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Apostolis Philippopoulos , Petros Varthalitis and Vanghelis Vassilatos

76 Patission Str., Athens 104 34, Greece
Tel. (++30) 210-8203911 - Fax: (++30) 210-8203301
www.econ.aueb.gr

Fiscal consolidation in an open economy with sovereign premia*

Apostolis Philippopoulos †

(Athens University of Economics and Business, and CESifo)

Petros Varthalitis

(Athens University of Economics and Business)

Vanghelis Vassilatos

(Athens University of Economics and Business)

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Abstract

We welfare rank various tax-spending-debt policies in a New Keynesian model of a small open economy featuring sovereign premia and loss of monetary policy independence. When we compute optimized state-contingent policy rules, our results are: (a) Debt consolidation comes at a short-term pain but the medium- and long-term gains can be substantial. (b) In the early phase of pain, the best fiscal policy mix is to cut public consumption spending and raise consumption tax rates to address the public debt problem, while, at the same time, cut capital tax rates to mitigate the recessionary effects of debt consolidation. (c) In the long run, the best way of using the fiscal space created is to reduce capital and labor taxes; the anticipation of such reductions plays a key role in the recovery from fiscal consolidation. (d) The fiscal authorities should also care about the output gap.

Keywords: Feedback policy, New Keynesian, Sovereign premia, Debt consolidation.

JEL classification: E6, F3, H6

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†Corresponding author: Apostolis Philippopoulos, Department of Economics, Athens University of Economics and Business, Athens 10434, Greece. tel:+30-210-8203357. email: aphil@aueb.gr

1 Introduction

Since the global crisis in 2008, and after years of deficits and rising debt levels, public finances have been at the center of attention in most eurozone periphery countries. Although several policy proposals are under discussion, a particularly debated one is public debt consolidation.[1] Proponents claim this is for good reason: as a result of high and rising public debt, borrowing costs have increased, causing crowding out problems and undermining government solvency. Opponents, on the other hand, claim that debt consolidation worsens the economic downturn and leads to a vicious cycle. At the same time, as members of the single currency, these countries cannot use monetary policy to counter the recession and/or monetize public debt. Thus, the only macroeconomic tool available is fiscal policy.

What is the best use of fiscal policy under these circumstances? Is debt consolidation beneficial? Should the debt ratio be stabilized at its currently historically high level or should it be brought down? If brought down, how quickly? Do the answers to these questions depend on which tax-spending policy instruments are used over time?[2]

This paper welfare ranks various fiscal policies in light of the above. The setup is a rather conventional New Keynesian model of a semi-small open economy. By semi-small, we mean that the interest rate, at which the country borrows from the world capital market, increases with the public debt-to-GDP ratio.[3] We focus on a monetary policy regime in which the semi-small open economy fixes the exchange rate and, at the same time, loses monetary policy independence; this mimics membership in a currency union. Hence, the only macroeconomic tool left is fiscal policy. Then, following most of the related literature on debt consolidation, we assume that policy is conducted via simple and implementable feedback policy rules.[4] In particular, we assume that public spending and tax rates on consumption, capital income and labor income are all allowed to respond, among other things, to the gap between actual public debt and target public debt as shares of output, as well as to the gap between actual and target

[1] We will use the terms debt consolidation, fiscal adjustment and fiscal austerity interchangeably.

[2] For a discussion of the tradeoffs faced by policymakers in the case of fiscal adjustment, see e.g. the EEAG Report on the European Economy (2014).

[3] For empirical support of this assumption, see e.g. European Commission (2012). See also e.g. Bi (2010, 2012). For the small open economy model and deviations from it, see Schmitt-Grohé and Uribe (2003).

[4] See e.g. Coenen et al. (2008), Forni et al. (2010), Cantore et al. (2012), Cogan et al. (2013), Erceg and Lindé (2012, 2013), Almeida et al. (2013) and Pappa et al. (2014). Econometric studies on the effects of debt consolidation include e.g. Perotti (1996), Alesina et al. (2012) and Batini et al. (2012).

output.[5] We experiment with various policy target levels depending on whether policymakers aim just to stabilize the economy around its status quo (defined as a solution consistent with the current data), or whether they also want to move the economy to a new reformed long run (defined as a solution with lower public debt than in the current data and without sovereign premia). In addition, since we do not want our results to be driven by ad hoc differences in feedback policy coefficients across different policy rules, we focus on optimized ones, namely, on simple and implementable policy rules that also maximize households' welfare. In particular, adopting the methodology of Schmitt-Grohé and Uribe (2004 and 2007), we compute welfare-maximizing rules by taking a second-order approximation to both the equilbrium conditions and the welfare criterion.

The model is solved numerically using common parameter values and fiscal-public finance data from the Italian economy during 2001-2011. We choose Italy simply because it exhibits most of the features discussed in the opening paragraphs above. It thus looks as a natural choice to quantify our model.

Before presenting our results, it is worth recalling that there is no such a thing like "the" debt consolidation. The macroeconomic implications of debt consolidation depend heavily on which policy instrument bears the cost in the early phase of austerity and on which policy instrument is expected to reap the benefit in the late phase, once the debt burden has been reduced and fiscal space has been created.[6] The costs in the early phase are due to spending cuts and/or tax increases, while the opposite holds once fiscal space has been created. Our results (see below) confirm all this. Hence, the choice of fiscal policy instruments matters for lifetime utility and output. This choice also matters for how quickly public debt should be brought down: the more recessionary are the fiscal policy instruments used during the early costly phase, the slower the speed of fiscal adjustment should be. Naturally, there is more choice when we allow for policy mixes (for instance, when the policy instrument(s) used in the early costly phase can be different from those used in the late phase of fiscal space) than when

[5] For empirical support of such rules, see e.g. European Commission (2011). There is a rich literature on monetary and fiscal feedback policy rules that includes e.g. Schmitt-Grohé and Uribe (2005 and 2007), Pappa and Vassilatos (2007), Leith and Wren-Lewis (2008), Batini et al. (2008), Kirsanova et al. (2009), Leeper et al. (2009), Bi (2010), Bi and Kumhof (2011), Kirsanova and Wren-Lewis (2012), Cantore et al. (2012) and Herz and Hohberger (2013).

[6] See e.g. Leeper et al. (2009) and Davig and Leeper (2011) on how the impact of current policy depends on expectations of possible future policy regimes. See also Coenen et al. (2008) in a model with debt consolidation.

we are restricted to use a single instrument all the time.[7]

Our main results are as follows. First, irrespectively of the fiscal policy chosen, debt consolidation is beneficial only if we are relatively far-sighted. For instance, in our baseline computations, debt consolidation is welfare-improving only if we care beyond the first ten years. Debt consolidation always comes at a short-term loss in both welfare and output (especially when changes in fiscal policy instruments are restricted to be close to their historical average values). Thus, the argument for, or against, debt consolidation involves a value judgment. Nevertheless, once the short-term pain is over, the gains from debt consolidation get substantial over time.

Second, under debt consolidation, the best fiscal policy mix found is to make use of all available tax-spending instruments during the early costly phase of fiscal austerity and to reduce capital and labor tax rates - which are particularly distorting - during the late phase of fiscal space. Actually, the anticipation of such reductions plays a key role in the recovery from fiscal austerity. During the early costly phase, the assignment of instruments to intermediate targets should be as follows: cut public consumption spending and raise consumption tax rates to address the public debt problem, while, at the same time, reduce capital tax rates in order to mitigate the recessionary effects of austerity. Labor tax rates should also be used (i.e. raised) to help with the debt problem, if changes in public spending and consumption taxes are restricted. Therefore, as argued by Wren-Lewis (2010), the choice of the policy mix is important.

Third, during the phase of debt consolidation, fiscal policy instruments should, in general, react to both public debt imbalances and the output gap. The short-term recession becomes too sharp if the fiscal authorities pay attention to debt imbalances only. Thus, it is not right that paying attention to the output gap undermines the effort of fiscal consolidation. It is worth reporting that, relatively to a closed economy, recession is extra costly in a semi-small open economy, because a fall in ouput triggers a further rise in the debt ratio that pushes up sovereign premia. Nevertheless, it should be emphasized that feedback reaction to debt imbalances is necessary for ensuring determinacy.

[7] In other words, the debate about the benefits and costs of each instrument used for debt consolidation is essentially a debate about the size of the multiplier of each instrument. See the discussion in the EEAG Report on the European Economy (2014).

Papers close to ours include Coenen et al. (2008), Cantore et al. (2012), Erceg and Lindé (2013), Almeida et al. (2013) and Pappa et al. (2014). But most of these papers do not study optimized policy rules; they a priori choose the speed/pace of adjustment or, in other words, whether debt consolidation should be frontloaded or not. Cantore et al. (2012) do study optimal policy but they impose that all tax rates change by the same proportion; also, in their model for the US, there is monetary policy independence. Therefore, as far as we know, there have not been any previous attempts to: (i) Welfare rank a relatively rich menu of tax-spending policy instruments. (ii) Study how results depend on whether the government simply stabilizes the economy from shocks, or also reduces public debt, within a semi-small New Keynesian open economy with sovereign premia and without monetary policy independence. (iii) Search for the best mix of fiscal action. Actually, a message from our paper is that the popular question "spending cuts or tax rises?" could be replaced by the question "what is the best assigment of instruments to targets?".

The rest of the paper is as follows. Section 2 presents the model. Section 3 presents the data, parameterization and the status quo solution. Section 4 discusses how we work. Results are in Section 5. A sensitivity report is in Section 6. Section 7 closes the paper. Model details are in an Appendix.

2 Model

Consider a semi-small open economy where, as said above, semi-small means that the interest-rate premium is debt-elastic (see e.g. Schmitt-Grohé and Uribe, 2003). On other dimensions, our setup is the standard New Keynesian model of an open economy with domestic and imported goods featuring imperfect competition and nominal Calvo-type rigidities (see e.g. Gali and Monacelli, 2005 and 2008).

The domestic economy is composed of N identical households indexed by $i = 1, 2, ..., N$, of N firms indexed by $h = 1, 2, ..., N$, each one of them producing a differentiated domestically produced tradable good, as well as of monetary and fiscal authorities. Similarly, there are $f = 1, 2, ..., N$ differentiated imported goods produced abroad. Population, N, is constant over time.

2.1 Aggregation and prices

2.1.1 Consumption bundles

The quantity of variety h produced at home by domestic firm h and consumed by domestic household i is denoted as $c_{i,t}^{H}(h)$. Using a Dixit-Stiglitz aggregator, the composite of domestic goods consumed by each household i, $c_{i,t}^{H}$, is given by:[8]

$$c_{i,t}^{H} = \left[\sum_{h=1}^{N} \kappa [c_{i,t}^{H}(h)]^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}} \tag{1}$$

where $\phi > 0$ is the elasticity of substitution across goods produced in the domestic country and $\kappa \equiv 1/N$ is a weight chosen to avoid scale effects in equilibrium.

Similarly, the quantity of imported variety f produced abroad by foreign firm f and consumed by domestic household i is denoted as $c_{i,t}^{F}(f)$. Using a Dixit-Stiglitz aggregator, the composite of imported goods consumed by each household i, $c_{i,t}^{F}$, is given by:

$$c_{i,t}^{F} = \left[\sum_{f=1}^{N} \kappa [c_{i,t}^{F}(f)]^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}} \tag{2}$$

In turn, having defined $c_{i,t}^{H}$ and $c_{i,t}^{F}$, household i's consumption bundle, $c_{i,t}$, is:

$$c_{i,t} = \frac{\left(c_{i,t}^{H}\right)^{\nu} \left(c_{i,t}^{F}\right)^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{3}$$

where ν is the degree of preference for domestic goods (if $\nu > 1/2$, there is a home bias).

2.1.2 Consumption expenditure, prices and terms of trade

Household i's total consumption expenditure is:

$$P_t c_{i,t} = P_t^{H} c_{i,t}^{H} + P_t^{F} c_{i,t}^{F} \tag{4}$$

where P_t is the consumer price index (CPI), P_t^{H} is the price index of home tradables, and P_t^{F} is the price index of foreign tradables (expressed in domestic currency).

[8] As in e.g. Blanchard and Giavazzi (2003), we work with summations rather than with integrals.

Each household's total expenditure on home goods and foreign goods are respectively:

$$P_t^H c_{i,t}^H = \sum_{h=1}^{N} \kappa P_t^H(h) c_{i,t}^H(h) \tag{5}$$

$$P_t^F c_{i,t}^F = \sum_{f=1}^{N} \kappa P_t^F(f) c_{i,t}^F(f) \tag{6}$$

where $P_t^H(h)$ is the price of variety h produced at home and $P_t^F(f)$ is the price of variety f produced abroad, both denominated in domestic currency.

We assume that the law of one price holds meaning that each tradable good sells at the same price at home and abroad. Thus, $P_t^F(f) = S_t P_t^{H*}(f)$, where S_t is the nominal exchange rate (where an increase in S_t implies a depreciation) and $P_t^{H*}(f)$ is the price of variety f produced abroad denominated in foreign currency. A star denotes the counterpart of a variable or a parameter in the rest-of-the world. Note that the terms of trade are defined as $\frac{P_t^F}{P_t^H}$ $(= \frac{S_t P_t^{H*}}{P_t^H})$, while the real exchange rate is defined as $\frac{S_t P_t^*}{P_t}$.

2.2 Households

Each household i acts competitively to maximize expected lifetime utility given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_{i,t}, n_{i,t}, m_{i,t}, g_t\right) \tag{7}$$

where $c_{i,t}$ is i's consumption bundle as defined above, $n_{i,t}$ is i's hours of work, $m_{i,t}$ is i's real money holdings, g_t is per capita public spending, $0 < \beta < 1$ is the time discount rate, and E_0 is the rational expectations operator conditional on the information set.

The period utility function is assumed to be of the form (see e.g. Gali, 2008):

$$u_{i,t}\left(c_{i,t}, n_{i,t}, m_{i,t}, g_t\right) = \frac{c_{i,t}^{1-\sigma}}{1-\sigma} - \chi_n \frac{n_{i,t}^{1+\eta}}{1+\eta} + \chi_m \frac{m_{i,t}^{1-\mu}}{1-\mu} + \chi_g \frac{g_t^{1-\zeta}}{1-\zeta} \tag{8}$$

where χ_n, χ_m, χ_g, σ, η, μ, ζ are preference parameters. Thus, σ is a coefficient of intertemporal subsititution and η is the inverse of Frisch labour elasticity.

