of similar sizes. This criterion follows a core-periphery approach and reflects the idea that observed differences in pre-crisis competitiveness might partially explain the differences in post-crisis

responses with larger increase in public debts in countries such as Italy and Spain compared to Germany and the Netherlands.

The calibration is constructed to stay close to the traditional DSGE literature and to Eurostat's National Accounting data following a methodology similar to Campagne and Poissonnier (2016a).[2] It follows a two-step approach. First, "deep" structural parameters are calibrated based on an extensive literature review, and median values are selected within the range identified in the literature. When possible, country-specific data are used to construct adequate aggregate parameter values for both regions. Unfortunately, the lack of cross-country analyses crucially limits our ability to tailor region-specific calibrations, and a large number of parameters were calibrated to the EU empirical literature value. Moreover, even region-specific parameters tend to have identical values after regional aggregation (for instance, the degree of substitutability between goods). In a second step, remaining parameters are estimated by first order moment matching of observed data for a large number of endogenous variables (reverse inference) and subject to the steady state constraints.[3] All in all, values for the structural parameters and main endogenous steady state variables are presented in Tables 1 and 2. Parameters for inflation, TFP growth and technology are imposed to be equal across countries even if data suggests otherwise. As explained in Campagne and Poissonnier (2016a), these restrictions are necessary for the mathematical existence of a steady state solution[4].

Focusing on the fiscal policy block, the government follows a budget rule and hence targets a public debt to GDP ratio calibrated on National Accounting data.[5] We follow a calibration process similar to Coenen et al. (2008) for the calibration of NAWM (New Area-Wide Model of the Euro Area). Tax rates are calibrated using the implicit tax rates by economic function computed by Eurostat. Transfers (Φ^i) are used to clear the government budget constraints in the reverse inference process allowing to target the share of public consumption in GDP.

We also assume that public debts are considered safe by all agents. This assumption seems reasonable to us since as we simulate the effect of fiscal policy starting in 2013, and we argue that from December 2012 [6] the European Central Bank was perceived to act as a lender of last resort, and the importance of default risks' mechanisms for the conduct of fiscal policy was mitigated.

Note that in the long run our model represents a closed monetary union and the strict choice of a public debt

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[2] The methodology is presented in more details in the Appendix 1.

[3] Campagne and Poissonnier (2016a, 2016b) compare the simulations derived using this calibration procedure with standard DSGE models for standard transitory and/or permanent shocks. Results are in line with simulations presented in the extensive DSGE review in Coenen et al. (2012), as well as with the Insee-based macroeconometric model Mésange (Klein & Simon, 2010)

[4] If TFP growth was systematically higher in one region, it would have an infinite relative size at steady-state

[5] This debt to GDP ratio corresponds to public asset *net* of liabilities as a share of GDP and consequently differs from the debt in the sense of Maastricht relevant in the Stability and Growth Pact framework. However, the difference has no impact on the analysis later developed in the paper.

[6] Thanks to the now famous 'Whatever it takes' speech.

to GDP target implies that public debts for both governments have to be symmetrically found as private assets for households. Whereas the net foreign asset position of the North region vis-a-vis the Rest-of-the-World (including the rest of the Eurozone) is only 1% of GDP in 2007, and can therefore be neglected, the South net foreign asset position is of - 53% of GDP. This large external position is arbitrarily attributed within our regions, and the private assets to GDP ratios will not reflect actual data. In practice, the first order moment matching process suggests a solution where most of this external position is assumed to be held by South households.

in % if not specified elsewise	DATA		MELEZE	
	North	South	North	South
Output (GDP in billion euros)	1354	778	1354	778
Output per capita average growth rate[1]	2.3	1.3	1.9	1.9
Workin population (millions)	76.3	55.1	76.3	55.1
Total hours worked per week (thousands)	2765	2132	2765	2132
Gross Op. Surplus (in VA)	44.8	51.8	42.9	42.9
Gross wages (in VA)	54.2	46.7	42.5	42.5
Profit rate	-	-	14.6	14.6
Nominal 3 month Euribor[1]	3.2	3.2	3.2	3.2
Expected CPI-Inflation[1]	1.5	2.5	1.5	1.5
Private consumption (in GDP)	53.6	58.4	50.0	54.1
Public consumption (in GDP)	20.1	18.6	19.9	18.7
Investment (in GDP)	21.6	25.5	29.7	27.8
Trade balance (in GDP)	3.9	- 2.9	- 0.1	0.1
Imports from Euro area partner[2]	4.6	7.7	5.8	9.5
PPP (GDP, normalized to 1 in the North)	1.00	1.06	1.00	1.06
Gross consolidated general government debt (in GDP)[1]	- 62.0	- 80.0	- 62.0	- 80.1
Private assets including firms (S1 excl. S13,)[1]	40.0	5.0	107	5.6
Net financial position (S2)[1]	1.0	- 53.0	32	- 52.0
Implicit tax rate on consumption	20.6	17.5	20.6	17.5
Implicit tax rate on gross labor revenues	38.5	37.0	38.5	37.0
Implicit tax rate on capital revenues	26.9	34.5	25.2	36.3
Transfers (in GDP)	15.7	14.1	28.5	31.2

Sources: Eurostat, 2007 (ANA, inflation, Purchasing Power Parity (PPP), employment, Labor Force Survey), ECB average 2000-2007 (Euribor) and Eurostat, average 2000-2010 (CPI-inflation). North is Belgium, Germany, France and the Netherlands, South is Greece, Ireland, Italy, Spain and Portugal. S1 correspond to the whole domestic economy, S2 to the rest of the world and S13 to the public sector. (1) stands for annualized data and (2) for the share of imports from EU partners in private consumption

Table 1: Observed and simulated data at steady state

		North	South	
Union-wide				
Technology parameter	α	0.498		ANA
Depreciation rate	δ	0.016		D'Auria et al. (2009)
Capital rigidity	S	5.63		Smets & Wouters (2002)
Population size	$\mathbb{N}$	131417000		ANA
TFP growth rate*	g	1.9 %		ANA
Financial intermediation spread	ψ^g, ψ	0.005 %		Authors' computations
Monetary policy				
Smoothing parameter	ρ	0.9		Ratto et al. (2009)
Weight on inflation	r_π	1.68		Smets & Wouters (2003)
Regional specific				
Population share	n^i	0.58	0.42	ANA
Trade openness	α^i	5.8 %	9.5 %	ANA, authors' computations
Substitutability between goods	θ^i	6.85	6.84	D'Auria et al. (2009)
Substitutability between workers	θ_w^i	4.44 [EZC]	4.44 [EZC]	Bayoumi et al. (2004)
Households adjusted discount factor	$\widetilde{\beta}^i$	0.996	0.996	Authors' computations
Inverse risk aversion	σ_c^i	1.49 [EZC]	1.49 [EZC]	Smets & Wouters (2002, 2003)
Inverse Frisch elasticity	σ_l^i	1.69 [EZC]	1.69 [EZC]	Roeger et al. (2010)
Consumption habits	h_c^i	0.66 [EZC]	0.66 [EZC]	Roeger et al. (2010)
Share of non-Ricardian agents	μ^i	0.31 [EZC]	0.31 [EZC]	Roeger et al. (2010)
Price rigidity	ξ^i	0.88 [EZC]	0.88 [EZC]	Coenen et al. (2008)
Wage rigidity	ξ_w^i	0.66 [EZC]	0.66 [EZC]	Eggertsson et al. (2014)
Price indexation	γ_p^i	0.7 [EZC]	0.7 [EZC]	Authors' computations
Wage indexation	γ_w^i	0.8 [EZC]	0.8 [EZC]	Authors' computations
Fiscal policy				
Budget rule sensitivity	ρ_g	0.012	0.012	Authors' computations
Tax rate on consumption	$\bar{v}^{c,i}$	20.6 %	17.5 %	Eurostat (implicit tax rate)
Tax rate on net wages	$\bar{v}^{w,i}$	62.5 %	58.7 %	Eurostat (implicit tax rate)
Tax rate on capital revenues	$\bar{v}^{k,i}$	18.5 %	25.7 %	Eurostat (implicit tax rate)
Transfers to GDP ratio	$\overline{\Phi}^i$	27.8 %	31.3 %	Authors' computations
Government's objective (see section 6)				
Preference for spending-based consolidation	λ_g^i	0.34	0.37	Authors' computations
Preference for VAT-based consolidation	λ_c^i	0.47	0.48	Authors' computations
Output smoothing	σ_y	1	1	Authors' assumption
Deficit smoothing	σ_{pb}	5	5	Authors' assumption

ANA stands for Annual National Accounting data from Eurostat in 2007. Author's computations correspond to values determined by inverse inference as explained in the text. Papers cited for calibration are given as an example of a paper close to the median of our literature review. *EZC* stands for Eurozone Calibration and corresponds to parameters calibrated on Eurozone data in the absence of adequate region-specific information. North represents Belgium, Germany, France and the Netherlands, whereas South includes Greece, Ireland, Italy, Spain and Portugal. Parameters name are those in Campagne and Poissonnier (2016).

Table 2: Key structural parameters calibration

Baseline shocks

The Eurozone reached the Zero-Lower-Bound at the end of 2012, when the Euribor rate fell below 25 bps. We argue that fiscal shocks starting in 2013 may have had different effects on domestic and foreign outputs, that in turn affected the optimal behavior of regional governments.

Using Eurostat quarterly data on consumption, investment, output, public debt, inflation and interest rate, we estimate standard deviations and persistence of the following shocks from 2004 to 2012: monetary policy, productivity, preference, labor supply, investment cost, public spending and transfers, external assets and financial spreads, conditionally on the linearized model. We back out the corresponding structural shocks, extending the period to the end of 2015. Finally, we use a piecewise-linear model with two monetary policy regimes following Guerrieri and Iacoviello (2015), which we calibrate using parameters estimated on the linearized model and simulate trajectories with the estimated structural shocks. This approximation allows us to use a linear filter from 2012 to 2015, much simpler for a model of this size. Trajectories in the baseline scenario obtained using the linearized or the piecewise-linear model are very similar.

Following this procedure, Table A2-1 in Appendix 2 shows a measure of fit for each variable, as well as the dependency of the estimation to the calibration of crucial deep parameters like the share of *non-Ricardian* Households, the elasticity of substitutions across goods and across labor inputs. The best fit is obtained with the calibration presented in Table 2.

Underlying structural shocks, and their estimated persistence and standard deviation are detailed in Table A2-2 and Figure A2-I in Appendix 2. The financial crisis' impact is best characterized by a persistent and large (four standard deviations) exogenous shock on investment costs, by successive and persistent and moderate shocks on productivity (half a standard deviation), successive and very persistent shocks on labor supply, and a very persistent and large shock on public spending. Monetary policy is considered somewhat neutral compared to the Taylor rule, over the period, despite the very low rates.

Figure I shows the trajectory under the shocks previously estimated, as well as the point at which the model enters the Zero-Lower-Bound, denoted by the vertical line. Under that baseline scenario, output relative to its pre-crisis trend is depressed in both regions, as well as investment, consumption and hours worked. Public deficits are higher than their long-run average, especially in the South. Capital returns and interest rates are expected to stay low for long time.