The period budget constraint of each household i written in real terms is:

$$
\begin{aligned}
&(1+\tau_t^c)\left[\frac{P_t^H}{P_t}c_{i,t}^H+\frac{P_t^F}{P_t}c_{i,t}^F\right]+\frac{P_t^H}{P_t}x_{i,t}+b_{i,t}+m_{i,t}+\frac{S_tP_t^*}{P_t}f_{i,t}^h+\frac{\phi^h}{2}\left(\frac{S_tP_t^*}{P_t}f_{i,t}^h-\frac{SP^*}{P}f_i^h\right)^2=\\
=\;&\left(1-\tau_t^k\right)\left[r_t^k\frac{P_t^H}{P_t}k_{i,t-1}+\widetilde{\omega}_{i,t}\right]+(1-\tau_t^n)\,w_tn_{i,t}+R_{t-1}\frac{P_{t-1}}{P_t}b_{i,t-1}+\\
&+\frac{P_{t-1}}{P_t}m_{i,t-1}+Q_{t-1}\frac{S_tP_t^*}{P_t}\frac{P_{t-1}^*}{P_t^*}f_{i,t-1}^h-\tau_{i,t}^l
\end{aligned}
\tag{9}
$$

where $x_{i,t}$ is i's domestic investment, $b_{i,t}$ is the real value of i's end-of-period domestic government bonds, $m_{i,t}$ is i's end-of period real domestic money holdings, $f_{i,t}^h$ is the real value of i's end-of-period internationally traded assets denominated in foreign currency, r_t^k denotes the real return to the beginning-of-period domestic capital, $k_{i,t-1}$, $\widetilde{\omega}_{i,t}$ is i's real dividends received by domestic firms, w_t is the real wage rate, $R_{t-1}\geq 1$ denotes the gross nominal return to domestic government bonds between $t-1$ and t, $Q_{t-1}\geq 1$ denotes the gross nominal return to international assets between $t-1$ and t, $\tau_{i,t}^l$ are real lump-sum taxes/transfers to each household, and $0\leq \tau_t^c,\ \tau_t^k,\ \tau_t^n\leq 1$ are tax rates on consumption, capital income and labour income respectively. Small letters denote real values, namely, $m_{i,t}\equiv\frac{M_{i,t}}{P_t}$, $b_{i,t}\equiv\frac{B_{i,t}}{P_t}$, $f_{i,t}^h\equiv\frac{F_{i,t}^h}{P_t^*}$, $w_t\equiv\frac{W_t}{P_t}$, $\widetilde{\omega}_{i,t}\equiv\frac{\widetilde{\Omega}_{i,t}}{P_t}$, $\tau_{i,t}^l\equiv\frac{T_{i,t}^l}{P_t}$, where capital letters denote nominal values. The parameter $\phi^h\geq 0$ measures transaction costs related to foreign assets as a deviation from their long-run value, f_i^h.

The law of motion of physical capital for each household i is:

$$
k_{i,t}=(1-\delta)k_{i,t-1}+x_{i,t}-\frac{\xi}{2}\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)^2k_{i,t-1}
\tag{10}
$$

where $0<\delta<1$ is the depreciation rate of capital and $\xi\geq 0$ is a parameter capturing adjustment costs related to physical capital.

Each household i acts competitively taking prices and policy as given. Details of the household's problem and first-order conditions are in Appendix 1. These conditions include the demand for the firm's product used below.

2.3 Implications for price bundles

Given the above, the three price indexes are:

$$P_t = (P_t^H)^{\nu}(P_t^F)^{1-\nu} \tag{11}$$

$$P_t^H = \left[\sum_{h=1}^{N} \kappa [P_t^H(h)]^{1-\phi}\right]^{\frac{1}{1-\phi}} \tag{12}$$

$$P_t^F = \left[\sum_{f=1}^{N} \kappa [P_t^F(f)]^{1-\phi}\right]^{\frac{1}{1-\phi}} \tag{13}$$

2.4 Firms

Each domestic firm h produces a differentiated good of variety h under monopolistic competition and facing Calvo-type nominal fixities.

Nominal profits of firm h are defined as:

$$\widetilde{\Omega}_t(h) \equiv P_t^H(h)y_t^H(h) - r_t^k P_t^H(h)k_{t-1}(h) - W_t n_t(h) \tag{14}$$

All firms use the same technology as represented by the production function:

$$y_t^H(h) = A_t[k_{t-1}(h)]^{\alpha}[n_t(h)]^{1-\alpha} \tag{15}$$

where A_t is an exogenous stochastic TFP process whose motion is defined below.

Profit maximization by firm h is subject to the demand for its product:

$$y_t^H(h) = y_t^H\,(h) = c_t^H(h) + x_t(h) + g_t\,(h) + c_t^{F*}(h) = \left[\frac{P_t^H\,(h)}{P_t^H}\right]^{-\phi} y_t^H \tag{16}$$

so that, demand for firm h's product, $y_t^H\,(h)$, comes from domestic households' consumption and investment, $c_t^H(h)$ and $x_t(h)$, where $c_t^H(h) \equiv \sum_{i=1}^{N} c_{i,t}^H(h)$ and $x_t(h) \equiv \sum_{i=1}^{N} x_{i,t}(h)$, from the domestic government, $g_t\,(h) = \left[\frac{P_t^H(h)}{P_t^H}\right]^{-\phi} g_t$, and from foreign households' consumption, $c_t^{F*}(h) \equiv \sum_{i=1}^{N*} c_{i,t}^{F*}(h)$.

In addition, following Calvo (1983), firms choose their prices facing a nominal fixity. In particular, in each period, each firm h faces an exogenous probability θ of not being able to reset its price. A firm h, which is able to reset its price at time t, chooses its price $P_t^{\#}(h)$ to maximize the sum of discounted expected nominal profits for the next k periods in which it may have to keep its price fixed. This objective is given by:

$$E_t \sum_{k=0}^{\infty} \theta^k \Xi_{t,t+k} \widetilde{\Omega}_{t+k}(h) = E_t \sum_{k=0}^{\infty} \theta^k \Xi_{t,t+k} \left\{ P_t^{\#}(h)\, y_{t+k}^H(h) - \Psi_{t+k}\left(y_{t+k}^H(h)\right)\right\}$$

where $\Xi_{t,t+k}$ is a discount factor taken as given by the firm, $y_{t+k}^H(h) = \left[\frac{P_t^{\#}(h)}{P_{t+k}^H}\right]^{-\phi} y_{t+k}^H$ and $\Psi_t(.)$ is the minimum nominal cost function for producing $y_t^H(h)$ at t so that $\Psi_t'(.)$ is the associated nominal marginal cost. Details of the firm's problem and first-order conditions are in Appendix 2.

2.5 Government budget constraint

The period budget constraint of the government written in real terms is (details are in Appendix 3):

$$\begin{aligned} d_t + m_t = {} & R_{t-1}\frac{P_{t-1}}{P_t}\lambda_{t-1}d_{t-1} + Q_{t-1}\frac{S_tP_t^*}{P_t}\frac{P_{t-1}^*}{P_t^*}\frac{P_{t-1}}{P_{t-1}^*S_{t-1}}(1-\lambda_{t-1})\,d_{t-1} + \frac{P_{t-1}}{P_t}m_{t-1} \\ & + \frac{P_t^H}{P_t}g_t - \tau_t^c\left(\frac{P_t^H}{P_t}c_t^H + \frac{P_t^F}{P_t}c_t^F\right) - \tau_t^k\left(r_t^k\frac{P_t^H}{P_t}k_{t-1} + \widetilde{\omega}_t\right) - \tau_t^n w_t n_t - \tau_t^l + \frac{\phi^g}{2}\left[(1-\lambda_t)\,d_t - (1-\lambda)\,d\right]^2 \end{aligned} \qquad (17)$$

where $d_t \equiv \frac{D_t}{P_t}$ is the real value of end-of-period total public debt and m_t is the end-of-period total stock of real money balances. As above, small letters denote real values, e.g. $d_t \equiv \frac{D_t}{P_t}$. Total public debt, D_t, can be held by domestic private agents, $\lambda_t D_t$, as well as by foreign private agents, $(1-\lambda_t)\,D_t$, where the share $0 \leq \lambda_t \leq 1$ is treated as a fiscal policy instrument.[9] Also, since the government allocates its total expenditure among product varieties h by solving an identical problem with household i, $g_t(h) = \left[\frac{P_t^H(h)}{P_t^H}\right]^{-\phi} g_t$. The parameter $\phi^g \geq 0$ measures transaction costs related to foreign liabilities similar to those of the household.

In each period, one of the fiscal policy instruments (τ_t^c, τ_t^k, τ_t^n, g_t, τ_t^l, λ_t, d_t) adjusts to satisfy the government budget constraint (see subsection 2.7 below).

[9] Focusing on a single open economy, we do not model the behavior of foreign investors.

2.6 Closing the model: the world interest rate

As is known, to avoid nonstationarities, we have to depart from the benchmark small open economy model (see Schmitt-Grohé and Uribe, 2003). Here, we do so by endogenizing the interest rate faced by the domestic country when it borrows from the world capital market, Q_t. In particular, we assume that Q_t, namely, the gross nominal interest rate between t and $t+1$, is an increasing function of the end-of-period total public debt as share of output, $\frac{D_t}{P_t^H Y_t^H}$, when the latter exceeds a certain threshold.[10]

In particular, following Schmitt-Grohé and Uribe (2003) and Christiano et al. (2011), we use the functional form:

$$Q_t = Q_t^* + \psi \left(e^{\left(\frac{D_t}{P_t^H Y_t^H} - \overline{d} \right)} - 1 \right) \tag{18}$$

where Q_t^* is exogenously given, $\overline{d}$ is an exogenous threshold value above which the interest rate on government debt starts rising above Q_t^* and the parameter ψ measures the elasticity of the interest rate with respect to deviations of total public debt from its threshold value.[11] See subsection 3.1 below for these values.

2.7 Monetary and fiscal policy regimes

To solve the model, we need to specify the exchange rate and the fiscal policy regimes. Concerning the exchange rate regime, since the model is applied to Italy over the last decade, we solve it for a case without monetary policy independence. In particular, we assume that the nominal exchange rate, S_t, is exogenously set (see subsection 2.9 below) and, at the same time, the domestic nominal interest rate on domestic government bonds, R_t, becomes an endogenous variable.[12] Concerning fiscal policy, we start by assuming that, along the transition, the residually determined public financing policy instrument is the end-of-period total public debt, D_t (see below for other cases).

[10] As said above, this rather common assumption is supported by a number of empirical studies (see e.g. European Commission, 2012). Alternatively, to model sovereign premia, we could appeal to the notion of a fiscal limit or to the notion that default is a strategic choice of the sovereign (see Corsetti et al., 2013).

[11] The value of $\overline{d}$ can be thought of as any value of debt above which sustainability concerns start arising. As we report below, our qualitative results are robust to the exact value of $\overline{d}$ used.

[12] This is similar to the modeling of e.g. Erceg and Linde (2012). Recall that in the popular case of flexible, or managed floating, exchange rates, S_t and R_t switch positions, in the sense that S_t becomes an endogenous variable, while R_t is used as a policy instrument usually assumed to follow a Taylor-type rule.

2.8 Fiscal policy rules

Without room for monetary policy independence, only fiscal policy can be used for policy action. Following Schmitt-Grohé and Uribe (2007) and many others, we focus on simple rules, meaning that the fiscal authorities react to a small number of easily observable macroeconomic indicators (as we report below in section 6, our main results do not change when we add more indicators).

In particular, we allow the spending-tax policy instruments,[13] namely, government spending as share of output, s_t^g, and the tax rates on consumption, capital income and labor income, τ_t^c, τ_t^k and τ_t^n, to react to the output share of the beginning-of-period public liabilities as deviation from a target value, $(l_{t-1} - l)$, as well as to the current output gap, $\left(y_t^H - y^H\right)$, according to the simple linear rules:[14]

$$s_t^g - s^g = -\gamma_l^g \left(l_{t-1} - l\right) - \gamma_y^g \left(y_t^H - y^H\right) \tag{19}$$

$$\tau_t^c - \tau^c = \gamma_l^c \left(l_{t-1} - l\right) + \gamma_y^c \left(y_t^H - y^H\right) \tag{20}$$

$$\tau_t^k - \tau^k = \gamma_l^k \left(l_{t-1} - l\right) + \gamma_y^k \left(y_t^H - y^H\right) \tag{21}$$

$$\tau_t^n - \tau^n = \gamma_l^n \left(l_{t-1} - l\right) + \gamma_y^n \left(y_t^H - y^H\right) \tag{22}$$

where variables without time subscripts denote policy target values (defined below), and $\gamma_l^q \geq 0$ and $\gamma_y^q \geq 0$, for $q \equiv (g, c, k, n)$, are feedback policy coefficients on public debt and output respectively. From the government budget constraint in subsection 2.5 above, l_{t-1} is defined as:

$$l_{t-1} \equiv \frac{R_{t-1}\lambda_{t-1}D_{t-1} + Q_{t-1}\frac{S_t}{S_{t-1}}(1-\lambda_{t-1})D_{t-1}}{P_{t-1}^H y_{t-1}^H}$$

where $\frac{S_t}{S_{t-1}}$ is the gross rate of exchange rate depreciation between $t-1$ and t.

[13] We focus on distorting policy instruments, because using lump-sum ones to bring public debt down would be like a free lunch.

[14] For similar rules, see e.g Schmitt-Grohé and Uribe (2007), Bi (2010) and Cantore et al. (2012). As said above, see European Commission (2011) for similar fiscal reaction functions used in practice.

2.9 Exogenous variables and shocks

We assume that foreign imports or equivalently domestic exports, c_t^{F*}, are a function of terms of trade, $TT_t \equiv \frac{P_t^F}{P_t^H}$, where both variables are expressed as deviations from their long-run values:

$$\frac{c_t^{F*}}{c^{F*}} = \left(\frac{TT_t}{TT}\right)^{\gamma} \tag{23}$$

where $0 < \gamma < 1$ is a parameter. The idea is that foreign imports rise when the domestic economy becomes more competitive.

Regarding the other rest-of-the-world variables, namely, the exogenous part of the foreign interest rate, Q_t^*, and the gross rate of domestic inflation in the foreign country, $\Pi_t^{H*} \equiv \frac{P_t^{H*}}{P_{t-1}^{H*}}$, we assume that they are constant over time and equal to $Q_t^* = 1.03$ (which is the data average - see below) and for simplicity $\Pi_t^{H*} = 1$ at all t.

We set the exogenous gross rate of exchange rate depreciation, $\epsilon_t \equiv \frac{S_{t+1}}{S_t}$, at one, while, the output share of lump-sum taxes/tranfers, s_t^l, and the share of domestic public debt in total public debt, λ_t, are set respectively at $s_t^l = -0.21$ and $\lambda_t = 0.6$ at all t, which are their data average values (see below).

Finally, stochasticity comes from TFP, which follows:

$$\log(A_t) = (1-\rho^a)\log(A) + \rho^a \log(A_{t-1}) + \varepsilon_t^{\alpha} \tag{24}$$

where $0 < \rho^a < 1$ is a parameter, $\varepsilon_t^a \sim N\left(0,\ \sigma_a^2\right)$ and, as said above, variables without time subscript denote long-run values. As we report below, our main results do not change when we add extra shocks.

2.10 Decentralized equilibrium (given feedback policy coefficients)

We now combine all the above to present the Decentralized Equilibrium (DE) which is for any feasible policy and, in particular, for any feedback policy coefficients. The DE is defined to be a sequence of allocations, prices and policies such that: (i) households maximize utility; (ii) a fraction $(1-\theta)$ of firms maximize profits by choosing an identical price defined as $P_t^{\#}$, while a fraction θ just set prices at their previous period level; (iii) all constraints, including the government budget constraint and the balance of payments, are satisfied; (iv) markets clear;

(v) policy makers follow the feedback rules as specified in subsection 2.8. This DE is given the exogenous variables, $\{c_t^{F*}, Q_t^*, \Pi_t^{H*}, \epsilon_t,\ s_t^l,\ \lambda_t, A_t\}_{t=0}^{\infty}$, which have been defined in subsection 2.9, initial conditions for the state variables and the values of the feedback policy coefficients in the policy rules.

We end up with a first-order dynamic system of 33 equations. Details and the final equilibrium system are in Appendix 4. To solve this system, we take a second-order approximation of the model around its steady state. We start with the status quo steady state solution in the next section. In turn, we will study transition dynamics and the optimal choice of feedback policy coefficients along the transition to a new reformed steady state.

3 Data, parameterization and steady state solution

This section parameterizes the model by using the averages of fiscal and public finance data from Italy over 2001-2011 and then presents the resulting steady state solution. Recall that, since policy instruments react to deviations of macroeconomic indicators from their long-run values, feedback policy coefficients do not play any role in the long-run solution.

3.1 Data and parameter values

The sources of fiscal and public finance data for Italy are OECD and Eurostat. The time unit is meant to be a year. The baseline parameter values, as well as the values of policy variables, are summarized in Table 1.

Table 1: Baseline parameter values and policy variables

Parameter	Value	Description
a	0.42	share of capital
β	0.9603	rate of time preference
ν	0.5	home goods bias parameter at home
μ	3.42	parameter related to money demand elasticity
δ	0.04	rate of capital depreciation
ϕ	6	price elasticity of demand
η	1	inverse of Frisch labour elasticity
σ	1	elasticity of intertemporal substitution
ν^*	0.5	home goods bias parameter abroad
θ	0.5	price rigidity parameter
ψ	0.05	risk premium parameter
χ_m	0.001	preference parameter related to real money balances
χ_n	7	preference parameter related to work effort
χ_g	0.1	preference parameter related to public spending
$\bar{d}$	0.9	threshold value for public debt as share of output
ρ^a	0.92	persistence of TFP
σ_a	0.017	standard deviation of TFP
γ	0.9	terms of trade elasticity of foreign imports
ξ	0.3	adjustment cost parameter on physical capital
ϕ^g	0.3	adjustment cost parameter on foreign public debt
ϕ^h	0.3	adjustment cost parameter on private foreign assets
τ^c	0.17	consumption tax rate
τ^k	0.32	capital tax rate
τ^n	0.42	labour tax rate
s^g	0.22	government spending as share of GDP
s^l	-0.21	lump-sum transfers as a share of GDP
λ	0.6	share of total public debt held by domestic private agents

The value of the rate of time preference, β, follows from setting the gross nominal interest rate at $R = 1.0413$ (this implies a risk premium of 1.1% over the German 10-year bond rate, which is the average value in the data) and the long-run gross price inflation rate at $\Pi = 1$. The real money balances elasticity, μ, is borrowed from Pappa and Neiss (2005). We employ conventional values used by the literature for the elasticity of intertemporal substitution, σ, the inverse of Frisch labour elasticity, η, and the price elasticity of demand, ϕ, which are all taken from Andrès and Doménech (2006) and Gali (2008). Regarding preference parameters in the utility function, χ_m is chosen so as to obtain a yearly steady-state value for real money balances as ratio of output equal to 0.46, χ_n is chosen so as to obtain yearly steady-state labour hours equal to 0.27, while χ_g is set at 0.1. The price rigidity parameter, θ, is set at 0.5 (as we report below, we have experimented with various values of θ and all key results remain unaffected).

In our baseline parameterization, the critical value of the output share of public debt, above which sovereign risk premia emerge, $\overline{d}$, is set at 0.9. This value is consistent with evidence provided by e.g. Reinhart and Rogoff (2010) and Checherita-Westphal and Rother (2012) that, in most advanced economies, the adverse effects of public debt arise when it is around 90-100% of GDP. It is also within the range of thresholds for sustainable public debt estimated by the European Commission (2011). In turn, the associated sovereign premium parameter, ψ, is set at 0.05, which, jointly with the value of $\overline{d}$, implies a steady-state premium for Italy over the German rate equal to 1.1. These values are in line with empirical findings for OECD countries (see Ardagna et al., 2004). As we report below in section 6, our results are robust to changes in these parameter values.

Concerning exogenous variables, the persistence and standard deviation parameters of the TFP shock are set respectively at $\rho^a = 0.92$ and $\sigma_a = 0.017$ (the value of ρ^a is similar to that in Schmitt-Grohé and Uribe, 2007, while the value of σ_a is close to that in Bi, 2010, and Bi and Kumhof, 2009). As reported below, our results are robust to changes in these values. Regarding the rest-of-the world variables, Π_t^{H*}, Q_t^* and c_t^{F*}, we set their long-run average values equal to $\Pi^{H*} = 1$, $Q^* = 1.03$ and $c^{F*} = 0.9c^F$, where 0.9 is calibrated to replicate the net export position found in the Italian data. In the baseline parameterization, γ in equation (23) for foreign imports is set at 0.9.

The long-run values of fiscal and public finance policy instruments, τ_t^c, τ_t^k, τ_t^n, s_t^g, s_t^l, λ_t are set at their data averages. In particular, τ^c, τ^k, τ^n are the effective tax rates on consumption, capital and labor in the data over 2001-2011. Moreover, s^g and $-s^l$, namely, government spending and lump-sum transfer payments as shares of output, are set at their average values in the data, which are 0.22 and 0.21 respectively. Finally, λ, the share of total public debt held by domestic private agents is set at 0.6, which is again its average value in the data during the same period.

3.2 Steady state solution or the "status quo"

Table 2 presents the steady state solution of the model economy when we use the parameter values and the policy instruments in Table 1. In this solution, we treat total public debt, d, as the residually determined public finance instrument. In Table 2, we also present some key ratios in the Italian data whenever available. Notice that most of the solved ratios are close to their actual values. In particular, notice the solution for total foreign debt as share of output, which is $\frac{(1-s)dTT^{1-\nu}-TT^{\nu^*}f^h}{y^H}=0.36$; its value in the data is very close, around 0.35 (see Diz Dias, 2010, for external debt statistics of the euro area). Also, the solution for total public debt as share of output, $\frac{D}{P^H y^H}$, is 1.1, which is again close to the data average, 1.09.

This solution will serve as a point of departure. That is, in what follows, we depart from this solution to study various policy experiments. This is why we call it the "status quo" solution. In this solution, a lower public debt to output ratio implies a lower sovereign premium and this leads to higher capital, higher output and higher welfare. This can rationalize the debt consolidation policies studied in what follows.

Table 2: Steady state solution (the "status quo")

Variables	Description	Steady-state solution	Data
n	hours worked	0.27	-
w	real wage rate	1.13	-
r^k	real return to physical capital	0.12	-
$Q-Q^*$	interest rate premium	0.013	0.01
$TT^{1-\nu}\frac{c}{y^H}$	consumption as share of GDP	0.65	0.73
$\frac{k}{y^H}$	physical capital as share of GDP	2.95	3.48
$TT^{\nu^*}\frac{f^h}{y^H}$	private foreign assets as share of GDP	0.08	0.1
$s^d\equiv\frac{D}{P^H y^H}$	total public debt as share of GDP	1.1	1.09
$\frac{(1-s)dTT^{1-\nu}-TT^{\nu^*}f^h}{y^H}$	total foreign debt as share of GDP	0.36	0.35

Note: Variables and shares are denominated in domestic currency.

4 The role of policy and solution strategy

In this section, we explain the policy scenaria, how we model debt consolidation and how we compute optimized feedback policy rules.

Recall that, along the transition path, nominal rigidities imply that money is not neutral so that monetary policy and the exchange rate regime matter to the real economy. As said in subsection 2.7, here we focus on fixed exchange rates and loss of monetary policy independence. Also, recall that, along the transition path, different counter-cyclical policy rules can have different implications. Thus, our aim is to welfare rank different counter-cyclical fiscal policy rules when there is no room for monetary policy.

4.1 Two policy scenaria

Motivated by the recent policy debate, we study two scenaria regarding policy action. In the first, used as a benchmark, the role of policy is only to stabilize the economy against shocks. For instance, say that the economy is hit by an adverse temporary TFP shock, which, as the impulse response functions reveal, produces a contraction in output, a rise in the public debt to output ratio and a rise in the sovereign premium. Then, the policy questions are which policy instrument to use, and how strong the reaction of policy instruments to deviations from targets should be, in order to maximize household's welfare criterion (see subsection 4.3 below). Note that, in this case, the policy targets in the feedback rules (19)-(22) are given by the steady state status quo solution. In other words, in this policy scenario, we depart from, and end up, at the status quo solution in subsection 3.2 above, so that transition dynamics are driven by shocks only.

The second scenario is richer. Now the role of policy is twofold: to stabilize the economy against the same shocks as above and, at the same time, to improve resource allocation by gradually reducing the public debt to GDP ratio over time. The policy questions are as above except that, now, the policy targets in the feedback rules (19)-(22) are given by the steady state solution of the new reformed economy. In other words, in this case, we depart from the status quo solution with sovereign premia, but we end up at a new reformed steady state with lower public debt and zero premia. Thus, now there are two sources of transition dynamics: temporary shocks and the deterministic difference between the initial and the new reformed long run (see also Cantore et al., 2012).

The next subsection provides details for the debt consolidation scenario.

4.2 Debt consolidation

We assume that, in the reformed economy, the government reduces the share of public debt from 110% (which is its average value in the data over the sample period and was also our status quo solution) to the target value of 90%. Since, in our model, sovereign risk premia arise whenever public debt happens to be above the 90% threshold, premia are also eliminated once such consolidation has been achieved. Debt reductions can be accommodated by adjustments in the tax-spending policy instruments, namely, the output share of public spending, and the tax rates on capital income, labour income and consumption.

It is widely recognized that debt consolidation implies a tradeoff between short-term pain and medium-term gain. During the early phase of the transition, debt consolidation comes at the cost of higher taxes and/or lower public spending. In the medium- and long-run, a reduction in the debt burden allows, other things equal, a cut in tax rates, and/or a rise in public spending. Thus, one has to value the early costs of stabilization vis-a-vis the medium- and long-term benefits from the fiscal space created.

It is also widely recognized that the implications of fiscal reforms, like debt consolidation, depend heavily on the public financing policy instrument used, namely, which policy instrument adjusts endogenously to accommodate the exogenous changes in fiscal policy (see e.g. Leeper et al., 2009, and Davig and Leeper, 2011). In the case of debt consolidation, such implications are expected to depend both on which policy instrument bears the cost of adjustment in the early period of adjustment and on which policy instrument is expected to reap the benefit, once consolidation has been achieved. Notice that if lump-sum policy instruments were available, the costs of fiscal adjustment would be trivial.

Given the above, to understand the logic of our results, and following usual practice in related studies, we will start by experimenting with one fiscal instrument at a time. This means that we allow only one of the fiscal policy instruments to react to debt and output gaps during the transition phase and, at the same time, it is the same fiscal policy instrument that adjusts in the long-run to close the government budget. Thus, we will start by assuming that the same policy instrument bears the cost of, and reaps the benefit from, debt consolidation. In turn, we will experiment with fiscal policy mixes, which means that we can use different instruments in the transition and in the long run.

Specifically, we work as follows. We first compare the steady state equilibria with, and without, debt consolidation. In turn, setting as initial conditions for the state variables, their values from the solution of the economy without debt consolidation (in particular, from the status quo solution in subsection 3.2), we compute the equilibrium transition path as we travel towards the steady state of the new reformed economy. This is for each method of public financing used. The feedback policy coefficients of the instrument(s) used along the transition path are chosen optimally. The way we compute optimized feedback policy rules with, or without, debt consolidation is explained in the next subsection.

4.3 Optimized feedback policy rules

Irrespectively of the policy experiments studied, to make the comparison of different policies meaningful, we compute optimized policy rules, so that results do not depend on ad hoc differences in feedback policy coefficients across different policy rules. The welfare criterion is household's expected lifetime utility.

To do so, we work in two steps. In the first preliminary step, we search for the ranges of feedback policy coefficients, as defined in equations (19-22), which allow us to get a locally determinate equilibrium (this is what Schmitt-Grohé and Uribe, 2007, call implementable rules). If necessary, these ranges will be further restricted so as to give economically meaningful solutions for the policy instruments (e.g. tax rates less than one and non-negative nominal interest rates). In our search for local determinacy, we experiment with one, or more, policy instruments and one, or more, operating targets at a time.

In the second step, within the determinacy ranges found above, we compute the welfare-maximizing values of feedback policy coefficients (this is what Schmitt-Grohé and Uribe, 2005 and 2007, call optimized policy rules). The welfare criterion is to maximize the conditional welfare of the household, as defined in equation (26), where conditionality refers to the initial conditions chosen; the latter are given by the status quo solution above. To this end, following e.g. Schmitt-Grohé and Uribe (2004), we take a second-order approximation to both the equilibrium conditions and the welfare criterion. As is known, this is consistent with risk-averse behavior on the part of economic agents and can also help us to avoid possible spurious welfare results that may arise when one takes a second-order approximation to the welfare criterion combined with a first-order approximation to the equilibrium conditions (see e.g. Gali, 2008, pp. 110-111, Malley et al., 2009, and Benigno and Woodford, 2012).