This "baseline scenario" constitutes the central path of our simulations, around which the impact of additional fiscal shocks will be assessed, the question here being: in hindsight, knowing that the Eurozone economy would be stuck at the Zero-Lower-Bound for at least three years starting from 2013, what would have been the impact of more stimulus or more fiscal consolidation?
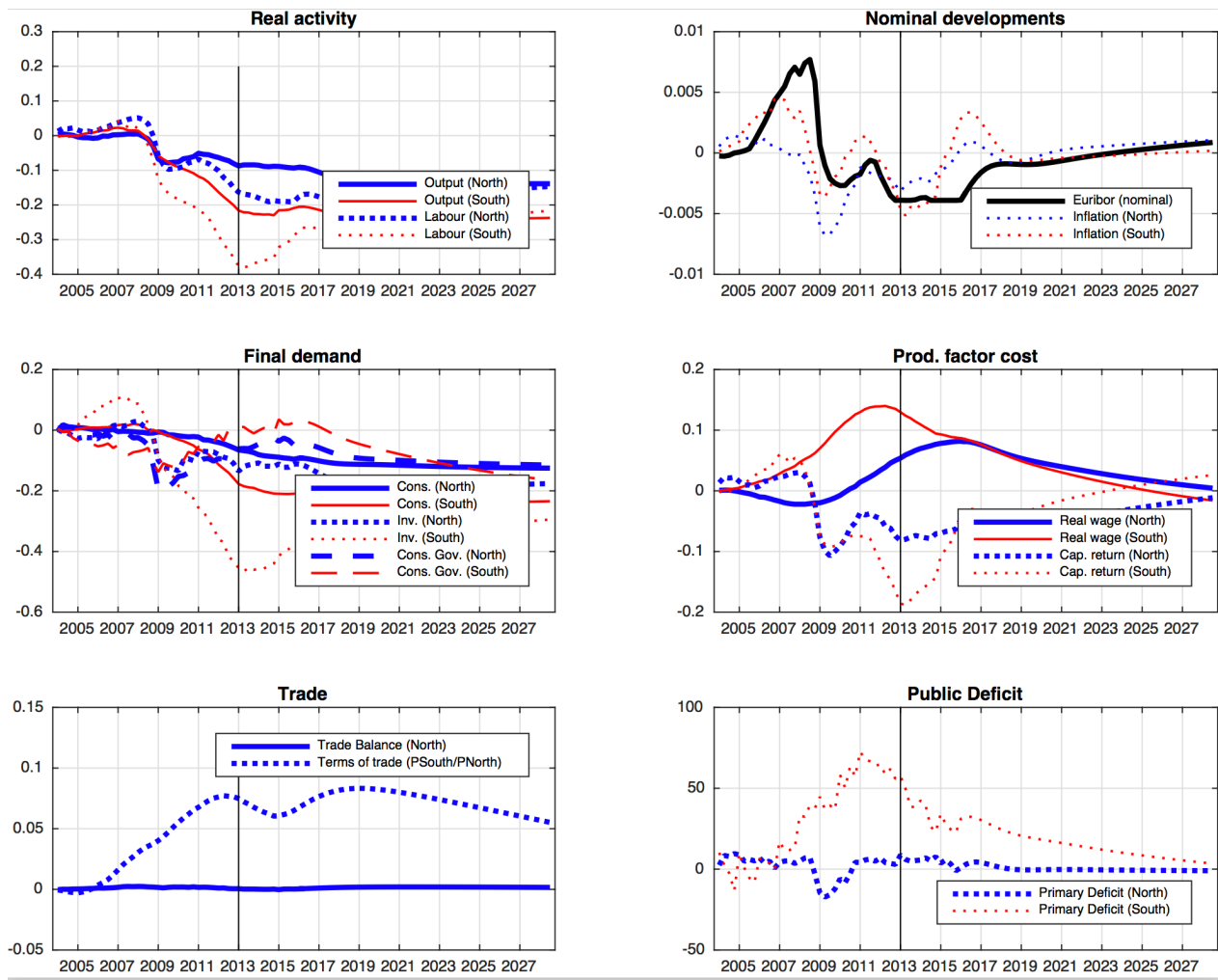
Real activity

Nominal developments

Final demand

Prod. factor cost

Trade

Public Deficit

North represents Belgium, Germany, France and the Netherlands, whereas South includes Greece, Ireland, Italy, Spain and Portugal. The trajectories correspond to the simulation around the steady state using estimated structural shocks.

Figure I: Baseline scenario

5. Fiscal multipliers

As can been seen in Figure II, the channels through which fiscal policy in one region affects output in the other region are external domestic demand, monetary policy and competitiveness. A stimulus package directly boosts domestic demand, with a positive effect on the output of the domestic economy. It also tends to have inflationary effects in the domestic economy, which may be offset by the central bank who sets higher interest rate. This hike will decrease aggregate demand in both the domestic and foreign economies and lead to negative spillovers. On the other hand, the resulting inflation differential, coupled with fixed nominal exchange rates, increases foreign competitiveness and thus, foreign exports. The positive effect on domestic demand also increases foreign exports, leading to positive spillovers. The net effect on foreign output then depends on how inflationary fiscal policy is relative to its effect on domestic imports.

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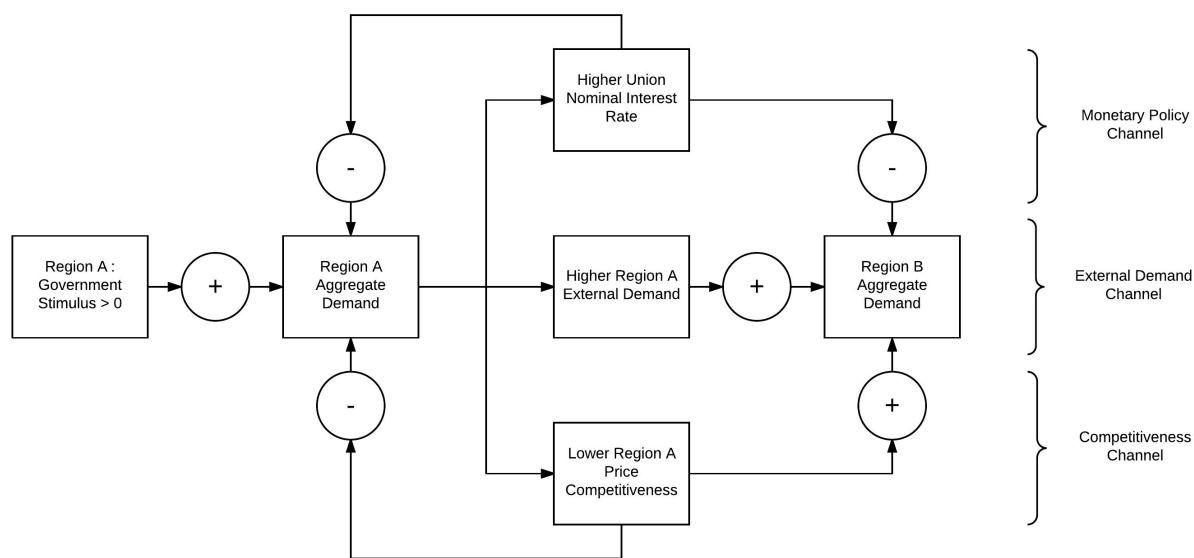
Figure II: Three propagation channels for spillovers of fiscal policy

Figures III and IV display the impact and cumulative marginal multipliers of spending-based and VAT-based temporary[7] fiscal consolidations of different sizes on domestic and foreign output, under the two cases, as deviations around the baseline scenario outlined above. As detailed in Campagne and Poissonnier (2016b) for the purely linear case, those multipliers compare with those obtained in most institutional DSGE models as well as with macroeconometric models[8].

First, as expected, in the case of stimulus packages big enough to immediately lift the Eurozone out of the ZLB, the marginal effect of the last unit spent or raised is constant. In the case of spending shocks, the impact multiplier is around 1.1 while the 3-years average multiplier is comprised between 0.4 and 0.5. The effect on foreign output, yet relatively small, goes opposite to domestic consolidation or expansion in the short and medium run translating the fact that, with our calibrations and our assumption that public consumption is entirely domestic, the monetary offset effect is higher than the external demand effect: if the North implements a spending-based deficit reduction outside the ZLB, the subsequent decrease in interest rate by the central bank dominates and favors activity in the South.

In the case of VAT shocks outside the ZLB, impact and cumulative multipliers are similar and around 0.5 at impact. Spillovers on foreign output go in the same direction as Northern output and are negligible on impact. This translates the fact that VAT increases are less deflationary than spending cuts, and also that

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[7] with an average duration of twelve quarters
[8] See Coenen et al. (2012) for a thorough comparison of fiscal multipliers across IMF, OCDE, and central banks' DSGE models, and Klein and Simon (2010) for the French macroeconometric model *Mésange*.

their effect on consumption has a bigger impact on external demand, both of which tend to correlate the domestic and the foreign effect. However, over three years, spillovers are weaker and even slightly negative as for public spending cuts.

Second, at the ZLB, the marginal effect of fiscal policy on domestic as well as foreign output changes. Spending cuts tend to have an increasing negative effect on domestic output and a negative and increasing effect on foreign output. In the case of VAT shocks, the effect is even stronger.

Figures A3-I and A3-II in Appendix 3 show that the spillovers, *i.e.* the marginal multiplier on foreign output relative to the marginal multiplier on domestic output, increase significantly with the size of the consolidation package, a conclusion that is robust to several calibrations. In particular, the marginal effect of big VAT-based consolidation in the North on the South's output is between 20 % and 50 % of the domestic effect, compared to only - 20 % in the linear case. Cooperative governments will take this externality into account.

As previously mentioned in section 3, those public spending multipliers rely on the simplification of all public spending into public consumption, while in the current context of low TFP growth in the Euro area, international institutions advise changes in the composition of fiscal spending in order to favor public investment and support potential growth. In the long run, public investment shocks are indeed expected to have higher multipliers than public consumption.

However, in the short run, fiscal multipliers tend to be close (Coenen et al., 2012) and the productivity boost of public investment with respect to public consumption materializes slowly (around five years in Abiad et al. (2015) or using the European Commission Quest III model). As such, focusing in the present paper on short-lived and transitory fiscal behaviors, we can expect to obtain similar results with public investment over the short and medium term, as transmissions channels would not differ significantly. In particular, our model remains focused on business cycles and does not include endogenous growth mechanisms that would allow higher long-term fiscal multipliers of public investment.

Effects are normalized as the ratio of the marginal effect on output of the additional fiscal shock to its ex-ante size as a percentage of domestic GDP. Responses to a fiscal shock in the North are in blue, to a fiscal shock in the South are in red. Dotted lines (LIN) corresponds to multipliers in the linear case, whereas solid lines (ZLB) corresponds to the existence of a zero lower bound. Lastly, "1st quarter" corresponds to the impact multiplier, whereas "3-year average" corresponds to a multiplier computed over three years. Lower spillovers from Southern fiscal shocks partly relates to the smaller size of the South region. These figures read like regular multiplier: when positive, the effect of a consolidation on domestic (resp. foreign) output is negative.

Figure III: Marginal fiscal multipliers of spending-based consolidation

Effects are normalized as the ratio of the marginal effect on output of the additional fiscal shock to its ex-ante size as a percentage of domestic GDP. Responses to a fiscal shock in the North are in blue, to a fiscal shock in the South are in red. Dotted lines (LIN) corresponds to multipliers in the linear case, whereas solid lines (ZLB) corresponds to the existence of a zero lower bound. Lastly, "1st quarter" corresponds to the impact multiplier, whereas "3-year average" corresponds to a multiplier computed over three years. Lower spillovers from southern fiscal shocks partly relates to the smaller size of the South region. These figures read like regular multiplier: when positive, the effect of a consolidation on domestic (resp. foreign) output is negative.