In other words, we first compute a second-order accurate approximation of both the conditional welfare and the decentralized equilbrium, as functions of feedback policy coefficients, by using the perturbation method of Schmitt-Grohé and Uribe (2004) and, in turn, we use a matlab function (such as fminsearch.m) to compute the values of the feedback policy coefficients that maximize this approximation. In this exercise, as said above, if necessary, the feedback policy coefficients are restricted to be within some prespecified ranges so as to deliver determinacy and give meaningful values for policy instruments. All this is with, and without, debt consolidation.

5 Results

In this section, we present the main results. The emphasis will be on the case of the reformed economy but, for reasons of comparison, we also present results for the case without debt consolidation. We start by defining the region of feeback policy coefficients that give local determinacy. Recall that, as said in subsection 4.1 above, in the case of debt consolidation, transition dynamics are driven both by a temporary adverse supply shock and by changes in fiscal policy instruments aiming at public debt reduction and elimination of sovereign premia over time.

5.1 Determinacy areas

As is known, local determinacy depends crucially on the values of feedback policy coefficients. Our experiments show that economic policy can guarantee determinacy when fiscal policy instruments (s_t^g, τ_t^c, τ_t^k, τ_t^n) react to public liabilities between critical minimum and maximum values, where these values differ across different policy instruments. In particular, the ranges of fiscal reaction to public liabilities are $0.06 < \gamma_l^g < 1.7$, $0.11 < \gamma_l^c < 3.79$, $0.13 < \gamma_l^k < 2.35$ and $0.14 < \gamma_l^n < 1.58$ for s_t^g, τ_t^c, τ_t^k and τ_t^n respectively. By contrast, the values of γ_y^q, where $q \equiv (g, c, k, n)$, measuring the reaction of fiscal policy instruments to the output gap, have not been found to be critical to determinacy.

5.2 Results with debt consolidation (one fiscal instrument at a time)

Within the determinacy ranges, we now compute optimized policy rules and the associated macroeconomic outcomes under debt consolidation. As explained in subsection 4.2, to understand how the model works, we start with one fiscal instrument at at time (fiscal policy mixes are studied in subsections 5.3 and 5.4 below).

5.2.1 Policy reaction and welfare

Welfare results, with debt consolidation, are reported in Table 3. The first colunm lists the fiscal policy instrument used, while the optimal feedback reaction of this instrument to the debt and output gaps during the transition are in the second column. Steady state utility, u, is reported in the third column, while expected discounted lifetime utility, $E_0 V_0$, is reported in the last column (below we also report welfare differences expressed in consumption equivalents). We report that the resulting values of all instruments used are well-defined in all solutions and over all periods, meaning that tax rates and public spending shares are between zero and one and that the nominal interest rate is above zero (below, in subsection 5.4, we also report results for the case in which changes in policy instruments are further restricted).

The results in Table 3 show that, if we rank fiscal instruments according to expected discounted lifetime utility or steady state utility, and we are restricted to use a single fiscal instrument at a time, then capital and labor tax rates score better than the consumption tax rate or the share of public spending. This superiority becomes clearer when the comparison is in terms of steady state utility.

Table 3 : Optimized policy rules and welfare with debt consolidation
(one fiscal instrument at a time)

fiscal instrument	optimal reaction to debt and output	steady state utility u	expected discounted lifetime utility E_0V_0
s_t^g	$\gamma_l^g = 0.1163$ $\gamma_y^g = 0.0085$	0.732515	23.4068
τ_t^c	$\gamma_l^c = 0.4599$ $\gamma_y^c = 0$	0.733221	23.5520
τ_t^k	$\gamma_l^k = 0.4182$ $\gamma_y^k = 0$	0.772301	24.4192
τ_t^n	$\gamma_l^n = 0.2677$ $\gamma_y^n = 0.0692$	0.759887	24.3221

Notes: In all solutions, $R_t \geq 1$, $0 < s_t^g$, τ_t^c, τ_t^k, $\tau_t^n < 1$ at all t.

The result that capital and, in turn, labor taxes are better when the criterion is steady state utility is not surprising; once public debt has been reduced, the most efficient way of taking advantage of the fiscal space created is to reduce particularly distorting taxes like capital and labor. This is consistent with the Chamley-Judd normative result that the long-run capital tax rate should be zero. A more interesting result is that capital and labor taxes remain superior even when the criterion is expected discounted lifetime utility. That is, although now there is an intertemporal tradeoff, expectations of cuts in capital and labor taxes in the future dominate over any other short-term effects and this shapes the lifetime welfare ranking in Table 3. Therefore, when we are restricted to use a single fiscal policy instrument all the time, the common belief that it is better to use public spending for debt consolidation (see e.g. European Commission, 2011) is not confirmed in a semi-small open economy with sovereign premia.[15] Erceg and Lindé (2013) also find that labor taxes are better in the short run of an open economy.

Table 4 : Optimized policy rules and welfare with debt consolidation when the residual instrument in the long run is lump-sum transfers

fiscal instrument	optimal reaction to debt and output	steady state utility u	expected discounted lifetime utility E_0V_0
s_t^g	$\gamma_l^g = 0.1127$ $\gamma_y^g = 0.0091$	0.742729	23.7482
τ_t^c	$\gamma_l^c = 0.4505$ $\gamma_y^c = 0$	0.742729	23.8103
τ_t^k	$\gamma_l^k = 0.4007$ $\gamma_y^k = 0$	0.742729	23.5129
τ_t^n	$\gamma_l^n = 0.2567$ $\gamma_y^n = 0.0608$	0.742729	23.7269

Notes: In all solutions, $R_t \geq 1$, $0 < s_t^g$, τ_t^c, τ_t^k, $\tau_t^n < 1$ at all t.

The fact that expectations of cuts in capital and labor taxes in the future play a key role in shaping expected discounted lifetime utility is confirmed when we assume instead that the fiscal space created by debt consolidation is used to increase lump-sum transfers, rather than to reduce distorting taxes, at steady state. In this case, with trivial expected benefits from debt consolidation, consumption taxes and government spending score better than capital and labor taxes in terms of lifetime utility. Results for this case are reported in Table 4. Notice that now, since lump-sum transfers do not affect the real allocation, the steady state solution

[15] By contrast, in a closed economy without sovereign premia, public spending scores the best in terms of expected discounted lifetime utility. That is, transition effects dominate over steady state effects. See Philippopoulos et al. (2012).

is the same across different fiscal policy instruments.

5.2.2 Public debt and output

Inspection of the optimal values of the feedback policy coefficients in Table 3 reveals that the reaction to the output gap should be much smaller in magnitude than the reaction to public debt. In other words, when we are resctricted to use one fiscal instrument at a time, the concern for debt consolidation should more than offset the concern for output stabilization. As a result, public spending should fall, while all tax rates should rise, over time until they converge to their new reformed steady state values.[16]

Figure 1 shows the implications of the above policies for the path of public debt as share of output. This is for each fiscal policy instrument used. For instance, the continuous line shows the case in which we use the output share of public spending, s_t^g, as the state-contingent instrument; that is, as reported in Table 3, row 1, s_t^g reacts to public debt and output with feedback coefficients $\gamma_l^g = 0.1163$ and $\gamma_y^g = 0.0085$ respectively, while all other policy feedback coefficients are set at zero, meaning that the other policy instruments remain constant at their steady-state values (data averages). In a similar manner, the other lines show results when we use τ_t^c, τ_t^k and τ_t^n. As can be seen, debt starts at 110%, which is its status quo value, and ends up at 90% at the new reformed long run. In the short run, the economy is also hit by a temporary adverse shock that reduces output and further increases the debt-to-output ratio but eventually, thanks to fiscal reaction, debt starts falling towards its 90% threshold.[17]

Inspection of Figure 1 reveals that the duration of the debt consolidation phase, or equivalently the speed of debt reduction, varies depending on which fiscal instrument is used. In this policy experiment, if we use the consumption tax rate, τ_t^c, it should take around five years only to bring debt down; if we use capital taxes, τ_t^k, around seven years; if we use public spending, s_t^g, above 15 years; and, finally, it should take about 20 years, in the case of labor taxes, τ_t^n. In other words, debt reduction should take place at a much lower speed when we use public spending and especially labor taxes. This is because these two instruments, namely cuts in public spending and rises in labor taxes, are more recessionary than rises in consumption and

[16] The associated impulse response functions are available upon request.

[17] As also discussed in European Commission (2012), consolidations can lead to increases in the debt to output ratio in the short run. This is driven by "the denominator effect".

capital taxes during the early phase of debt consolidation. That consumption taxes are less distorting is well known (see e.g. Bi, 2010). On the other hand, the explanation for capital taxes is that, in the very short run, the capital tax base is inelastic. Namely, in the very short run, capital taxes act like a capital levy on predetermined wealth and this is not so distorting in short time horizons.

Figure 1 : Path of public debt as share of output

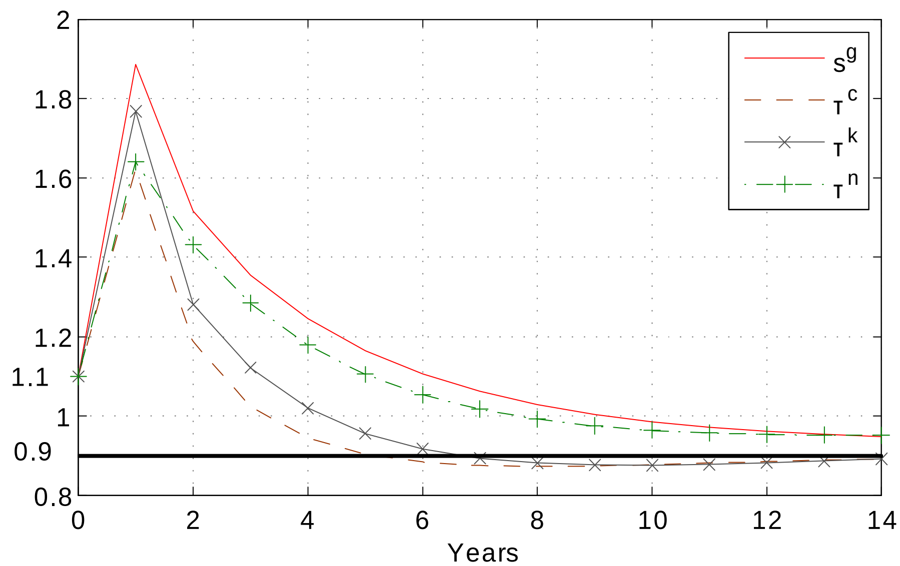
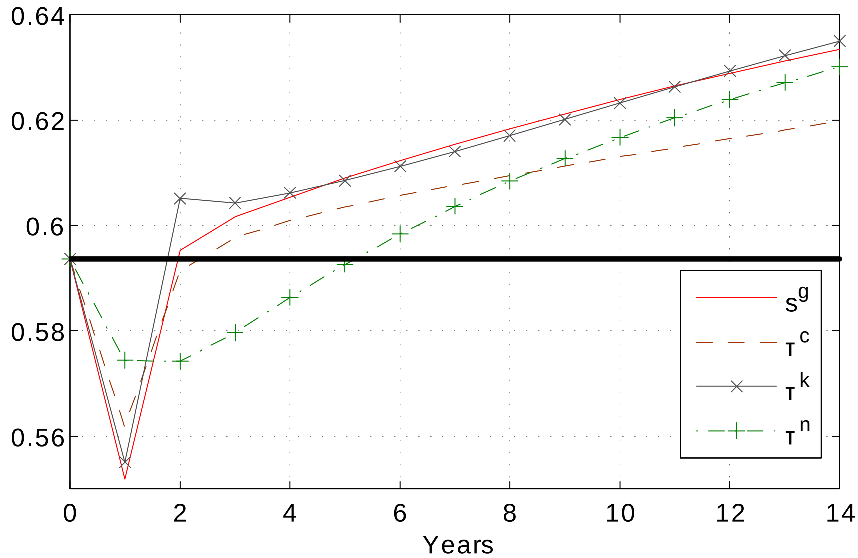


Figure 2 shows the implications of the above policies for the path of output, again for each fiscal policy instrument used. As can be seen, since it is optimal to reduce debt gradually when we use labor taxes, the recession lasts longer; this is the cost of gradualism. By contrast, when we use the other fiscal policy instruments, it is optimal to engineer a deeper recession at impact, which is at the benefit of a quicker recovery later on.[18] Notice that although the use of public spending, s^g, is particularly recessionary in the short run (this is also the case in Erceg and Lindé, 2013), the associated fall in output is not so prolonged as when we use labor

[18] Our results imply that, at impact, the use of government spending causes an output loss of around 7%, while the same loss is around 6.5% if we use capital taxes, 5.3% if we use consumption taxes and only 3.2% if we use labor taxes. We also report that these dynamics are primarily driven by debt consolidation; even if we switch off the adverse TFP shock, the optimized policy rules imply that debt consolidation leads to a short term recession, irrespectively of whether there are adverse shocks or not at the same time.

taxes.[19]

Figure 2 : Path of output



5.3 Results with and without debt consolidation (fiscal policy mixes)

So far, we have studied one fiscal instrument at a time. In particular, as discussed in subsection 4.2 above, we have restricted ourselves to the case in which we use a single instrument all the time. Although this has helped us to understand how the model works, it is too restrictive. Policymakers are free to use policy mixes. Therefore, we now study the richer case in which policymakers can use different instruments in the transition and in the long run and, in addition, they can use all available fiscal instruments at the same time during the transition. Since feedback policy cofficients are chosen optimally, this can also tell us how to assign different policy instruments to different intermediate policy targets.

[19]Thus, if we use labor taxes only, it is optimal to spread the cost of debt consolidation over more periods. To understand this, recall that here we have an open economy distorted by sovereign premia, where the latter further rise when the debt-to-output ratio rises, or equivalenty when output falls. Thus, a big drop in output would be extra costly here. Since an increase in labor tax rates is particularly recessionary, it is better to go for a relatively mild use of labor taxes at impact which comes at the cost of a prolonged recession. By contrast, in a closed economy without sovereign premia, the short-term recession is much sharper when we use labor taxes (see Philippopoulos et al., 2012).

To save on space, we directly focus on the best policy mix found.[20] This is the case in which we allow all available fiscal instruments, and at the same time, to follow the state-contingent rules (19)-(22) during the transition, while it is the capital tax rate that takes advantage of the fiscal space created once the debt burden has been reduced and sovereign premia have been eliminated in the new reformed long run. Our solution implies that, in this new reformed long run, the capital tax rate can be cut from 0.32 in the data to 0.289.

5.3.1 Policy reaction and welfare

The optimal reaction of the four fiscal instruments to debt and output gaps are reported in Table 5. The values of the optimized feedback policy coefficients imply a clear-cut assigment of instruments to targets. Government spending and consumption tax rates should be used to address the debt problem, while capital tax rates should be used to address the output gap. On the other hand, it is better to avoid changes in labor tax rates (the optimized feedback coefficients in the rule for the labor tax rate are practically zero in this case). These signs and magnitudes of feedback policy coefficients mean that government spending should fall, and consumption tax rates should rise, to bring public debt down, while, at the same time, the capital tax rates should be cut to stimulate the real economy in an attempt to increase the denominator in the debt-to-output ratio.[21]

Table 5: Optimal reaction to debt and output with debt consolidation (fiscal policy mix)

fiscal instruments	optimal reaction to debt	optimal reaction to output
s_t^g	$\gamma_l^g = 0.2857$	$\gamma_y^g = 0.0091$
τ_t^c	$\gamma_l^c = 0.4331$	$\gamma_y^c = 0$
τ_t^k	$\gamma_l^k = 0.0022$	$\gamma_y^k = 3.61$
τ_t^n	$\gamma_l^n = 0.006$	$\gamma_y^n = 0$

Setting the feedback policy coefficients as in Table 5, the associated expected discounted utility over various time horizons is reported in the first row of Table 6. Studying what happens

[20] Results for other suboptimal mixes are available upon request.
[21] The associated impulse response functions are available upon request.

to welfare over various time horizons can be useful because, for several (e.g. political-economy) reasons, economic agents can be short-sighted. It can also help us to understand the possible conflicts between short-, medium- and long-term effects from debt consolidation. The second row in Table 6 reports results without debt consolidation, other things equal. Thus, we again compute the best policy mix meaning that all fiscal policy instruments, and at the same time, are allowed to react to debt and output gaps but now the debt and output targets in the policy rules remain as in the status quo solution (as we explained above in subsection 4.1, without debt consolidation, we again compute optimized feedback policy rules but now the economy starts from, and also returns to, its status quo with transition dynamics driven by shocks only). Finally, the last row in Table 6 gives the welfare gain or loss of debt consolidation in consumption equivalents (see e.g. Lucas, 1990). A positive number means that welfare would increase with debt consolidation; and vice versa: a negative number means that welfare would decrease with debt consolidation.

Table 6: Welfare over different time horizons

with, and without, debt consolidation (fiscal policy mix)

	2 periods	4 periods	10 periods	20 periods	lifetime
with consolid.	1.0508	2.0505	5.2723	10.1918	24.8749
without consolid.	1.2668	2.4350	5.4208	9.0363	16.2853
welfare gain/loss	-0.0722	-0.0799	-0.0163	0.0864	0.4071

Notes: In all solutions, $R_t \geq 1$, $0 < s_t^g$, τ_t^c, τ_t^k, $\tau_t^n < 1$ at all t.

The results in Table 6 reveal that, other things equal, debt consolidation improves welfare only if we are relatively far-sighted. In particular, expected discounted utility is higher with debt consolidation, only when we care beyond the first ten years. Reversing the argument, debt consolidation comes at a short-term cost.[22] Once the short- term pain is over, the welfare gain in consumption equivalents is substantial: welfare would increase by around 40 percent over lifetime.[23] Also, notice that a comparison of the results in Tables 3 and 6 implies that policy

[22] It should be pointed out that the rise in welfare is partly driven by the fact that debt consolidation and elimination of sovereign premia in the reformed long-run equilibrium allow a higher value of the time preference rate than in the pre-reformed long-run solution in section 3 (in particular, the calibrated value of β was 0.9603 in the status quo solution in section 3, while it is 0.9709 without premia).

[23] Prescott (2002) finds welfare gains of similar magnitude when Japan or France adopt the tax policy or the production efficiency of the USA.

mixes lead to higher welfare. This is natural: policy mixes give more choice to policymakers.

5.3.2 Public debt and output

We now study the implications of the above policy mix for the time paths of public debt-to-output ratio and output. These are shown in Figures 3 and 4 respectively. Actually, in these Figures, we compare two different policy mixes. First, the mix where all fiscal instruments are allowed to react to both debt and output. This was the case reported in Tables 5-6 above and is illustrated by the continuous dotted line in Figures 3 and 4. Second, the mix where all fiscal instruments are allowed to react to debt only. This is illustrated by the dashed line in Figures 3 and 4. We study the latter case because we want to evaluate the macroeconomic implications of policies that focus on debt stabilization only.

We again compute optimized policy rules. We report that, when fiscal instruments are allowed to react to debt only, the expected discounted lifetime utility is 24.6262, which is less than in Table 6. Figures 3 and 4 show why it is not a good idea to react to debt only: public debt is reduced too quickly, and this comes at the cost of a recession relative to the richer case in which the policy instruments are allowed to react to both debt and output. Actually, notice that Figure 4 implies that, to the extent that we use a policy mix and we follow the assignment of instruments to targets as explained above, it is possible to bring debt down without any recessionary costs. But this is possible only when we are free to change the fiscal policy instruments as much as needed, even if this implies large changes from their historical data. In what follows, we reexamine the above mixes when changes in policy instruments are restricted.

Figure 3: Path of public debt as share of output

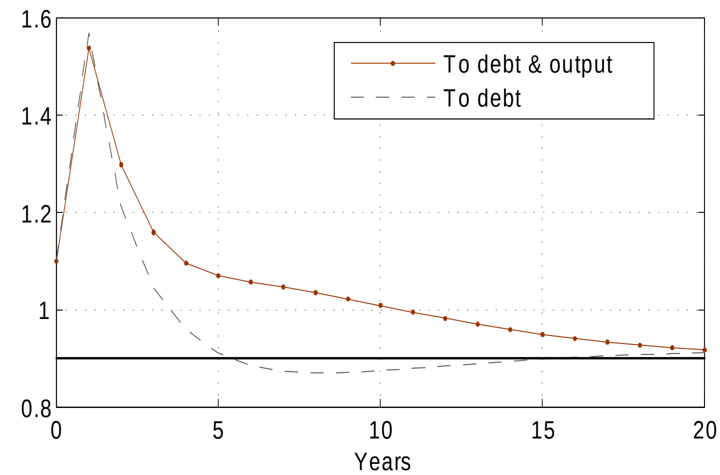
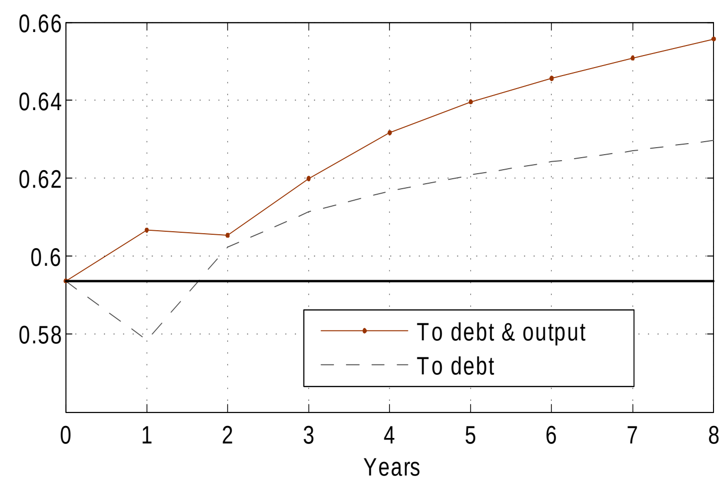


Figure 4: Path of output



5.4 Restricted changes in policy instruments (fiscal policy mixes)

In the analysis so far, all policy instruments were well-defined economically, in the sense that tax rates and public spending shares were between zero and one all the time. Nevertheless, one could argue that, in addition, the values of policy instruments cannot differ substantially from those in the historical data (for various political economy reasons). Therefore, in this subsection, we redo all the above computations restricting now the magnitude of feedback coefficients in the policy rules (19)-(22) so as the policy instruments cannot change by more than 10 percentage points from their averages in the data.

5.4.1 Policy reaction and welfare

Restricted results for optimal feedback policy coefficients and welfare over various time horizons are reported in Tables 7 and 8 (which correspond to Tables 5 and 6 respectively in the previous subsection). We prefer to postpone discussion of results until the end of this subsection.

Table 7 : Optimal reaction to debt and output with debt consolidation

(restricted fiscal policy mix)

fiscal instruments	optimal reaction to debt	optimal reaction to output
s_t^g	$\gamma_l^g = 0.08$	$\gamma_y^g = 0.0013$
τ_t^c	$\gamma_l^c = 0.08$	$\gamma_y^c = 0.001$
τ_t^k	$\gamma_l^k = 0$	$\gamma_y^k = 0.4935$
τ_t^n	$\gamma_l^n = 0.18$	$\gamma_y^n = 0.0008$

Table 8 : Welfare over different time horizons

with, and without, debt consolidation (restricted fiscal policy mix)

	2 periods	4 periods	10 periods	20 periods	lifetime
with consolid.	1.0585	2.1737	5.4673	10.1918	24.7237
without consolid.	1.2668	2.4350	5.4208	9.0363	16.2853
welfare gain/loss	-0.0697	-0.0550	0.0051	0.0834	0.3979

5.4.2 Public debt and output

The restricted time paths of debt-to-output ratio and output are shown in Figures 5 and 6 (which correspond to Figures 3 and 4 respectively in the previous subsection).

Figure 5 : Path of public debt as a share of output

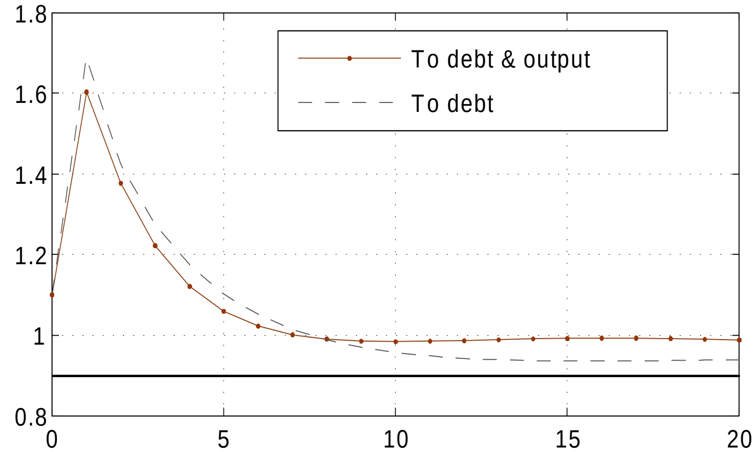
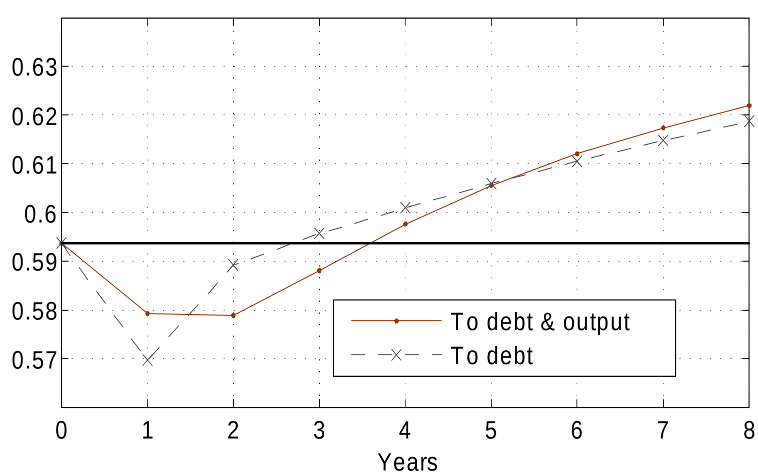


Figure 6: Path of output



Inspection of the new tables and figures, and comparison to their counterparts in the previous subsection, implies that the main qualitative results do not change. Namely, debt consolidation is again preferable to non-debt consolidation after the first ten years. Also, although obviously feedback policy coefficients are now much smaller than in the previous subsection, the best fiscal policy mix again implies that we should earmark public spending and consumption taxes for the reduction of public debt and, at the same time, cut capital taxes to mitigate the recessionary effects of debt consolidation. Besides, as above, it is better to react to output too (via cuts in capital taxes) meaning that the short term recession will be too sharp and counter-productive if we care about debt imbalances only. Actually, we report that, when fiscal instruments are allowed to react to debt imbalances only, the expected discounted lifetime utility is 24.6008, which is less than in Table 8.

On the other hand, there are also some new results relative to the previous subsection. For instance, since now the cut in public spending and the rise in consumption taxes are restricted, we also need to raise labor taxes to cope with the debt problem (see Table 7). Besides, now we cannot avoid a recession in the early phase of fiscal austerity (see Figure 6), which makes these restricted results more realistic than the unrestricted ones.

6 Sensitivity analysis

We finally check the sensitivity of our results. All results reported below are available upon request.

First, our results are robust to changes in all key parameter values. Among the latter, we have extensively experimented with changes in the values of the parameter in the sovereign premium equation, ψ, the parameter in the exports function, γ, the Calvo parameter in the firm's problem, θ, and the adjustment cost parameters on assets and physical capital, ϕ^g, ϕ^h and ξ, whose values are relatively unknown empirically. We report that our main results do not change within $0.002 \leq \psi \leq 0.09$, $0.5 \leq \gamma \leq 1$, $0.1 \leq \theta \leq 0.5$ and $0.01 \leq \phi^g$, ϕ^h, $\xi \leq 2$. Our results also do not depend on the value of χ_g, namely, how much agents value public consumption spending.