Figure IV: Marginal fiscal multipliers of VAT-based consolidation

6. Policy coordination

Policy objective

Regional governments are expected to obey a simple budget rule linking current public consumption to past level of public debt, whole sole objective is to stabilize the debt-to-GDP ratio around its steady-state level. However, the realism of such a rule might be questioned when big shocks occur. Following the 2008 crisis, governments in the Euro Area implemented successive additional fiscal plans. This suggests that, given their national preferences and the global environment, governments may choose to foster activity at the cost of debt convergence or, on the contrary, to achieve a faster debt convergence at the expense of activity.

Our goal is to analyze how governments in each region could have decided to accelerate or reduce the pace of debt convergence by implementing additional fiscal policies when the Zero-Lower-Bound was reached.

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For illustrative and simplification purposes, we consider fiscal policies that take the form of a punctual change in public consumption or VAT, starting in 2013. Effects of the initial shocks then propagate exogenously by following an auto-regressive process with a persistence calibrated as to amount to an average duration of twelve quarters.

In order to model governments behaviors, we focus on a *policy* approach based on the definition of an objective function for the government weighing its preference for deficit reduction against activity. We assume governments maximize an objective function (or minimize a loss function). We consider a static *game*, meaning that the government decides in 2013Q1 which fiscal surprise shock will be implemented, while agents in the model do not expect the government to act strategically.

We assume that there exists a trade-off between fostering activity and reducing the deficit. However, the definition of such preferences is a difficult task and relates to the construction of an adequate objective function for the fiscal authorities, analogous to the central bank loss function used to derive optimal Taylor rules (Gali, 2008). We argue that a reasonable objective function needs to answer to a few constraints or expected properties: (*i*) it increases with activity, (*ii*) it decreases with the public deficit, (*iii*) it should not "unreasonably" favor one objective over the other, (*iv*) the government tries to smooth both its deficit and activity over the medium-term.

The two first properties represent the trade-off between fostering activity and improving debt sustainability. The third property relates to the fact that governments will not seek to boost activity by such an amount that debt will explode, and vice versa. The fourth property ensures that the further from the steady state a deviation is, the costlier it is. We also assume that spending-based and VAT-based consolidation have separable effects on governments' payoffs.

Having in mind all of these suitable properties, we assume government i will seek to maximize the static payoff V^i, choosing public consumption and VAT surprise shocks leading to a *ex ante* deficit reduction of respectively v^g % and v^c % of GDP:

$$V^i(v^g, v^c) = \sum_{t=0}^{H} \left(\frac{\left[1 + \hat{y}_t^i(v^g, v^c)\right]^{1-\sigma_y} + 1}{1 - \sigma_y} + \lambda_g^i . \frac{\left[1 + \bar{pb}\hat{pb}_t^i(v^g)\right]^{1-\sigma_{pb}} + 1}{1 - \sigma_{pb}} \right.$$
$$\left. + \lambda_c^i . \frac{\left[1 + \bar{pb}\hat{pb}_t^i(v^c)\right]^{1-\sigma_{pb}} + 1}{1 - \sigma_{pb}} \right)$$

where $\hat{y}(v^g, v^c)$ is the percentage deviation of output from its steady state level, $\bar{pb}\hat{pb}(v^g)$ (resp. $\bar{pb}\hat{pb}(v^c)$) is the spending-based (resp. VAT-based) deviation of primary balance from steady state, expressed in unit of GDP. The parameter λ_g^i (resp. λ_c^i) defines the preference for spending-based (resp.

VAT-based) fiscal consolidation and H is both the expected length of the fiscal policy and the government's objective horizon, here twelve quarters. Finally, σ_y and σ_{pb} define the degree of smoothing preference for each government.

Lacking appropriate data to calibrate the parameters λ_g^i and λ_c^i, we assume that governments have no incentive to deviate from the budget rule when the economy is at the steady state. Namely, in the absence of shocks, we assume that governments will hold to the budget rule and choose to maintain a debt to GDP ratio at its target. This assumption implies that, in the vicinity of the steady state, $\partial V / \partial v^j (v^j = 0, v^{-j} = 0) = 0$. In other words, the marginal effects on the government payoff of a public consumption shock v^g (resp. of a VAT shock v^c) cancel each other for λ_j^i given by:

$$\lambda_j^i = \left(\sum_{t=0}^{H} \frac{\partial \hat{y}_t^i}{\partial v} (v^j = 0, v^{-j} = 0) \right) \left(\sum_{t=0}^{H} \frac{\partial \hat{p} \hat{b}_t^i}{\partial v^j} (v^j = 0) \right)^{-1}$$

Table 2 gives the resulting calibrated values of λ^i for each government. A calibrated value of around 1/3 means that at the steady state, the payoff of a 3-percentage points improvement in the primary deficit or a 1 percentage point improvement in output is the same. Since the λ^i are calibrated as to maximize the governments payoff at the steady state, they depend on the government spending marginal multiplier at the steady-state and the elasticity of the primary deficit to output. We assume a log-utility for output ($\sigma_y = 1$) and calibrate $\sigma_{pb} = 5$ as the minimum value leading to interior solutions in the allowed range of possible fiscal shocks (ie. *ex ante* deficit reduction of − 5 % to + 5 % of GDP).

Optimal Policy

As shown in section 5, there exist union-wide spillovers from regional fiscal policies. Therefore, there is room for strategic interactions within the monetary union. Outside the ZLB, and following and consolidation package in the North, expansionary monetary policy will have positive effects in the South, and objectives will diverge. However negative spillovers will prevail at the ZLB and regional objectives will converge. The optimal amount of coordination will thus differ whether monetary policy is responsive or not.

As in Mendoza et al. (2014), we study the solutions to one-shot cooperative and non-cooperative games defined as follows.[9] The strategy space is defined in terms of pairs of instrument values (v^N, v^S) chosen by regional governments [10]. As explained in the previous section, the game is static with payoffs taking into account the dynamic of the economy over an horizon of twelve quarters. We also assume that the strategy

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[9] We keep the notations of Mendoza et al. (2014).
[10] For simplification purposes, we suppose that governments use only one instrument at a time, that is $(v^N, v^S) = (v^{N,g}, v^{S,g})$ or $(v^N, v^S) = (v^{N,c}, v^{S,c})$, making the policy space two-dimensional.

space does not include the possibility of transfers from one region's government to the other. Each regional government chooses its instrument value so as to maximize the objective functions V^i defined in the previous section. Given the decision v^j of the region j's government, the best response of region i is given by:

$$v^{i,\mathring{a}}(v^j) = \underset{v^i}{argmax}V^i(v^i|v^j)$$

The *Nash non-cooperative* equilibrium is therefore given by the intersection of both best response curves at $\left(v^{N,\mathring{a}}(v^{S,\mathring{a}}), v^{S,\mathring{a}}(v^{N,\mathring{a}})\right)$. We define the *cooperative* equilibrium as the solution from the optimization program of a union-wide social planner with the following payoff:

$$\omega V^N(\tau^N|\tau^S) + (1 - \omega)V^S(\tau^S|\tau^N)$$

where ω defines the weight attributed to the North region. Our central assumption is that regions are weighted according to their population share (that is 58% for the North and 42 % for the South), but this may not always be the case and therefore, multiple cooperative equilibrium can be sustained for different values of ω.

Each of these cooperative equilibria is said to be *sustainable* if and only if both countries are at least as well off as under the Nash equilibrium. Although each decision maker will have an idiosyncratic incentive to deviate from the coordinated policy, we assume that she expects that deviating will result in the other decision maker also deviating. Both decision makers agree to stay at the cooperative equilibrium if they are both better-off by doing so.

In practice, since our solution is non-linear, we only solve for solutions on a discrete grid. At each node (v^N, v^S) within a given set of potential fiscal shocks ranging from *ex ante* deficit reductions of -5 % to 5 % of GDP*)*, we simulate the trajectory of the economy and compute the values of Northern and Southern objective functions.

Note that for all the following figures, shocks are expressed (and grid is indexed) by this *ex ante* effect on the deficit expressed in % of GDP.

Figure V-A: Spending Shock, 'North' Objective

Figure V-B: Spending Shock, 'South' Objective

Figure V-C: VAT Shock, 'North' Objective

Figure V-D: VAT Shock, 'South' Objective
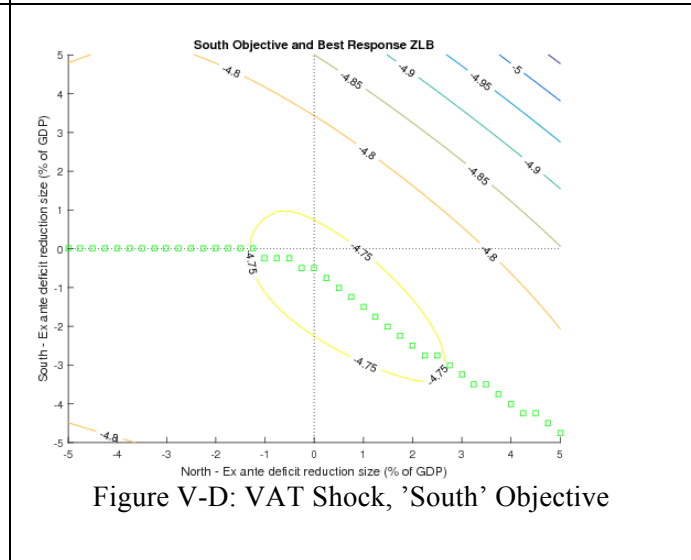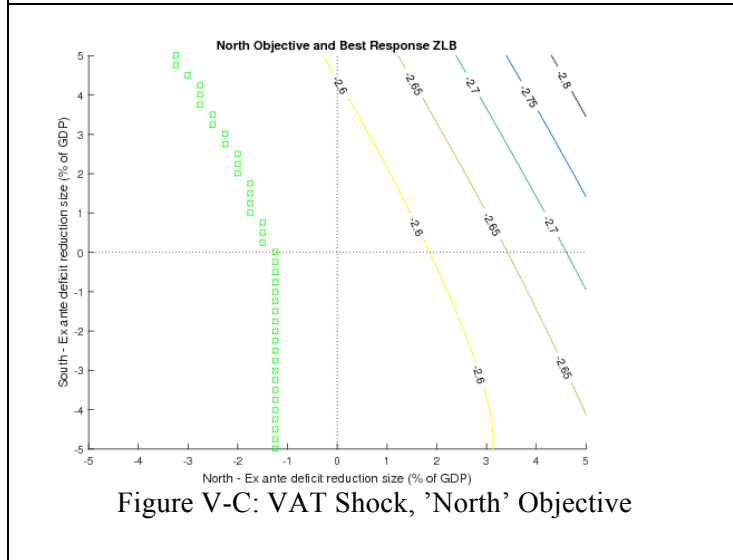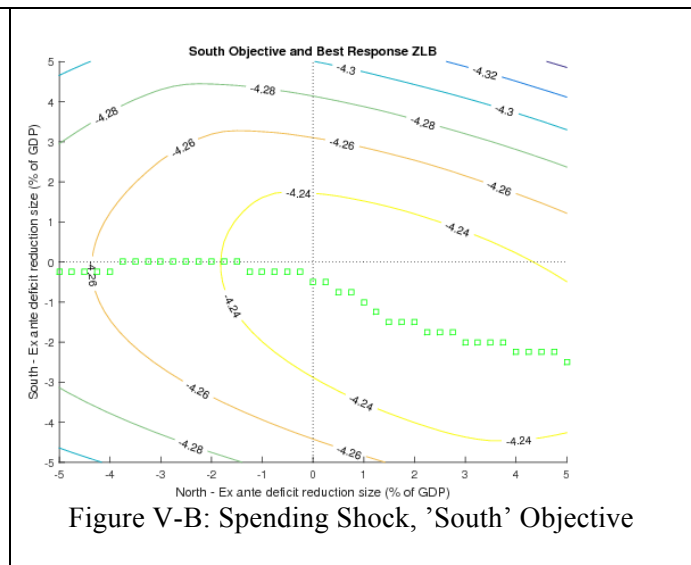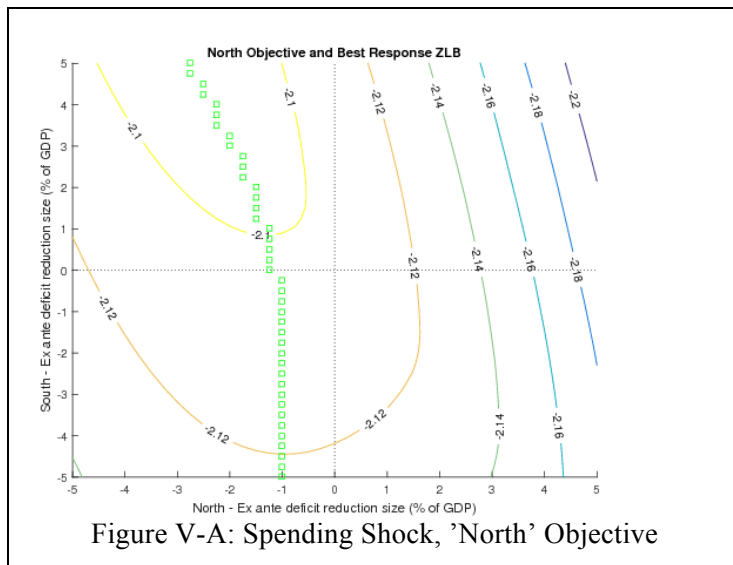
Governments' objectives being surfaces, they are displayed through multiple iso-payoff curves. Green squares are best responses.