Second, following several related papers (see e.g. Coenen et al., 2008, Forni et al., 2010, and Erceg and Lindé, 2013), we have experimented with time-varying and stochastic debt targets. Thus, instead of using a constant over time debt target, l, like in equations (19)-(22) above, we assume that the debt target, defined as l_t^*, follows a stochastic $AR(1)$ process of the form:

$$l_t^* = \left(1 - \rho^l\right) l + \rho^l l_{t-1}^* + \varepsilon_t^l \tag{25}$$

where $0 \leq \rho^l \leq 1$ is an autogressive policy parameter and ε_t^l a debt target shock. In our experiments, we assume that ε_t^l follows an $AR(1)$ process with persistence 0.9 and standard deviation equal to 0.01. We report that our main results remain the same under this new specification. Actually, we have also allowed the autogressive policy parameter, ρ^l, to be determined optimally, along with the other (feedback) policy parameters. It is interesting that, when we use the labor tax rate, the optimal value of ρ^l is found to be rather high during the consolidation phase, confirming the result discussed above, namely, it is optimal to use a smooth path of labor tax rates.

Third, our results are robust to adding more indicators in the feedback policy rules (like inflation or terms of trade) as well as to assuming a more volatile economy (for instance, by increasing the standard deviation of the existing TFP shock or by adding new shocks). Specifically, regarding the latter, we have experimented with adding shocks to the fiscal policy rules in subsection 2.8 and/or to the time-varying debt target in equation (25) above, and the main results again do not change.

7 Concluding remarks and extensions

This paper has studied fiscal policy in a New Keynesian model of a semi-small open economy facing debt-elastic interest-rate premia and not being able to use monetary policy. The focus has been on optimized, simple and implementable feedback policy rules for various categories of taxes and public spending.

Since the results have been written in the Introduction, we close with some possible extensions. It would be interesting to add heterogeneity both in terms of economic agents within a country and in terms of countries. In particular, we could distinguish between private and public employees and so study the distributional implications of the fiscal adjustment policies studied here. It is also interesting to use a two-country model, where countries can differ in, say, fiscal imbalances and/or time preferences and so study the cross-border effects of national stabilization and debt consolidation policies. We leave these extensions for future work.

References

[1] Alesina A., Favero C. and Giavazzi F., 2012. The output effect of fiscal consolidations. NBER, Working Paper no. 18336.

[2] Almeida V., Castro G., Félix R.M. and Maria J.R., 2013. Fiscal consolidation in a small euro-area economy. International Journal of Central Banking, 9, 1-38.

[3] Andrès J. and Doménech R., 2006. Automatic stabilizers, fiscal rules and macroeconomic stability. European Economic Review, 50, 1487-1506.

[4] Ardagna S., Caselli F. and Lane T., 2004. Fiscal discipline and the cost of public debt service: Some estimates for OECD Countries. European Central Bank, Working Paper no. 411.

[5] Batini N., Levine P. and Pearlman J., 2008. Monetary and fiscal rules in an emerging small open economy. University of Surrey, CDMC 08/10.

[6] Batini N., Gallegari G., and Giovanni M., 2012. Successful austerity in the United States, Europe and Japan. IMF Working Paper No 12/190.

[7] Benigno P. and Woodford M., 2012. Linear-quadratic approximation of optimal policy problems. Journal of Economic Theory 147, 1-42.

[8] Bi H., 2010. Optimal debt targeting rules for small open economies. Mimeo.

[9] Bi H., 2012. Sovereign default risk premia, fiscal limits and fiscal policy. European Economic Review, 56, 389-410.

[10] Bi H. and Kumhof M., 2011. Jointly optimal monetary and fiscal policy rules under liquidity constraints. Journal of Macroeconomics, 33, 373-389.

[11] Bi H., Leeper E. and Leith C., 2012. Uncertain fiscal consolidations. Mimeo.

[12] Blanchard O. and Giavazzi F., 2003. Macroeconomic effects of regulation and deregulation in goods and labor markets. Quarterly Journal of Economics, 118, 879-907.

[13] Calvo G., 1983. Staggered prices in a utility-maximizing framework. Journal of Monetary Economics, 12, 383-398.

[14] Cantore C., Levine P., Melina G. and Pearlman J., 2012. Optimal fiscal and monetary rules in normal and abnormal times. University of Surrey, mimeo.

[15] Checherita-Westphal C. and Rother P., 2012. The impact of high government debt on economic growth and its channels: An empirical investigation for the euro area. European Economic Review, 56, 1392-1405.

[16] Christiano L., Trabandt M. and Walentin K., 2011. Introducing financial frictions and unemployment into a small open economy model. Journal of Economics Dynamics and Control, 35, 1999-2041.

[17] Coenen G., Mohr M. and Straub R., 2008. Fiscal consolidation in the euro area: Long-run benefits and short-run costs. Economic Modelling, 25, 912-932.

[18] Cogan J., Taylor J., Wieland V. and Wolters M., 2013. Fiscal consolidation strategy. Journal of Economic Dynamics and Control, 37, 404-421.

[19] Collard F. and Dellas H., 2006. Price rigidity and the selection of the exchange rate regime. Open Economies Review, 17, 5-26.

[20] Corsetti G., Kuester K., Meier A. and Muller G., 2013. Sovereign risk, fiscal policy and macroeconomic stability. Economic Journal, 123, F99-F132.

[21] Davig T. and Leeper E., 2011. Monetary-fiscal policy intreractions and fiscal stimulus, European Economic Review, 55, 211-227.

[22] Diz Dias J., 2010. External debt statistics of the euro area. Mimeo, European Central Bank.

[23] EEAG Report on the European Economy, 2014. CESifo, Munich.

[24] Erceg C. and Lindé J., 2012. Fiscal consolidation in an open economy. American Economic Review, 102, 186-191.

[25] Erceg C. and Lindé J., 2013. Fiscal consolidation in a currency union: Spending cuts vs. tax hikes. Journal of Economic Dynamics and Control, 37, 422-445.

[26] European Commission, 2011. Public Finances in EMU-2011. Brussels.

[27] European Commission, 2012. Public Finances in EMU-2012. Brussels.

[28] Fernández-Villaverde J., Guerron-Quintana P., Rubio-Ramirez J.F. and Uribe M., 2011. Risk matters: The real effects of volatiliy shocks. American Economic Review, 101, 2530-2561.

[29] Forni L., Gerali A. and Pisani M., 2010. The macroeconomics of fiscal consolidation in euro area countries. Journal of Economic Dynamics and Control, 34, 1791-1812.

[30] Gali J. and Monacelli T., 2005. Monetary policy and exchange rate volatility in a small open economy. Review of Economic Studies, 72, 707–734.

[31] Gali J. and Monacelli T., 2008. Optimal monetary and exchange rate policy in a currency union. Journal of International Economics, 76, 116-132.

[32] Gali J., 2008. Monetary Policy, Inflation and the Business Cycle: An Introduction to the New Keynesian Framework. Princeton University Press.

[33] Ghosh A., Kim J., Mendoza E., Ostry J. and Qureshi M., 2013. Fiscal fatique, fiscal space and debt sustainability in advanced economies. Economic Journal, 123, F4-F30.

[34] Herz B. and Hohberger S., 2013. Fiscal policy, monetary regimes and current account dynamics. Review of International Economics, 21, 118-136.

[35] Kirsanova T., Leith C. and Wren-Lewis S., 2009. Monetary and fiscal policy interaction: the current consensus assignment in the light of recent developments. Economic Journal, 119, F482-F495.

[36] Kirsanova T. and Wren-Lewis S., 2012. Optimal fiscal feedback on debt in an economy with nominal rigidities. Economic Journal, 122, 238-264.

[37] Leeper E., 1991. Equilibria under active and passive monetary and fiscal policies. Journal of Monetary Economics, 27, 129-147.

[38] Leeper E., Plante M. and Traum N., 2009. Dynamics of fiscal financing in the United States. Journal of Econometrics, 156, 304-321.

[39] Leith C. and Wren-Lewis S., 2008. Interactions between monetary and fiscal policy under flexible exchange rates. Journal of Economic Dynamics and Control, 32, 2854-2882.

[40] Lucas R., 1990. Supply side economics: An analytical review. Oxford Economic Papers, 42, 293-316.

[41] Malley J., Philippopoulos A. and Woitek U., 2009. To react or not? Technology shocks, fiscal policy and welfare in the EU-3. European Economic Review, 689-714.

[42] Pappa E. and Neiss K., 2005. Persistence without too much price stickiness: The role of factor utilization. Review of Economics Dynamics, 8, 231-255.

[43] Pappa E. and Vassilatos V., 2007. The unbearable tightness of being in a monetary union: Fiscal restrictions and regional stability. European Economic Review, 51, 1492-1513.

[44] Pappa E., Sajedi R. and Vella E., 2014. Fiscal consolidation with tax evasion and rent seeking: spending cuts or tax hikes?. Mimeo, EUI, Florence.

[45] Perotti R.,1996. Fiscal consolidation in Europe: Composition matters. Americal Economic Review, 86, 105-110.

[46] Philippopoulos A., Varthalitis P. and Vassilatos V., 2012. On the optimal mix of monetary and fiscal policy actions in a closed economy. Available on http://www.aueb.gr/users/aphil/files/Phil_et_al_2012.pdf

[47] Prescott E., 2002. Prosperity and depression. American Economic Review, 92, 1-15.

[48] Reinhart C. and Rogoff K., 2010. Growth in a time of debt. American Economic Review, 100, 573-578.

[49] Schmitt-Grohé S. and Uribe M., 2003. Closing small open economies. Journal of International Economics, 61, 163-185.

[50] Schmitt-Grohé S. and Uribe M., 2004. Solving dynamic general equilibrium models using a second-order approximation to the policy function. Journal of Economic Dynamics and Control, 28, 755-775.

[51] Schmitt-Grohé S. and Uribe M., 2005. Optimal fiscal and monetary policy in a medium-scale macroeconomic model. In Gertler M. and Rogoff K., eds., NBER Macroeconomics Annual, MIT Press, Cambridge MA, 385-425.

[52] Schmitt-Grohé S. and Uribe M., 2007. Optimal simple and implementable monetary and fiscal rules. Journal of Monetary Economics, 54, 1702-1725.

[53] Wren-Lewis S., 2010. Macroeconomic policy in light of the credit crunch: the return of counter-cyclical fiscal policy?. Oxford Review of Economic Policy, 26, 71-86.

8 Appendix 1: Households

This Appendix presents and solves the problem of the household. There are $i = 1, 2, ..., .N$ identical domestic households who act competitively.

8.1 Household's problem

Each i maximizes expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_{i,t}, n_{i,t}, m_{i,t}, g_t\right) \tag{26}$$

where $c_{i,t}$ is i's consumption bundle as defined above, $n_{i,t}$ is i's hours of work, $m_{i,t} \equiv \frac{M_{i,t}}{P_t}$ is i's real money holdings, g_t is per capita public spending, $0 < \beta < 1$ is the time discount rate, and E_0 is the rational expectations operator conditional on the information set.

The period utility function is of the form (see also e.g. Gali, 2008):

$$u_{i,t}\left(c_{i,t}, n_{i,t}, m_{i,t}, g_t\right) = \frac{c_{i,t}^{1-\sigma}}{1-\sigma} - \chi_n \frac{n_{i,t}^{1+\eta}}{1+\eta} + \chi_m \frac{m_{i,t}^{1-\mu}}{1-\mu} + \chi_g \frac{g_t^{1-\zeta}}{1-\zeta} \tag{27}$$

where χ_n, χ_m, χ_g, σ, η, μ, ζ are preference parameters.

The period budget constraint of each i expressed in real terms is:

$$\begin{aligned}
& \left(1+\tau_t^c\right)\left[\frac{P_t^H}{P_t} c_{i,t}^H + \frac{P_t^F}{P_t} c_{i,t}^F\right] + \frac{P_t^H}{P_t} x_{i,t} + b_{i,t} + m_{i,t} + \frac{S_t P_t^*}{P_t} f_{i,t}^h + \frac{\phi^h}{2}\left(\frac{S_t P_t^*}{P_t} f_{i,t}^h - \frac{S P^*}{P} f^h\right)^2 \\
= \; & \left(1-\tau_t^k\right)\left[r_t^k \frac{P_t^H}{P_t} k_{i,t-1} + \widetilde{\omega}_{i,t}\right] + \left(1-\tau_t^n\right) w_t n_{i,t} + R_{t-1} \frac{P_{t-1}}{P_t} b_{i,t-1} + \\
& + \frac{P_{t-1}}{P_t} m_{i,t-1} + Q_{t-1} \frac{S_t P_t^*}{P_t} \frac{P_{t-1}^*}{P_t^*} f_{i,t-1}^h - \tau_{i,t}^l
\end{aligned} \tag{28}$$

where $x_{i,t}$ is i's domestic investment, $b_{i,t}$ is i's end-of-period real domestic government bonds, $m_{i,t}$ is i's end-of period real domestic money holdings, $f_{i,t}^h$ is i's end-of-period real internationally traded assets denominated in foreign currency, r_t^k is the real return to inherited domestic capital, $k_{i,t-1}$, $\widetilde{\omega}_{i,t}$ is i's real dividends received by domestic firms, w_t is the real wage rate, $R_{t-1} \geq 1$ is the gross nominal return to domestic government bonds between $t-1$ and t, $Q_{t-1} \geq 1$ is the gross nominal return to international assets between $t-1$ and t, $\tau_{i,t}^l$ are real lump-sum taxes/transfers to each household, and τ_t^c, τ_t^k, τ_t^n are tax rates on consumption, capital income and labour income respectively. Thus, small letters denote real variables, namely, $m_{i,t} \equiv \frac{M_{i,t}}{P_t}$, $b_{i,t} \equiv \frac{B_{i,t}}{P_t}$, $f_{i,t}^h \equiv \frac{F_{i,t}^h}{P_t^*}$, $w_t \equiv \frac{W_t}{P_t}$, $\widetilde{\omega}_{i,t} \equiv \frac{\widetilde{\Omega}_{i,t}}{P_t}$, $\tau_{i,t}^l \equiv \frac{T_{i,t}^l}{P_t}$, where capital letters denote nominal variables. The parameter $\phi^h \geq 0$ captures transaction costs related to foreign assets, where variables without time subscripts denote long-run values (these costs are not important to the main results but help the model with the data - see also below).

The law of motion of physical capital for household i is:

$$k_{i,t} = (1-\delta)k_{i,t-1} + x_{i,t} - \frac{\xi}{2}\left(\frac{k_{i,t}}{k_{i,t-1}} - 1\right)^2 k_{i,t-1} \tag{29}$$

where $0 < \delta < 1$ is the depreciation rate of capital and $\xi \geq 0$ is a parameter capturing adjustment costs related to physical capital.

8.2 Household's optimality conditions

Each household i acts competitively taking prices and policy as given. Following the literature, to solve the household's problem, we follow a two-step procedure. We first suppose that the household determines its desired consumption of composite goods, $c_{i,t}^H$ and $c_{i,t}^F$, and, in turn, chooses how to distribute its purchases of individual varieties, $c_{i,t}^H(h)$ and $c_{i,t}^F(f)$.

The first-order conditions of each i include the budget constraints and also:

$$\begin{gathered}\frac{\partial u_{i,t}}{\partial c_{i,t}}\frac{\partial c_{i,t}}{\partial c_{i,t}^H}\frac{P_t}{P_t^H(1+\tau_t^c)} = \\ \beta E_t\frac{\partial u_{i,t+1}}{\partial c_{i,t+1}}\frac{\partial c_{i,t+1}}{\partial c_{i,t+1}^H}\frac{P_{t+1}}{P_{t+1}^H\left(1+\tau_{t+1}^c\right)}R_t\frac{P_t}{P_{t+1}}\end{gathered} \tag{30}$$

$$\begin{gathered}\frac{\partial u_{i,t}}{\partial c_{i,t}}\frac{\partial c_{i,t}}{\partial c_{i,t}^H}\frac{P_t}{P_t^H(1+\tau_t^c)}\frac{S_tP_t^*}{P_t}\left[1+\phi^h\left(\frac{S_tP_t^*}{P_t}f_t^h - \frac{SP^*}{P}f^h\right)\right] \\ = \beta E_t\frac{\partial u_{i,t+1}}{\partial c_{i,t+1}}\frac{\partial c_{i,t+1}}{\partial c_{t+1}^H}\frac{P_{t+1}}{P_{t+1}^H\left(1+\tau_{t+1}^c\right)}Q_t\frac{S_{t+1}P_{t+1}^*}{P_{t+1}}\frac{P_t^*}{P_{t+1}^*}\end{gathered} \tag{31}$$

$$\begin{gathered}\frac{\partial u_{i,t}}{\partial c_{i,t}}\frac{\partial c_{i,t}}{\partial c_{i,t}^H}\frac{1}{(1+\tau_t^c)}\left\{1-\xi\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)\right\} \\ = \beta E_t\frac{\partial u_{i,t+1}}{\partial c_{i,t+1}}\frac{\partial c_{i,t+1}}{\partial c_{i,t+1}^H}\frac{1}{\left(1+\tau_{t+1}^c\right)}\left\{(1-\delta) - \frac{\xi}{2}\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)^2 + \xi\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)\frac{k_{i,t+1}}{k_{i,t}} + \left(1-\tau_{t+1}^k\right)r_{t+1}^k\right\}\end{gathered} \tag{32}$$

$$\chi_m\frac{\partial u_{i,t}}{\partial m_{i.t}} = \frac{\partial u_{i,t}}{\partial c_{i,t}}\frac{\partial c_{i,t}}{\partial c_{i,t}^H}\frac{P_t}{P_t^H\left(1+\tau_t^c\right)} - \beta E_t\frac{\partial u_{i,t+1}}{\partial c_{i,t+1}}\frac{\partial c_{i,t+1}}{\partial c_{i,t+1}^H}\frac{P_{t+1}}{P_{t+1}^H\left(1+\tau_{t+1}^c\right)}\frac{P_t}{P_{t+1}} \tag{33}$$

$$-\chi_n \frac{\partial u_{i,t}}{\partial n_{i,t}} = \frac{(1-\tau_t^n)}{(1+\tau_t^c)} w_t \frac{\partial u_{i,t}}{\partial c_{i,t}} \frac{\partial c_{i,t}}{\partial c_{i,t}^H} \frac{P_t}{P_t^H} \tag{34}$$

$$\frac{c_{i,t}^H}{c_{i,t}^F} = \frac{\nu}{1-\nu} \frac{P_t^F}{P_t^H} \tag{35}$$

$$c_{i,t}^H(h) = \left[\frac{P_t^H(h)}{P_t^H}\right]^{-\phi} c_{i,t}^H \tag{36}$$

$$c_{i,t}^F(f) = \left[\frac{P_t^F(f)}{P_t^F}\right]^{-\phi} c_{i,t}^F \tag{37}$$

Equations (30)-(32) are respectively the Euler equations for domestic bonds, foreign assets and domestic capital, (33) is the optimality condition for money balances and (34) is the optimality condition for work hours. Finally, (35) shows the optimal allocation between domestic and foreign goods, while (36) and (37) show the optimal demand for each variety of domestic and foreign goods respectively.

8.3 Implications for price bundles

Equations (35), (36) and (37), combined with the household's budget constraints, imply that the three price indexes are:

$$P_t = (P_t^H)^{\nu}(P_t^F)^{1-\nu} \tag{38}$$

$$P_t^H = \left[\sum_{h=1}^{N} \kappa [P_t^H(h)]^{1-\phi}\right]^{\frac{1}{1-\phi}} \tag{39}$$

$$P_t^F = \left[\sum_{f=1}^{N} \kappa [P_t^F(f)]^{1-\phi}\right]^{\frac{1}{1-\phi}} \tag{40}$$

9 Appendix 2: Firms

This Appendix presents and solves the problem of the firm. There are $h = 1, 2, ..., .N$ domestic firms. Each firm h produces a differentiated good of variety h under monopolistic competition facing Calvo-type nominal fixities.

9.1 Demand for firm's product

Each firm h faces demand for its product, $y_t^H(h)$, coming from domestic households' consumption and investment, $c_t^H(h)$ and $x_t(h)$, where $c_t^H(h) \equiv \sum_{i=1}^N c_{i,t}^H(h)$ and $x_t(h) \equiv \sum_{i=1}^N x_{i,t}(h)$, from the domestic government, $g_t(h)$, and from foreign households' consumption, $c_t^{F*}(h) \equiv \sum_{i=1}^{N*} c_{i,t}^{F*}(h)$. Thus, the demand for each domestic firm's product is:

$$y_t^H(h) = c_t^H(h) + x_t(h) + g_t(h) + c_t^{F*}(h) \tag{41}$$

where,

$$c_t^H(h) = \left[\frac{P_t^H(h)}{P_t^H}\right]^{-\phi} c_t^H \tag{42}$$

$$x_t(h) = \left[\frac{P_t^H(h)}{P_t^H}\right]^{-\phi} x_t \tag{43}$$

$$g_t(h) = \left[\frac{P_t^H(h)}{P_t^H}\right]^{-\phi} g_t \tag{44}$$

$$c_t^{F*}(h) = \left[\frac{P_t^{F*}(h)}{P_t^{F*}}\right]^{-\phi} c_t^{F*} \tag{45}$$

where, using the law of one price, we have in (45):

$$\frac{P_t^{F*}(h)}{P_t^{F*}} = \frac{\frac{P_t^H(h)}{S_t}}{\frac{P_t^H}{S_t}} = \frac{P_t^H(h)}{P_t^H} \tag{46}$$

Since, at the economy level, agreggate demand for domestically produced goods is:

$$y_t^H = c_t^H + x_t + g_t + c_t^{F*} \tag{47}$$

the above equations imply that the demand for each domestic firm's product is:

$$y_t^H(h) = c_t^H(h) + x_t(h) + g_t(h) + c_t^{F*}(h) = \left[\frac{P_t^H(h)}{P_t^H}\right]^{-\phi} y_t^H \tag{48}$$

9.2 Firm's problem

Each domestic firm h maximizes nominal profits, $\widetilde{\Omega}_t(h)$, defined as:

$$\widetilde{\Omega}_t(h) = P_t^H(h)y_t^H(h) - r_t^k P_t^H(h)k_{t-1}(h) - W_t n_t(h) \tag{49}$$

All firms use the same technology represented by the production function:

$$y_t^H(h) = A_t[k_{t-1}(h)]^{\alpha}[n_t(h)]^{1-\alpha} \tag{50}$$

where A_t is an exogenous stochastic TFP process whose motion is defined below.

Since the firm operates under imperfect competition, profit maximization is subject to the demand for its product as derived above:

$$y_t^H(h) = \left[\frac{P_t^H(h)}{P_t^H}\right]^{-\phi} y_t^H \tag{51}$$

In addition, following Calvo (1983), firms choose their prices facing a nominal fixity. In each period, firm h faces an exogenous probability θ of not being able to reset its price. A firm h, which is able to reset its price, chooses its price $P_t^{\#}(h)$ to maximize the sum of discounted expected nominal profits for the next k periods in which it may have to keep its price fixed. This is modeled right below.

9.3 Firm's optimality conditions

To solve the firm's problem, we follow a two-step procedure. We first solve a cost minimization problem, where each firm h minimizes its cost by choosing factor inputs given technology and prices. The solution will give a minimum nominal cost function, which is a function of factor prices and output produced by the firm. In turn, given this cost function, each firm, which is able to reset its price, solves a maximization problem by choosing its price.

The solution to the cost minimization problem gives the input demand functions:

$$w_t = mc_t(1-a)\frac{y_t\,(h)}{n_t\,(h)} \tag{52}$$

$$\frac{P_t^H}{P_t} r_t^k = mc_t a \frac{y_t(h)}{k_{t-1}(h)} \tag{53}$$

where mc_t is real marginal cost.

Then, the firm chooses its price to maximize nominal profits written as:

$$E_t \sum_{k=0}^{\infty} \theta^k \Xi_{t,t+k} \widetilde{\Omega}_{t+k}(h) = E_t \sum_{k=0}^{\infty} \theta^k \Xi_{t,t+k} \left\{ P_t^{\#}(h) \, y_{t+k}^H(h) - \Psi_{t+k}\left(y_{t+k}^H(h)\right) \right\}$$

where $\Xi_{t,t+k}$ is a discount factor taken as given by the firm, $y_{t+k}^H(h) = \left[\frac{P_t^{\#}(h)}{P_{t+k}^H}\right]^{-\phi} y_{t+k}^H$ and $\Psi_t(.)$ denotes the minimum nominal cost function for producing $y_t^H(h)$ at t so that $\Psi_t'(.)$ is the associated marginal cost.

The first-order condition gives:

$$E_t \sum_{k=0}^{\infty} \theta^k \Xi_{t,t+k} \left[\frac{P_t^{\#}(h)}{P_{t+k}^H}\right]^{-\phi} y_{t+k}^H \left\{ P_t^{\#}(h) - \frac{\phi}{\phi - 1} \Psi_{t+k}' \right\} = 0 \tag{54}$$

Dividing by the aggregate price index, P_t^H, we have:

$$E_t \sum_{k=0}^{\infty} \theta^k [\Xi_{t,t+k} \left[\frac{P_t^{\#}(h)}{P_{t+k}^H}\right]^{-\phi} y_{t+k}^H \left\{ \frac{P_t^{\#}(h)}{P_t^H} - \frac{\phi}{\phi - 1} mc_{t+k} \frac{P_{t+k}}{P_t^H} \right\}] = 0 \tag{55}$$

Therefore, the behaviour of each firm h is summarized by (52), (53) and (55). A recursive expression of this problem is presented below.

Notice that each firm h, which can reset its price in period t, solves an identical problem, so $P_t^{\#}(h) = P_t^{\#}$ is independent of h, and each firm h, which cannot reset its price, just sets its previous period price $P_t^H(h) = P_{t-1}^H(h)$. Thus, the evolution of the aggregate price level is given by:

$$\left(P_t^H\right)^{1-\phi} = \theta \left(P_{t-1}^H\right)^{1-\phi} + (1-\theta) \left(P_t^{\#}\right)^{1-\phi} \tag{56}$$

10 Appendix 3: Government budget constraint

This Appendix presents the government budget constraint and the menu of fiscal policy instruments. The period budget constraint of the government is (in aggregate and nominal quantities):

$$
\begin{aligned}
B_t + M_t + S_t F_t^g = {} & P_t \frac{\phi^g}{2} \left(\frac{S_t F_t^g}{P_t} - \frac{S F^g}{P} \right)^2 + R_{t-1} B_{t-1} + M_{t-1} + Q_{t-1} S_t F_{t-1}^g \\
& + P_t^H g_t - \tau_t^c (P_t^H c_t^H + P_t^F c_t^F) - \tau_t^k (r_t^k P_t^H k_{t-1} + \widetilde{\Omega}_t) - \tau_t^n W_t n_t - T_t^l
\end{aligned} \tag{57}
$$

where B_t is the end-of-period nominal domestic public debt and F_t^g is the end-of-period nominal foreign public debt expressed in foreign currency so it is multiplied by the exchange rate, S_t. The rest of the notation is as above. Notice that $B_t \equiv \sum_{i=1}^N B_{i,t}$, $M_t \equiv \sum_{i=1}^N M_{i,t}$, $g_t \equiv \sum_{i=1}^N g_{i,t}$, $c_t^H \equiv \sum_{i=1}^N c_{i,t}^H$, $c_t^F \equiv \sum_{i=1}^N c_{i,t}^F$, $k_{t-1} \equiv \sum_{i=1}^N k_{i,t-1}$, $\widetilde{\Omega}_t \equiv \sum_{i=1}^N \widetilde{\Omega}_{i,t}$ $n_t \equiv \sum_{i=1}^N n_{i,t}$ and $T_t^l \equiv \sum_{i=1}^N T_{i,t}^l$.