Figure V: Governments' objectives and best responses

Strategic vs cooperation

Figure V displays each regional governments' payoff (that is, the value of the objective function) for the two fiscal shocks of interest, and their best responses to each possible action of the foreign government[11].

Those first figures can be analyzed along three dimensions:

1. For a given foreign action, what is the optimal domestic strategy?
2. How does that optimal domestic strategy vary with the foreign action?
3. What is the combination of shocks that maximizes the domestic government's payoff?

Consider spending shocks from the point of view of the North region (top left panel). If the South chooses inaction, the optimal action of the North is to implement a small stimulus package, of around 1.5 % of GDP. This choice (*i.e.* the value of the curve's x-intercept) depends on the North's preference for consolidation: both output and public balance were below their long-term value, the North has to choose which it favors. Moreover, the more the South chooses to consolidate (moving upward on the figure), the more deflationary pressures to the economies and the longer the duration of the ZLB. Therefore, a domestic consolidation package would become costlier to the North. Hence, North's optimal choice shifts to the left on the figure, towards a bigger stimulus package, and the overall best response slope for the North region is negative. Finally, as spending-based consolidations tend to have positive (but decreasing) spillovers inside the ZLB, the global maximum of the North's payoff function is obtained when the South consolidates a lot and the North compensates by stimulating. This global maximum is out of the range of allowed fiscal shocks. A symmetric behavior is observed for the South region Consequently, the uncoordinated equilibrium is to increase spending by 1.25 % of GDP in the North and increase spending by 0.25 % of GDP in the South. Considering VAT shocks, the form of the best responses of North and South region are similar: due to the positive spillovers of VAT shocks, the North chooses stimulus packages when the South consolidates a lot, and the situation is symmetric for the South.

Now, superposing both best responses, Figure VI compares the resulting Nash equilibrium to the optimal coordination equilibrium, and assesses the sustainabiliy of the coordination equilibrium under different weights attributed to each country. Panels on the left display the average objective of the entire monetary union when each region are weighed according to their population share, and compares it to the strategic interaction. In both case (public spending or VAT shock), the optimal and strategic equilibria are close, translating the fact that when foreign and domestic are similarly impacted by a domestic package, uncoordinated policies tend to be closer to the optimum. Given the level of output and primary deficit in 2013Q1 (compared to the steady state), optima tend to be in the upper left quadrant, which means more

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[11] The action $(v^N, v^S) = (0,0)$ corresponds to the baseline scenario detailed in Section 4.2.

fiscal stimulus in the North and more fiscal consolidation in the South than in the baseline scenario. The panels on the right show that for regions weights that are close to the population share, the cooperative equilibrium is sustainable.

By comparison, Figure VII shows the same graphs, with the same calibration but in the case where monetary policy is never constrained by the Zero-Lower-Bound. In that case, spillovers are smaller or negative, and best responses are less reactive. Indeed, when foreign actions by the other government do not affect significantly the domestic multiplier, the optimal choice by the domestic government mostly depends on the domestic trade-off between fiscal consolidation and activity fostering policies. Moreover, when spillovers are small or slightly negative, coordinating fiscal policies becomes preferable. Consequently, outside the ZLB and in the spending public case, the uncoordinated equilibrium would be to increase spending by 1 % of GDP in the North and do nothing in the South. The North-East location of the cooperative equilibrium with respect to the Nash equilibrium means that both countries would prefer the other country to consolidate more.

Outside the ZLB, the cooperative equilibrium is "far" from the Nash equilibrium. Given negative spillovers of fiscal expansion in one country due to the monetary contraction, each region wishes its partner to consolidate, so as to benefit from the resulting monetary expansion. Coordination would therefore lead to more consolidation by both regions than their natural tendency to do so. Stated in terms of our government objectives, the loss implied by the stronger consolidation in one region will be offset by the partner's stronger consolidation, and therefore be smaller than at the Nash equilibrium. All in all, both regions will be better off at the cooperative equilibrium.
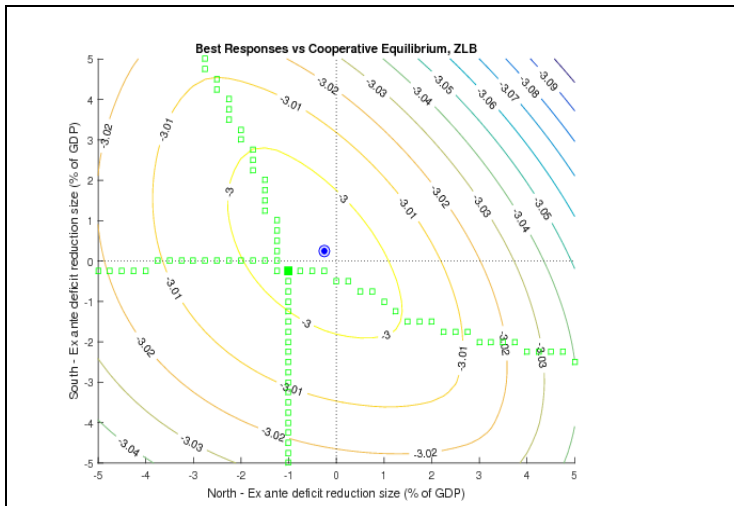
Figure VI-A: Spending Shock, Eurozone Objective
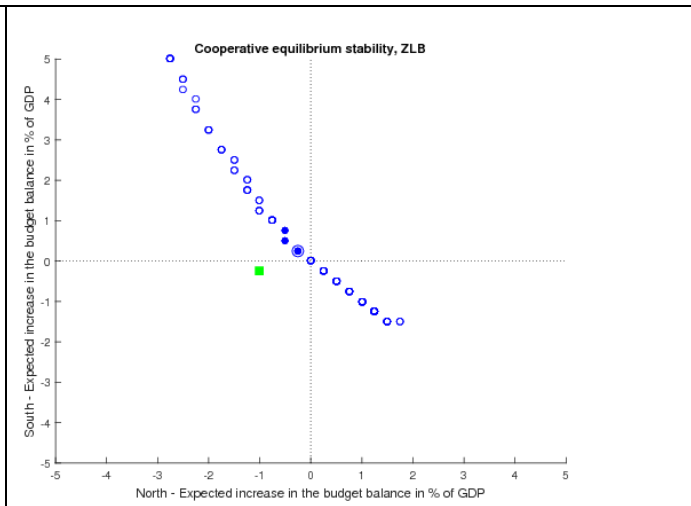
Figure VI-B: Spending Shock, Cooperative equilibria
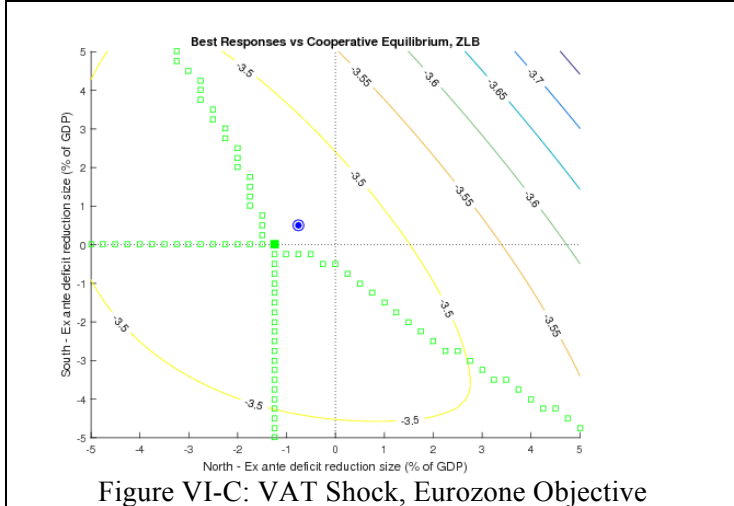
Figure VI-C: VAT Shock, Eurozone Objective
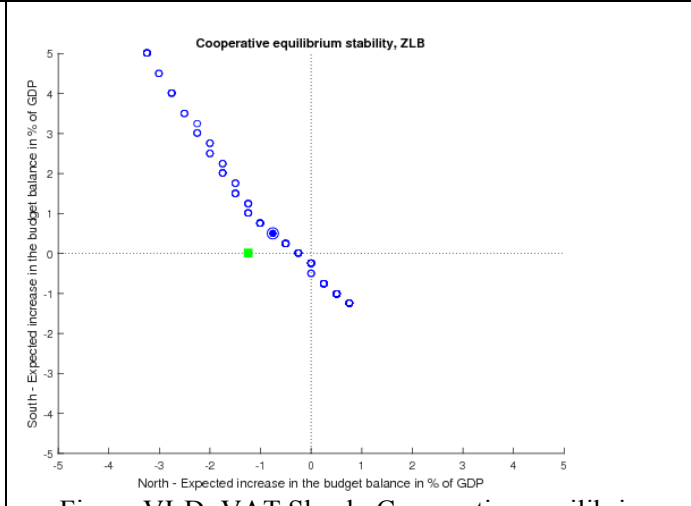
Figure VI-D: VAT Shock, Cooperative equilibria

On the left figures, the Eurozone aggregate (cooperative) objective being a surface, it is displayed through multiple iso-payoff curves. Uncoordinated strategic interactions are represented by empty green squares for best responses. The Nash equilibrium corresponds to the filled green square. The cooperative equilibrium using population weights is indicated by the blue circle. On the right figures, the weight associated to the North region in the aggregate cooperative objective varies from 0 to 1, and the corresponding cooperative equilibrium are still represented by blue circles. Full circles are sustainable equilibria; empty circles are unsustainable equilibria.

Figure VI: Uncoordinated vs cooperative equilibria at the ZLB
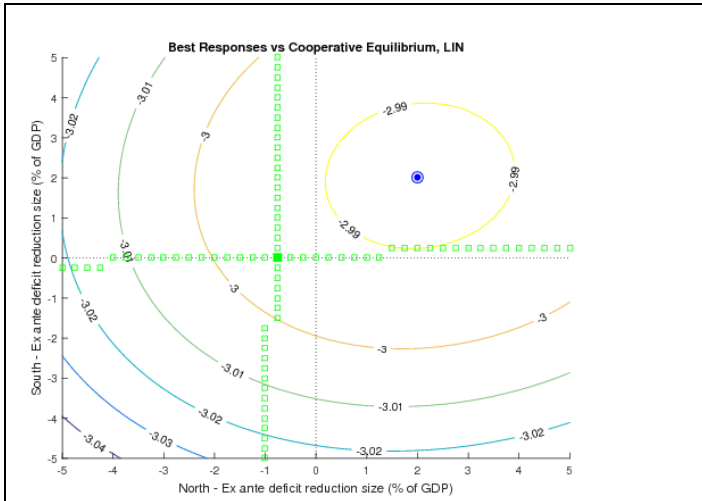
Figure VII-A: Spending Shock, Eurozone Objective
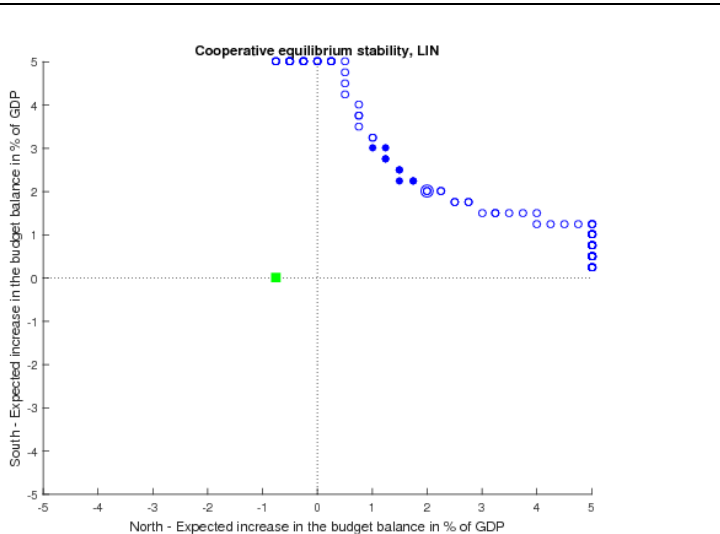
Figure VII-B: Spending Shock, Cooperative equilibria
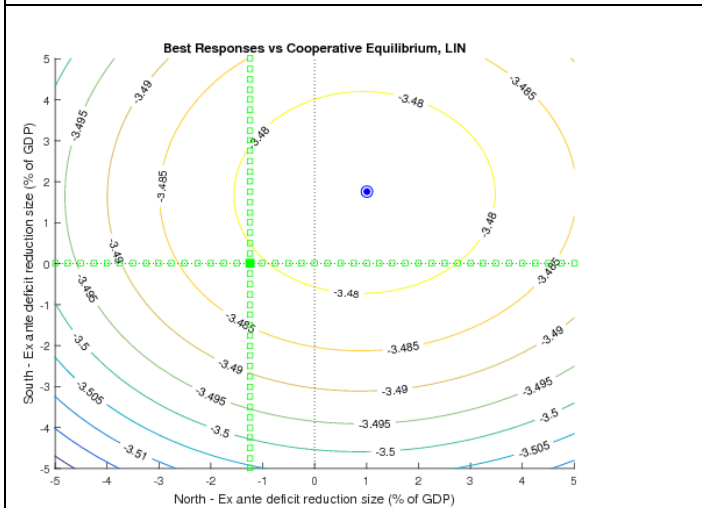
Figure VII-C: VAT Shock, Eurozone Objective
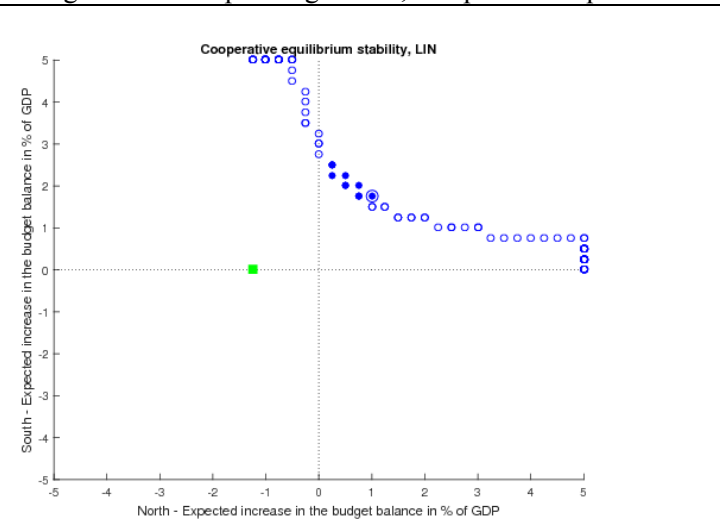
Figure VII-D: VAT Shock, Cooperative equilibria

On the left figures, the Eurozone aggregate (cooperative) objective being a surface, it is displayed through multiple iso-payoff curves. Uncoordinated strategic interactions are represented by empty green squares for best responses. The Nash equilibrium corresponds to the filled green square. The cooperative equilibrium using population weights is indicated by the blue circle. On the right figures, the weight associated to the North region in the aggregate cooperative objective varies from 0 to 1, and the corresponding cooperative equilibrium are still represented by blue circles. Full circles are sustainable equilibria; empty circles are unsustainable equilibria.

Figure VII: Uncoordinated vs cooperative equilibrium outside the ZLB

7. Conclusion

Using the *Mélèze* fiscal DSGE model developed at the Insee and estimating structural shocks to replicate the conditions where, absent any additional shock, the Eurozone economy would have been stuck at the ZLB for three year starting in 2013, we have shown that in a monetary union, when monetary policy is constrained by a Zero-Lower-Bound episode and the duration of this episode is endogenous, domestic effects of fiscal policy on output are in general much larger than when monetary policy is unconstrained.

Second, spillover effects from fiscal policy are substantially higher at the margin when monetary policy is constrained than when it is not. Increasing with the size of fiscal consolidation measures, spillover effects can amount up to 15% of the domestic impact in the case of spending-based consolidations, and to 50% of the domestic impact in the case of VAT-based consolidations.

Outside the ZLB, there are gains from fiscal coordination across countries as consolidation in one region benefits to the activity of the other region due to the reaction of monetary policy. At the ZLB however, national objectives tend to be closely related and there are fewer gains from consolidation. The existence of a ZLB and consequently of higher spillovers implying closer regional and union-wide objectives implies that one of the rationales behind coordination of fiscal policies by external fiscal rules such as the Stability and Growth Pact is less stringent in the current economic environment. However, as the recovery strengthens in the Eurozone, and as the normalization of monetary policy is closing in, divergence across national objectives will gradually increase, and as for gains from cooperation. Therefore, a thorough and in-depth reflection could be engaged on the design and the implementation of fiscal rules in the EU.

This sets path for future research on the improvement of fiscal policies interactions in the Eurozone. Within the scope of the current paper, future work will focus on the study of more detailed fiscal packages allowing for shocks of different duration across regions, possibly permanent, or for mixed packages combining both tax and spending-based stimulus. One main limit of our analysis is the fact that most structural parameters are calibrated. This could be improved, notably by estimating the share of financially-constrained households, likely to play a role in the dynamic during the recession.

Lastly, going beyond the retrospective analysis of the 2008 crisis and going forward, in the current environment of low growth, focusing on permanent fiscal shocks should also require to address the impact of composition of public expenditures and receipts on potential TFP growth. As international organizations are now calling for more public investment expenditures, distinguishing between public consumption and investment in the present model will be key first steps.

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Appendix 1: Calibration

In the linearized form of the model, we identify three sets of parameters: *(i)* structural parameters, *(ii)* policy parameters and *(iii)* reduced-form parameters. First, structural parameters are parameters (technology, preferences, etc.) deemed purely exogenous, accounting for mechanisms outside of the model and not susceptible to change across simulations. Second, policy parameters correspond to discretely chosen parameters by fiscal and monetary authorities such as the inflation target and the tax rates. Lastly, some reduced-form coefficients of the model cannot be calibrated freely and are combinations of actual steady state values of the endogenous variables determined by the steady state equations. These coefficients are solved for a given set of structural and policy parameters.

Most structural parameters are calibrated based on the DSGE literature, and in order to set policy parameters to their observed values.

First, a few structural parameters are calibrated on National Accounting data. That is the case for the headcount of the total employed population $\mathbb{N}$, the respective regional share of this population n, the quarterly GDP per capita growth rate g, the HICP quarterly inflation $\overline{\Pi}$, and α^i the degree of trade openness. For the latter, intra-area trade flows are explicitly taken into account using bilateral trade data from the CHELEM database. In addition, the technology parameter α is computed as the GDP-weighted average of gross operating surplus to value added ratios, computed at market prices.

However, most structural parameters have no direct real world counterparts. Hence, we proceed to an extensive literature review based on Annicchiarico et al. (2013), Auray et al. (2011), Bayoumi et al. (2004), Cacciatore et al. (2012), Clinton et al. (2011), Coenen et al. (2008), Eggertsson et al. (2014), Erceg and Lindé (2013), Forni et al. (2010), Kaplan et al. (2014), Ratto et al. (2009), Smets and Wouters (2002), Smets and Wouters (2003), Smets and Wouters (2005), Trabandt and Uhlig (2011), Vogel (2012). Using this review, we then select a value for each parameter that is close to the median of those observed in the literature, which have been estimated using a range of different methods, such as Bayesian methods on macro data or directly on micro data. However, except for the depreciation rate and the elasticity of substitution between goods, we do not have sufficient information to be able to calibrate each structural parameter to a region-specific value. Therefore, we assume that both our region share the same parameter value often based on Eurozone values. Regarding the other mentioned parameters, the depreciation rate, and the elasticity of substitution between goods, linked to the markup on goods, are calibrated using region-specific data found in D'Auria et al. (2009). A detailed discussion on the differences observed across models/papers for crucial parameters is given in Campagne and Poissonnier (2016a).

However, for an arbitrary calibration of structural parameters, the steady state structure of the model lead to values of the endogenous variables that differ from observed data, for instance the production level. Yet, our model also needs to be able to match some of the main economic indicators as measured in the National Accounts.

As such, having identified a list of structural and policy parameters, targets for some steady state values of endogenous variables are also identified in the National Accounts. In particular, six targets are selected: *(i)* the nominal main refinancing interest rate, *(ii)* the share of public consumption in GDP, *(iii)* the level of GDP, *(iv)* the number of hours worked, *(v)* the terms of trade, and *(vi)* the ratio of nominal GDP between countries. As explained in more details in Campagne and Poissonnier (2016a), the resolution of steady state equations allows to set the value for some structural parameters by reverse inference.

Those six National Accounting targets are calibrated as follows. The nominal main refinancing interest rate target is computed on the 3-months Euribor rate. The share of public consumption in GDP is directly

computed using the Eurostat National Accounts at current prices, so as for the level of GDP, and the ratio of GDP between the two regions. The terms of trade are computed as the ratio of Purchasing Power Parities of GDP normalizing the North region to unity. Weights for the aggregation across countries are therefore logically based on regional GDPs. Lastly, the number of hours worked in each region is computed using the Labor Force Survey data. This survey allows to estimate employment in capita terms, the average number of actual weekly hours worked in the main job, the average number of actual weekly hours worked in the second job, and the number of employed persons having a second job. This allows to reconstruct a homogeneous number of hours worked in each region, based on the small approximation that no worker holds more than two jobs.

Appendix 2: Baseline scenario and robustness checks

	Central calibration	Alternative calibrations				
		2	3	4	5	6
Correlation of simulated series and observed data						
Consumption growth (North)	0.74	0.32	0.39	0.34	0.47	0.67
Consumption growth (South)	0.93	0.46	0.54	0.50	0.54	0.94
Investment growth (North)	0.99	0.92	0.88	0.87	0.97	0.99
Investment growth (South)	0.99	0.95	0.96	0.97	0.98	0.99
Output growth (North)	0.98	0.85	0.82	0.67	0.81	0.98
Output growth (South)	0.97	0.88	0.89	0.89	0.91	0.97
Public debt growth (North)	0.99	0.96	0.95	0.91	0.97	0.99
Public debt growth (South)	0.97	0.89	0.90	0.89	0.91	0.98
Inflation (North)	0.46	0.68	0.57	0.46	0.57	0.48
Inflation (South)	0.61	0.20	0.33	0.27	0.49	0.63
Interest rate variation	1.00	0.97	1.00	1.00	1.00	1.00
Interest rate level	1.00	0.94	0.98	0.99	0.97	0.99
Cross-correlation of output and growth						
Data (North)	0.64	0.64	0.64	0.64	0.64	0.64
Simulated series (North)	0.36	0.18	- 0.13	- 0.40	0.14	0.44
Data (South)	0.35	0.35	0.35	0.35	0.35	0.35
Simulated series (South)	0.41	0.38	0.36	0.39	0.34	0.22
Ratio of simulated over observed volatility						
Consumption growth (North)	1.31	1.87	1.39	1.83	1.43	1.36
Consumption growth (South)	1.03	0.96	0.83	0.78	0.62	0.96
Investment growth (North)	1.03	1.18	1.08	1.10	1.06	1.01
Investment growth (South)	1.08	1.09	0.88	0.88	0.93	1.11
Output growth (North)	1.01	1.31	1.14	1.05	0.71	0.98
Output growth (South)	1.00	1.06	1.05	1.00	0.94	1.05
Public debt growth (North)	1.01	1.13	1.08	1.06	0.93	1.00
Public debt growth (South)	1.15	1.18	1.05	1.05	1.01	1.14
Inflation (North)	0.70	0.52	0.64	0.56	0.46	0.74
Inflation (South)	0.55	0.72	0.77	0.84	0.59	0.56

Each column indicates the correlation between observed quarterly data over the period 2004-2015 and their simulated counterparts using different calibration of deep parameters.

Central calibration corresponds to parameter values in Table 2, calibration 2 to a low share ($\mu = 0.15$) of Non Ricardian Households in both countries, calibration 3 to a high share ($\mu = 0.50$) of Non Ricardian Households in both countries, calibration 4 to a low (respectively high) share of Non Ricardian Households in the North (respectively in the South), calibration 5 introduces asymmetry in goods elasticity of substitution ($\theta^N = 3, \theta^S = 10$), whereas calibration 6 considers asymmetry in labour elasticity of substitution ($\theta_w^N = 2.5, \theta_w^S = 6.5$).

Table A2-1: Measures of fit according various calibrations

	Standard deviation		Persistence	
Shock	North	South	North	South
Monetary policy	0.012		0.149	
Productivity	0.028	0.027	0.827	0.532
Preference	0.017	0.018	0.087	0.100
Investment cost	0.027	0.033	0.588	0.790
Public spending	0.020	0.026	0.890	0.991
Transfers	0.029	0.034	0.508	0.888
Net foreign assets	0.026	0.030	0.000	0.000
Labour supply	0.046	0.072	0.994	0.994
Financial spreads	0.016	0.017	0.000	0.000
Public assets measurement error	0.018	0.019	0.000	0.000
Inflation measurement error	0.012	0.012	0.000	0.000

Bayesian estimation of shocks persistence and standard deviation over 2004-2015. Measurement errors are allowed in the inflation and public assets equation in the Bayesian estimation process.

Table A2-2: Estimated standard deviation and persistence for structural shocks
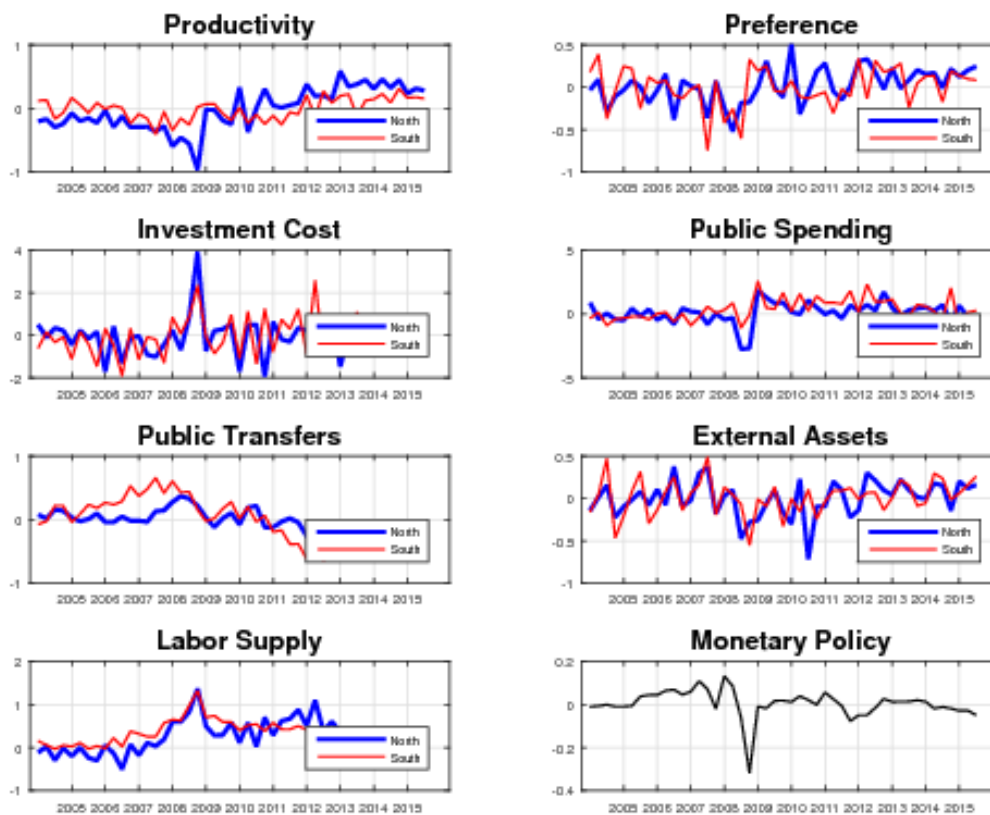
North represents Belgium, Germany, France and the Netherlands, whereas South includes Greece, Ireland, Italy, Spain and Portugal.

Figure A2-I: Underlying standardized structural shocks from 2004 to 2015

Appendix 3: Additional figures

Spillovers are computed as the marginal foreign effect of fiscal shocks divided by their marginal domestic effect. A spillover of 0.5 in the North means that a fiscal shock in the South has an effect in the North half the size it has in the South.

Central calibration corresponds to parameter values in Table 2, calibration 2 to a low share ($\mu = 0.15$) of Non Ricardian Households in both countries, calibration 3 to a high share ($\mu = 0.50$) of Non Ricardian Households in both countries, calibration 4 to a low (respectively high) share of Non Ricardian Households in the North (respectively in the South), calibration 5 introduces asymmetry in goods elasticity of substitution ($\theta^N = 3, \theta^S = 10$), whereas calibration 6 considers asymmetry in labour elasticity of substitution ($\theta_w^N = 2.5, \theta_w^S = 6.5$).

Figure A3-I: Spillovers of spending-based consolidation

Spillovers are computed as the marginal foreign effect of fiscal shocks divided by their marginal domestic effect. A spillover of 0.5 in the North means that a fiscal shock in the South has an effect in the North half the size it has in the South.

Central calibration corresponds to parameter values in Table 2, calibration 2 to a low share ($\mu = 0.15$) of Non Ricardian Households in both countries, calibration 3 to a high share ($\mu = 0.50$) of Non Ricardian Households in both countries, calibration 4 to a low (respectively high) share of Non Ricardian Households in the North (respectively in the South), calibration 5 introduces asymmetry in goods elasticity of substitution ($\theta^N = 3, \theta^S = 10$), whereas calibration 6 considers asymmetry in labour elasticity of substitution ($\theta_w^N = 2.5, \theta_w^S = 6.5$).

Figure A3-II: Spillovers of VAT-based consolidation

Appendix 4: Mélèze model

This appendix gives a more detailed presentation of the model used in the paper.

Households

Consumption and investment decision of Ricardian households

In both countries, we assume that a fraction $(1 - \mu^i)$ of households can participate to the financial markets. These households can borrow or lend money on an international market and doing so have the possibility to smooth their consumption across periods. Each household of this type (τ) maximizes her intertemporal utility function subject to her budget constraint. Utility is non-separable, CES in consumption with external habit formation in a multiplicative manner. This functional form stems from Trabandt & Uhlig (2011) and is compatible with long term growth King et al (2002), as under this form the disutility of labor is concave for any value of the intertemporal elasticity of substitution of consumption, and also ensures a constant Frisch elasticity. The representative Ricardian household solves:

$$\max_{C_T^{R,i}, FA_T^i, I_T^i, K_T^i} E_t \sum_{T=t}^{\infty} \beta^{i^{T-t}} \mathcal{U}\left(\frac{C_t^{R,i}}{(1-\mu^i)n^i\mathbb{N}}, C_{T-1}^i\right) \mathcal{V}\left(\frac{l_T^{R,i}}{(1-\mu^i)n^i\mathbb{N}}, L_{T-1}^i\right)$$

subject to the budget constraint

$$FA_T^i = \left(R_{T-1} - \psi\left(\frac{FA_{T-1}^i}{P_{T-1}^i \bar{Y}^i}\right)\right)FA_{T-1}^i + w_T^i l_T^{R,i} - CPI_T^i(1 + v_T^{c,i})C_T^{R,i} + (1 - v_T^{D,i})D_T^i$$
$$+ (1 - v_T^{FD,i})FD_T^i + \Phi_T^i + (1 - v_T^{K,i})CPI_T^i r_T^{K,i} K_{T-1}^i - CPI_T^i(1 + v_T^{c,i})I_T^i$$

and the capital accumulation equation

$$K_T^i = (1 - \delta)K_{T-1}^i + \left[1 - \mathcal{S}\left(\frac{\varepsilon_T^{i,I} I_T^i}{I_{T-1}^i}\right)\right] I_T^i$$

Under the most general form, we define utility as:

$$\mathcal{U}\left(\frac{C_t^{R,i}}{(1-\mu^i)n^i\mathbb{N}}, C_{t-1}^i\right) \mathcal{V}(L_t^{R,i}, L_{t-1}^i) =$$

$$\frac{1}{1-\sigma_c^i}\left(\frac{C_t^{R,i}}{(1-\mu^i)n^i\mathbb{N}}\left(\frac{C_{t-1}^i}{n^i\mathbb{N}}\right)^{-h_c^i}\right)^{1-\sigma_c^i}\left(1 - \kappa^i \varepsilon_t^{L,R,i}(1 - \sigma_c^i)\left(\frac{L_t^{R,i}}{(1-\mu^i)n^i\mathbb{N}}\right)^{1+\sigma_l^i}\right)^{\sigma_c^i}$$

$\mathbb{N}$ is the total population and n^i the share of located in region i. E_t, β^i are respectively the expectation at time t operator and the discount factor, $C_t^{R,i}$ is the aggregate consumption of Ricardian households in region i, σ_c^i is the inverse intertemporal elasticity of substitution. κ^i is the weight assigned to labor in the utility function, σ_l^i is the inverse of the Frisch elasticity. h_c^i are the external habit formation parameters on consumption. $l_t^{R,i}(\tau)$ is the labour supply of household τ, $w_t^i(\tau)$ its wage and $\varepsilon_t^{L,R,i}$ a labor supply shock.

FA_t^i is the aggregate level of private financial assets, R_t is the interest rate set by the monetary authority in the union, ψ is an interest premium on debt (and where $\bar{Y}^i$ corresponds to the steady state level of output). This cost is introduced to ensure the stationarity of the model (i.e. rule out unit roots). This premium is akin to a transaction cost on holding assets and are paid to an international financial intermediary.

$v_t^{c,i}$ is the tax rate on consumption or value-added tax (VAT) through which government expenditure is partially financed. D_t^i is the dividend paid by the firm to its owners taxed at rate $v_t^{D,i}$, FD_t^i are

equivalently the dividends paid by the financial sector taxed at rate $v_t^{FD,i}$ and Φ_t^i a lump-sum transfer from the government. Finally, K_t^i is the capital stock of *Ricardian* households depreciating at rate δ and which revenues are taxed at rate $v_t^{K,i}$.

In the capital accumulation equation, $I_t^i(\tau)$ is the investment level with an adjustment cost $S(\varepsilon_T^{i,I} I_T^i I_{T-1}^i)$ depending on previous period level of investment. As in Smets and Wouters (2003) to Smets and Wouters (2007), we assume that at steady state S=0, S'=0 and S">0. $\varepsilon_T^{i,I}$ represents an exogenous cost-push shock. The costate variable for the capital accumulation constraint is defined as $q_t CPI_t^i(1 + v_t^{c,i})$ times the costate variable of the budget constraint $\beta^{i^t}\lambda_t$, so that q_t is the market value of an additional unit of capital, that is Tobin's marginal Q.

We define the stochastic discount factor between t and $t + 1$ as follows:

$$Q_{t,t+1}^{R,i} = \frac{\mathcal{U}'\left(\frac{C_{t+1}^{R,i}}{(1 - \mu^i)n^i\mathbb{N}}, C_t^i\right) \mathcal{V}\left(\frac{L_{t+1}^{R,i}}{(1 - \mu^i)n^i\mathbb{N}}, L_t^i\right)}{\mathcal{U}'\left(\frac{C_t^{R,i}}{(1 - \mu^i)n^i\mathbb{N}}, C_{t-1}^i\right) \mathcal{V}\left(\frac{L_t^{R,i}}{(1 - \mu^i)n^i\mathbb{N}}, L_{t-1}^i\right)}$$

As a result, the Euler equation writes:

$$\beta^i E_t \left\{ Q_{t,t+1}^{R,i} \frac{R_t - \psi\left(\frac{FA_t^i}{P_t^i \overline{Y}^i}\right)}{\Pi_{t+1}^{c,i} \frac{1 + v_{t+1}^{c,i}}{1 + v_t^{c,i}}} \right\} = 1$$

where $\Pi_{t+1}^{c,i}$ is the inflation of the consumption price index in region i.

Investment and the marginal value of capital are described by the following first order conditions:

$$1 = q_t^i \left\{ 1 - S\left(\frac{\varepsilon_t^{i,I} I_t^i}{I_{t-1}^i}\right) - S'\left(\frac{\varepsilon_t^{i,I} I_t^i}{I_{t-1}^i}\right)\frac{I_t^i}{I_{t-1}^i} \right\} + \beta^i E_t \left\{ Q_{t,t+1}^{R,i} q_{t+1}^i \varepsilon_{t+1}^{i,I} S'\left(\varepsilon_{t+1}^{i,I} \frac{I_{t+1}^i}{I_t^i}\right)\left(\frac{I_{t+1}^i}{I_t^i}\right)^2 \right\}$$

$$q_t^i = \beta^i E_t \left\{ Q_{t,t+1}^{R,i}\left(q_{t+1}^i(1 - \delta) + \frac{(1 - v_{t+1}^{k,i})r_{t+1}^{k,i}}{1 + v_{t+1}^{c,i}}\right) \right\}$$

The latter, similar to the Euler equation on consumption, describes the trade-off between investment in capital and consumption.

Consumption decision of non-Ricardian households

The remaining fraction μ^i of households does not have access to financial intermediaries and therefore, their consumption cannot be smoothed across periods. These *non-Ricardian* households follow a rule-of-thumb:

$$0 = w_t^i(\tau)l_t^i(\tau) + \Phi_t^i(\tau) - CPI_t^i(1 + v_t^{c,i})C_t^i(\tau)$$

on aggregate $0 = W_t^{NR,i}L_t^{NR,i} + \Phi_t^{NR,i} - CPI_t^i(1 + v_t^{c,i})C_t^{NR,i}$

Labor supply decision and wage setting

Labor is assumed immobile across countries. Besides, we assume wage stickiness à la Calvo (1983), with parameter ξ_w^i denoting the probability not to adjust wages at each period. There is also partial indexation of wages on past inflation of consumption prices according to parameter γ_w^i and indexation on targeted

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inflation with parameter $1 - \gamma_w^i$. In addition, wages are also indexed on the deterministic trend of TFP. These indexations are necessary to ensure that the distribution of wages does not diverge when there is non zero inflation and exogenous growth at steady state. A given household τ solves the following program:

$$\max_{\widetilde{w}^i{}_t(\tau), \tilde{l}^i{}_{t,T}(\tau)} E_t \sum_{T=t}^{\infty} (\xi_w^i \beta^i)^{T-t} \mathcal{U}(C_T^i(\tau), C_{T-1}^i) \mathcal{V}(\tilde{l}^i{}_{t,T}(\tau), L_{T-1}^i)$$

subject to the labor demand function:

$$\tilde{l}_{t,T}^i(\tau) = \frac{1}{n^i \mathbb{N}} \left(\frac{\widetilde{w}_{t,T}^i(\tau)}{W_T^i} \right)^{-\theta_w^i} L_T^i$$

as well as their respective budget constraint, and the following indexation rule:

$$\widetilde{w}_{t,T}^i(\tau) = \widetilde{w}_t^i(\tau) \prod_{k=t}^{T-1} (\Pi_k^{c,i})^{\gamma_w^i} (\overline{\Pi}^{c,i})^{1-\gamma_w^i} = \widetilde{w}_t^i(\tau) \Gamma_{w,t}^{T-1}$$

where $\widetilde{w}_t^i(\tau)$ is the optimal wage set at time t by household τ and $\widetilde{w}_{t,T}^i(\tau)$ is its wage at time T when not reset between time t and T, $\tilde{l}_t^i(\tau)$ and $\tilde{l}_{t,T}^i(\tau)$ are the corresponding labour demands. $\Gamma_{w,t}^{T-1}$ denotes the indexation factor $\prod_{k=t}^{T-1} (\Pi_k^{c,i})^{\gamma_w^i}(\overline{\Pi}^{c,i})^{1-\gamma_w^i}$ with $\overline{\Pi}^{c,i}$ the steady state inflation of CPI^i.

The aggregate first order condition reads

$$0 = E_t \sum_{T=t}^{\infty} (\xi_w^i \beta^i)^{T-t} \tilde{l}_{t,T}(\tau) Q_{t,t+1}^{R,i} \left[\frac{\mathcal{U}(C_T^i(\tau), C_{T-1}^i) \mathcal{V}'(\tilde{l}^i{}_{t,T}(\tau), L_{T-1}^i)}{\mathcal{U}'(C_T^i(\tau), C_{T-1}^i) \mathcal{V}(\tilde{l}^i{}_{t,T}(\tau), L_{T-1}^i)} + \frac{\theta_w^i - 1}{\theta_w^i} \frac{\widetilde{w}_t^i(\tau)\Gamma_{w,t}^{T-1}}{CPI_T^i(1 + v_T^{c,i})} \right]$$

where one may recognize the stochastic discount factor between time t and T and between brackets, the wedge between the ratio of the marginal utility of labor and consumption and the real wage with a term in θ_w^i representing the market power of households. Note that this wage setting equation is at the individual level and therefore that the associated utility function and wages depend on the individual consumption of household τ. Therefore, there is two wage Phillips curves, one for each type of households. In addition, as for the Euler and investment equations, we make the standard assumption that individual dispersion can be neglected Campagne & Poissonnier (2016).

Firms

We assume an exogenous and global technological growth process in the form $\zeta_t^i = \varepsilon_t^{\zeta,i}(1+g)^t \bar{\zeta}^i$, where g is the deterministic growth rate of total factor productivity, $\bar{\zeta}$ the *de-trended* steady state level of technology, and ε_t^{ζ} a stochastic productivity shock. We assume that technology can be shared and transferred within the union, so that TFP growth is the same in both countries. However, the steady state detrended level of TFP, ie. $\bar{\zeta}^i$, differs across countries to take into account the initial differences in wealth across countries.

Production factors optimization

Firms hire domestic labor at the cost $W_t^i(1 + v_t^{w,i})$, where $v_t^{w,i}$ is the payroll tax rate levied by the government on firms.[12] They also rent capital from households at rate $r^{k,i}$. In real term the rental cost of demanded capital $K_t^{d,i}$ is then $r_t^{k,i} K_t^{d,i}$ paid at time t. In nominal terms, this cost equals $r_t^{k,i} K_t^{d,i} CPI_t^i$: the value of the rented capital in current is equal to the real capital stock times its market price CPI_t^i.[13] Note

that capital from previous period is used for production at time assuming installation delays. Therefore, at market equilibrium, we have on aggregate $K_t^{d,i} = K_{t-1}^i$.

In each region i, at first order, neglecting price dispersion, firms produce differentiated goods Y_t^i with the following technology:

$$Y_t^i = \left(\zeta_t^i L_t^i\right)^{1-\alpha}\left(K_t^{d,i}\right)^{\alpha} \text{ at cost } W_t^i(1 + v_t^{w,i})L_t^i + r_t^{k,i}CPI_t^i K_t^{d,i}$$

where α is the share of capital costs in value added. For sake of simplicity, firms hire both types of households indistinctly. First order conditions yield:

$$\frac{1-\alpha}{\alpha} = \frac{W_t^i(1+v_t^{w,i})L_t^i}{r_t^{k,i}K_t^{d,i}CPI_t^i} \text{ on aggregate } \frac{1-\alpha}{\alpha} = \frac{W_t^i(1+v_t^{w,i})L_t^i}{r_t^{k,i}K_{t-1}^i CPI_t^i}$$

The real marginal cost of production is identical across firms and does not depend on its size:

$$RMC_t^i = \frac{1}{\alpha^\alpha(1-\alpha)^{1-\alpha}}\left(\frac{RW_t^i}{\zeta_t^i}(1 + v_t^{c,i})(1 + v_t^{w,i})\right)^{1-\alpha}\left(r_t^{k,i}\right)^\alpha \frac{CPI_t^i}{P_t^i}$$

Price setting

The price setting follows *Calvo* process in each region. Firm ε can reset its price with exogenous probability $(1 - \xi_i)$. Producers know the relationship between their price and the demand for their product and choose their price $\tilde{P}_t^i(\varepsilon)$ so as to maximize their expected profit under that constraint:

$$\max_{\tilde{P}_t^i(\varepsilon)} E_t \sum_{T=t}^{\infty} (\beta^i \xi^i)^{T-t}\lambda_T^i\left(\tilde{P}_t^i(\varepsilon)\tilde{y}_{t,T}^i(\varepsilon) - W_T^i(1 + v_T^{w,i})L_{t,T}^i(\varepsilon) - r_T^{k,i}CPI_T^i K_{t,T}^{d,i}(\varepsilon)\right)$$

$$\text{subject to } \tilde{y}_{t,T}^i(\varepsilon) = \frac{1}{p^i\mathbb{P}}\left(\frac{\tilde{P}_{t,T}^i(\varepsilon)}{P_T^i}\right)^{-\theta^i} Y_T^i$$

$$\tilde{P}_{t,T}^i(\varepsilon) = \tilde{P}_t^i(\varepsilon)\prod_{k=t}^{T-1} (\Pi_k^i)^{\gamma_p^i}(\overline{\Pi}^i)^{1-\gamma_p^i} = \tilde{P}_t^i(\varepsilon)\Gamma_t^{T-1}$$

and previous technological constraints

where the Lagrange multiplier λ_T^i is the marginal utility of a representative *Ricardian* households in region i. These households own the firms, so logically their utility enters the price-setting program. This is however neutral on the linearized Phillips curve apart from a redefinition of β when there is long term growth, a redefinition which does not depend on households' type. $\tilde{y}_{t,T}^i(\varepsilon)$ is the demand for goods produced by firm ε of region i at time T when its price was last reset at time t. γ_p^i is the parameter of price indexation on past inflation and Γ_t^{T-1} denotes $\prod_{k=t}^{T-1} \Pi_k^{i\,\gamma_p^i}(\overline{\Pi}^i)^{1-\gamma_p^i}$. So $\tilde{P}_{t,T}^i(\varepsilon) = \tilde{P}_t^i(\varepsilon)\Gamma_t^{T-1}$ is the price of good ε of region i at time T when its price was last reset at time t. Note that Π_t^i is the inflation of goods produced in region i and differs from inflation of the consumption price index CPI_t^i, which includes inflation from imported goods as well. $\overline{\Pi}^i$ is the steady state value of Π_t^i.

The first order condition for firm ε reads:

$$0 = \sum_{T=t}^{\infty} (\beta^i \xi^i)^{T-t}\lambda_T^i \frac{Y_T^i}{p^i\mathbb{P}}\left(\frac{\tilde{P}_t^i(\varepsilon)\Gamma_t^{T-1}}{P_T^i}\right)^{-\theta^i}\left(\tilde{P}_t^i(\varepsilon)\Gamma_t^{T-1} - \frac{\theta^i}{\theta^i - 1}MC_T^i\right)$$

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assume that both goods are identical.

Dividends distribution

Firms cannot save or invest, so they redistribute their profits to households. This distribution can be thought of as dividends to firms' owners. We assume that only unconstrained households, who have access to financial and investment markets, are paid such dividends D_t^i.

$$D_t^i = P_t^i Y_t^i - W_t^i (1 + \nu_t^{w,i}) L_t^i - r_t^{k,i} K_{t-1}^i CPI_t^i = P_t^i Y_t^i (1 - RMC_t)$$

Financial Intermediation

As explained by Schmitt-Grohé and Uribe (2003), the stationarity of a small open economy model is not straightforward and can be ensured by some modeling elements, which are usually not micro-founded. The literature on monetary union model usually borrows the same solutions. In our model, we *micro-found* one of Schmitt-Grohe's proposals (debt elastic spreads) and introduce a simplified interregional financial market.

We assume that there exists an interregional financial market for assets (private or public). On the financial market, intermediaries can borrow money from the central bank of the monetary union to finance public or private credit, and conversely borrow money from agents to deposit it at the central bank. Through financial intermediaries, private (resp. public) agents can borrow or lend money by paying a debt premium ψ (resp. ψ^g). The interest rate for the exchange between the central bank and the financial intermediary is the interest rate set by the central bank. To ensure the orthogonality of financial intermediaries with respect to the rest of the monetary union, we assume that they work in perfectly competitive market and that their unique cost is the refinancing cost vis-a -vis the central bank. Assuming so generates no wage payment or capital and intermediate consumption purchases in this branch of activity hence no transfer between the real economy within the monetary union and financial operators located outside this union. Therefore, developments on the financial market do not affect the rest of the system.

Concretely, if households or the government in region i are net borrowers (i.e. $FA_t^i \leq 0$ or $PA_t^i \leq 0$), this agent has to pay an interest premium on his debt amounting to $|\psi(fa_t^i)|$, $|\psi^g(pa_t^i)|$. When the agent is net lender, returns are reduced by this same spread captured by the intermediary. As for good producing firms, we assume that financial intermediaries are owned by *Ricardian* households and their profits (ie. the sum of collected spreads) are paid lump-sum to *Ricardian* households $(FD_t^{(1,2)})$.

In addition, we assume that at each period, the financial intermediaries clear their position towards the central bank:

$$FA_t^1 + FA_t^2 + PA_t^1 + PA_t^2 = 0$$

This condition assumes that public debt is being held entirely by households within the union. This constraint ensures that the model satisfies the Walras law, and that the steady state is stable and the solution to the linearized model is unique. We however allow for a transitory discrepancy in this condition to enable us to introduce debt shocks.

Fiscal Authorities

The endogenous government behavior is modeled through a budget rule so that each regional government adjusts its public expenditures in order to ensure debt is on sustainable path. Namely, we set the following rule:

$$G_t^i - \bar{G}^i = \rho_g \left(pa_{t-1}^i - \overline{pa}^i \right)$$

where G_t^i denotes the level of public expenditures in region i and $pa_t^i = PA_t^i P_t^i \bar{Y}^i$ the public debt to GDP ratio. $\bar{G}$ and $\overline{pa}$ denotes the steady level of each variable.

Those expenditures are financed through constant and discretionarily chosen tax rates over consumption and labor as well as debt. In addition, governments also distribute constant lump-sum transfers to both types

of households. All in all, the government budget constrain is as follows:

$$PA_t^i = \left(R_{t-1} - \psi^g\left(\frac{PA_{t-1}^i}{P_{t-1}^i\bar{Y}^i}\right)\right)PA_{t-1}^i + v^{w,i}W_t^iL_t^i + v^{c,i}CPI_t^i(C_t^i + I_t^i) - P_t^iG_t^i - \Phi^i$$

where PA_t^i denotes the nominal public assets of region i at the end of period t. The budget balance decomposes along the value-added tax (v^c) base $CPI_t^i(C_t^i + I_t^i)$ including private consumption and investment valued at the consumption price, and the labor tax (v^w) base $W_t^iL_t^i$. Public consumption is denoted G_t and Φ^i nominal transfers to households. In addition, R_t denotes the nominal interest paid on financial assets reduced/augmented by negligible transaction spreads $\psi^g\left(\frac{PA_{t-1}^i}{P_{t-1}^i\bar{Y}^i}\right)$.

Central bank

The central bank sets the nominal interest rate R_t common to both regions through a Taylor rule (Taylor, 1993), where it reacts to current inflation of the consumption price index.

$$R_t = (R_{t-1})^\rho (R^*)^{1-\rho}\left(\frac{\Pi_t^{union,VAT}}{\Pi^*}\right)^{r_\pi(1-\rho)} + \varepsilon_t^M$$

where $\Pi_t^{union,VAT}$ is the consumption-weighted VAT-included CPI inflation in the monetary union. R^* is the interest-rate target of the central bank and Π^* its exogenous inflation target. r_π is the Taylor rule weights assigned to inflation, ρ is the interest-smoothing parameter. ε_t^M corresponds to a transitory monetary shock.

Debt shock vis-a-vis the rest of the world

As explained in Campagne and Poissonnier (2016), all financial assets are assumed to be held by households within the monetary union, so that no financial nor trade transactions exist with the rest of the world. As such, at each period, the financial intermediaries clear their position towards the central bank:

$$FA_t^1 + FA_t^2 + PA_t^1 + + PA_t^2 = 0$$

where FA_t^i is the level of private financial assets in the region i.

However, in the present paper, this assumption is highly restrictive when trying to model shocks to public debt to GDP ratios. Indeed, it implies that in order to match increases in public debt ratios observed in the Eurozone post-crisis, households' assets would mechanically have to increase. For post-crisis simulation purposes, this is however problematic as it would imply a large positive wealth effect for households that do not reflect post-crisis data. The budget constraint 3.2 is therefore modified to introduce a transitory real debt to GDP shock $\varepsilon_t^{d,i}$:

$$pa_t^i = \left(R_{t-1} - \psi^g(pa_{t-1}^i)\right)\frac{pa_{t-1}^i}{(1+g)\Pi_t^i}$$
$$+ v_t^{w,i}w_t^il_t^i + v_t^{k,i}r_t^{k,i}cpi_t^ik_{t-1}^i + v_t^{c,i}cpi_t^i(c_t^i + i_t^i) + v_t^{D,i}d_t^i + v_t^{FD,i}fd_t^i - g_t^i - \phi_t^i + \varepsilon_t^{d,i}$$

where $x_t^i = X_t^iP_t^i$ for $X = W$ or CPI, $y_t^i = Y_t^i\bar{Y}^i$ for $Y = L$, C, I or G, $z_t^i = Z_t^iP_t^i\bar{Y}^i$ for $Z = D$, FD or Φ and $k_{t-1}^i = K_{t-1}^iP_t^i$.

The $\varepsilon_t^{d,i}$ is assumed with no compensation to the household, that is:

$$FA_t^1 + FA_t^2 + PA_t^1 + + PA_t^2 = P_t^1\bar{Y}^1\varepsilon_t^{d,1} + P_t^2\bar{Y}^2\varepsilon_t^{d,2}$$

The $\varepsilon_t^{d,1}$ and $\varepsilon_t^{d,2}$ shocks can be seen as real debt shocks vis-a-vis a third party (the rest of the world) able to trade in assets with the Eurozone agents and assumed following a budget rule similar to the Eurozone

ones in order to stabilize its external debt with respect to the Eurozone.

Liste des documents de travail de la Direction des Études et Synthèses Économiques