Let $D_t = B_t + S_t F_t^g$ denote total nominal public debt. This can be held both by domestic private agents, $\lambda_t D_t$, where in equilibrium $B_t \equiv \lambda_t D_t$, and by foreign private agents, $S_t F_t^g \equiv (1-\lambda_t) D_t$, where the share $0 \leq \lambda_t \leq 1$ is a fiscal policy instrument. Then, the budget constraint can be rewritten as:

$$
\begin{aligned}
D_t + M_t = {} & P_t \frac{\phi^g}{2} \left(\frac{(1-\lambda_t) D_t}{P_t} - \frac{(1-\lambda) D}{P} \right)^2 + R_{t-1} \lambda_{t-1} D_{t-1} + M_{t-1} + Q_{t-1} \frac{S_t}{S_{t-1}} (1-\lambda_{t-1}) D_{t-1} \\
& + P_t^H g_t - \tau_t^c (P_t^H c_t^H + P_t^F c_t^F) - \tau_t^k (r_t^k P_t^H k_{t-1} + \widetilde{\Omega}_t) - \tau_t^n W_t n_t - T_t^l
\end{aligned} \tag{58}
$$

In turn, the budget constraint in real terms is:

$$
\begin{aligned}
d_t + m_t = {} & \frac{\phi^g}{2} [(1-\lambda_t) d_t - (1-\lambda) d]^2 + R_{t-1} \frac{P_{t-1}}{P_t} \lambda_{t-1} d_{t-1} + \frac{P_{t-1}}{P_t} m_{t-1} + Q_{t-1} \frac{S_t P_t^*}{P_t} \frac{P_{t-1}^*}{P_t^*} \frac{P_{t-1}}{P_{t-1}^* S_{t-1}} (1-\lambda_{t-1}) d_{t-1} \\
& + \frac{P_t^H}{P_t} g_t - \tau_t^c \left(\frac{P_t^H}{P_t} c_t^H + \frac{P_t^F}{P_t} c_t^F \right) - \tau_t^k \left(r_t^k \frac{P_t^H}{P_t} k_{t-1} + \widetilde{\omega}_t \right) - \tau_t^n w_t n_t - \tau_t^l
\end{aligned} \tag{59}
$$

where $d_t \equiv \frac{D_t}{P_t}$ is the real value of end-of-period total public debt and m_t is the end-of-period total stock of real money balances. In each period, one of the fiscal policy instruments (τ_t^c, τ_t^k, τ_t^n, g_t, τ_t^l, λ_t, d_t) needs to follow residually to satisfy the government budget constraint.

11 Appendix 4: Decentralized equilibrium (DE)

This Appendix presents the DE system. Following the related literature, we work in steps.

11.1 Equilibrium equations

The DE is summarized by the following 23 equations (quantities are in per capita terms):

$$\frac{\partial u_t}{\partial c_t}\frac{\partial c_t}{\partial c_t^H}\frac{1}{(1+\tau_t^c)}\frac{P_t}{P_t^H} = \beta E_t \frac{\partial u_{t+1}}{\partial c_{t+1}}\frac{\partial c_{t+1}}{\partial c_{t+1}^H}\frac{1}{\left(1+\tau_{t+1}^c\right)}\frac{P_{t+1}}{P_{t+1}^H}R_t\frac{P_t}{P_{t+1}} \tag{60}$$

$$\begin{gathered}\tfrac{\partial u_t}{\partial c_t}\tfrac{\partial c_t}{\partial c_t^H}\tfrac{1}{(1+\tau_t^c)}\tfrac{P_t}{P_t^H}\tfrac{S_t P_t^*}{P_t}\left(1+\phi^p\left(\tfrac{S_t P_t^*}{P_t}f_t^h - \tfrac{SP^*}{P}f^h\right)\right) \\ \beta\tfrac{\partial u_{t+1}}{\partial c_{t+1}}\tfrac{\partial c_{t+1}}{\partial c_{t+1}^H}\tfrac{1}{\left(1+\tau_{t+1}^c\right)}\tfrac{P_{t+1}}{P_{t+1}^H}Q_t\tfrac{S_{t+1}P_{t+1}^*}{P_{t+1}}\tfrac{P_t^*}{P_{t+1}^*}\end{gathered} \tag{61}$$

$$\begin{gathered}\tfrac{\partial u_t}{\partial c_t}\tfrac{\partial c_t}{\partial c_t^H}\tfrac{1}{(1+\tau_t^c)}\left\{1+\xi\left(\tfrac{k_t}{k_{t-1}}-1\right)\right\} \\ = \beta E_t \tfrac{\partial u_{t+1}}{\partial c_{t+1}}\tfrac{\partial c_{t+1}}{\partial c_{t+1}^H}\tfrac{1}{\left(1+\tau_{t+1}^c\right)}\left\{(1-\delta)-\tfrac{\xi}{2}\left(\tfrac{k_{t+1}}{k_t}-1\right)^2+\xi\left(\tfrac{k_{t+1}}{k_t}-1\right)\tfrac{k_{t+1}}{k_t}+\left(1-\tau_{t+1}^k\right)r_{t+1}^k\right\}\end{gathered} \tag{62}$$

$$\chi_m\frac{\partial u_{i,t}}{\partial m_{i,t}} = \frac{\partial u_{i,t}}{\partial c_{i,t}}\frac{\partial c_{i,t}}{\partial c_{i,t}^H}\frac{1}{(1+\tau_t^c)}\frac{P_t}{P_t^H} - \beta E_t\frac{\partial u_{i,t+1}}{\partial c_{i,t+1}}\frac{\partial c_{i,t+1}}{\partial c_{i,t+1}^H}\frac{1}{\left(1+\tau_{t+1}^c\right)}\frac{P_{t+1}}{P_{t+1}^H}\frac{P_t}{P_{t+1}} \tag{63}$$

$$\chi_n\frac{\partial u_t}{\partial n_t} = \frac{\partial u_t}{\partial c_t}\frac{\partial c_t}{\partial c_t^H}\frac{P_t}{P_t^H}\frac{(1-\tau_t^n)}{(1+\tau_t^c)}w_t \tag{64}$$

$$\frac{c_t^H}{c_t^F} = \frac{\nu}{1-\nu}\frac{P_t^F}{P_t^H} \tag{65}$$

$$k_t = (1-\delta)k_{t-1} + x_t - \frac{\xi}{2}\left(\frac{k_t}{k_{t-1}}-1\right)^2 k_{t-1} \tag{66}$$

$$c_t \equiv \frac{\left(c_t^H\right)^{\nu}\left(c_t^F\right)^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{67}$$

$$w_t = mc_t(1-a)\frac{y_t}{n_t} \tag{68}$$

$$\frac{P_t^H}{P_t}r_t^k = mc_t a\frac{y_t}{k_{t-1}} \tag{69}$$

$$\widetilde{\omega}_t = \frac{P_t^H}{P_t}y_t^H - \frac{P_t^H}{P_t}r_t^k k_{t-1} - w_t n_t \tag{70}$$

$$E_t \sum_{k=0}^{\infty} \theta^k [\Xi_{t,t+k} \left[\frac{P_t^{\#}}{P_{t+k}^H}\right]^{-\phi} y_{t+k}^H \left\{\frac{P_t^{\#}}{P_t} - \frac{\phi}{\phi - 1} mc_{t+k} \frac{P_{t+k}}{P_t}\right\}] = 0 \tag{71}$$

$$y_t^H = \frac{1}{\left[\frac{\widetilde{P}_t^H}{P_t^H}\right]^{-\phi}} A_t k_{t-1}^a n_t^{1-a} \tag{72}$$

$$\begin{gathered} d_t + m_t = R_{t-1} \tfrac{P_{t-1}}{P_t} \lambda_{t-1} d_{t-1} + \tfrac{P_{t-1}}{P_t} m_{t-1} + Q_{t-1} \tfrac{S_t P_t^*}{P_t} \tfrac{P_{t-1}^*}{P_t^*} \tfrac{P_{t-1}}{P_{t-1}^* S_{t-1}} (1 - \lambda_{t-1}) d_{t-1} \\ + \tfrac{P_t^H}{P_t} g_t - \tau_t^c (\tfrac{P_t^H}{P_t} c_t^H + \tfrac{P_t^F}{P_t} c_t^F) - \tau_t^k (r_t^k \tfrac{P_t^H}{P_t} k_{t-1} + \widetilde{\omega}_t) - \tau_t^n w_t n_t - \tau_t^l + \tfrac{\phi^g}{2} [(1 - \lambda_t) d_t - (1 - \lambda) d]^2 \end{gathered} \tag{73}$$

$$y_t^H = c_t^H + x_t + g_t + c_t^{F*} \tag{74}$$

$$\begin{gathered} -\tfrac{P_t^H}{P_t} c_t^{F*} + \tfrac{P_t^F}{P_t} c_t^F + \tfrac{\phi^g}{2} [(1 - \lambda_t) d_t - (1 - \lambda) d]^2 + \tfrac{\phi^p}{2} \left(\tfrac{S_t P_t^*}{P_t} f_t^h - \tfrac{SP^*}{P} f^h\right)^2 \\ Q_{t-1} \tfrac{S_t P_t^*}{P_t} \tfrac{P_{t-1}^*}{P_t^*} \left(\frac{(1-\lambda_{t-1}) d_{t-1}}{\frac{S_{t-1} P_{t-1}^*}{P_{t-1}}} - f_{t-1}^h\right) = (1 - \lambda_t) d_t - \tfrac{S_t P_t^*}{P_t} f_t^h \end{gathered} \tag{75}$$

$$\left(P_t^H\right)^{1-\phi} = \theta P_{t-1}^{1-\phi} + (1 - \theta) \left(P_t^{\#}\right)^{1-\phi} \tag{76}$$

$$P_t = \left(P_t^H\right)^{\nu} \left(P_t^F\right)^{1-\nu} \tag{77}$$

$$P_t^F = S_t P_t^{H*} \tag{78}$$

$$P_t^* = (P_t^{H*})^{\nu^*} (\frac{P_t^H}{S_t})^{1-\nu^*} \tag{79}$$

$$\left(\widetilde{P}_t^H\right)^{-\phi} = \theta \left(\widetilde{P}_{t-1}^H\right)^{-\phi} + (1 - \theta) \left(P_t^{\#}\right)^{-\phi} \tag{80}$$

$$Q_t = Q_t^* + \psi \left(e^{\frac{d_t}{\frac{P_t^H}{P_t} Y_t^H} - \bar{d}} - 1\right) \tag{81}$$

$$l_t \equiv \frac{R_t \lambda_t d_t + Q_t \frac{S_{t+1}}{S_t} (1 - \lambda_t) d_t}{\frac{P_t^H}{P_t} y_t^H} \tag{82}$$

where $f_t^{*g} \equiv \frac{(1-\lambda_t) d_t}{\frac{S_t P_t^*}{P_t}}$, $\Xi_{t,t+k} \equiv \beta^k \frac{c_{t+k}^{-\sigma}}{c_t^{-\sigma}} \frac{P_t}{P_{t+k}} \frac{\tau_t^c}{\tau_{t+k}^c}$ and $\widetilde{P}_t^H \equiv \left(\sum_{h=1}^{N} [P_t(h)]^{-\phi}\right)^{-\frac{1}{\phi}}$. Thus, $\left(\frac{\widetilde{P}_t^H}{P_t^H}\right)^{-\phi}$ is a measure of price dispersion.

We thus have 23 equations in 23 endogenous variables, $\{y_t^H$, c_t, c_t^H, c_t^F, n_t, x_t, k_t, f_t^h, m_t, P_t^F, P_t, P_t^H, $P_t^{\#}$, $\widetilde{P}_t^H$, w_t, mc_t, $\widetilde{\omega}_t$, r_t^k, Q_t, d_t, P_t^*, R_t, $l_t\}_{t=0}^{\infty}$. This is given the independently set monetary and fiscal policy instruments, $\{S_t, \tau_t^c, \tau_t^k, \tau_t^n, g_t, \tau_t^l, \lambda_t\}_{t=0}^{\infty}$, the rest-of-the-world variables, $\{c_t^{F*}, Q_t^*, P_t^{H*}\}_{t=0}^{\infty}$, technology, $\{A_t\}_{t=0}^{\infty}$, and initial conditions for the state variables.

In what follows, we transform the above equilibrium conditions. In particular, following the related literature, we rewrite them, first, by expressing price levels in inflation rates, secondly, by writing the firm's optimality conditions in recursive form and, thirdly, by introducing a new equation that helps us to compute expected discounted lifetime utility. Finally, we will present the final transformed system that is solved numerically.

11.2 Variables expressed in ratios

We first express prices in rate form. We define 7 new endogenous variables, which are the gross domestic CPI inflation rate $\Pi_t \equiv \frac{P_t}{P_{t-1}}$, the gross foreign CPI inflation rate $\Pi_t^* \equiv \frac{P_t^*}{P_{t-1}^*}$, the gross domestic goods inflation rate $\Pi_t^H \equiv \frac{P_t^H}{P_{t-1}^H}$, the auxiliary variable $\Theta_t \equiv \frac{P_t^{\#}}{P_t^H}$, the price dispersion index $\Delta_t \equiv \left[\frac{\widetilde{P}_t^H}{P_t^H}\right]^{-\phi}$, the gross exchange rate depreciation rate $\epsilon_t \equiv \frac{S_t}{S_{t-1}}$ and the terms of trade $TT_t \equiv \frac{P_t^F}{P_t^H} = \frac{S_t P_t^{*H}}{P_t^H}$.[24] Thus, in what follows, we use Π_t, Π_t^*, Π_t^H, Θ_t, Δ_t, ϵ_t, TT_t instead of P_t, P_t^*, P_t^H, $P_t^{\#}$, $\widetilde{P}_t$, S_t, P_t^F respectively.

Also, for convenience and comparison with the data, we express fiscal and public finance variables as shares of nominal output, $P_t^H y_t^H$. In particular, using the definitions above, real government spending, g_t, can be written as $g_t = s_t^g y_t^H$, real government transfers, τ_t^l, can be written as $\tau_t^l = s_t^l y_t^H TT_t^{\nu-1}$, where s_t^g, s_t^l and s_t^b denote respectively the output shares of government spending, government transfers and domestic public debt.

11.3 Equation (71) expressed in recursive form

We now replace equation (30) or equation (71), from the firm's optimization problem, with an equivalent equation in recursive form. In particular, following Schmitt-Grohé and Uribe (2007), we look for a recursive representation of the form:

$$E_t \sum_{k=0}^{\infty} \theta^k \Xi_{t,t+k} \left[\frac{P_t^{\#}}{P_{t+k}^H}\right]^{-\phi} y_{t+k}^H \left\{P_t^{\#} - \frac{\phi}{(\phi-1)} mc_{t+k} P_{t+k}\right\} = 0 \qquad (83)$$

[24] Thus, $\frac{TT_t}{TT_{t-1}} = \frac{\frac{S_t}{S_{t-1}}\frac{P_t^{*H}}{P_{t-1}^{*H}}}{\frac{P_t^H}{P_{t-1}^H}} = \frac{\epsilon_t \Pi_t^{*H}}{\Pi_t^H}$.

We define two auxiliary endogenous variables:

$$z_t^1 \equiv E_t \sum_{k=0}^{\infty} \theta^k \Xi_{t,t+k} \left[\frac{P_t^{\#}}{P_{t+k}^H} \right]^{-\phi} y_{t+k}^H \frac{P_t^{\#}}{P_t} \tag{84}$$

$$z_t^2 \equiv E_t \sum_{k=0}^{\infty} \theta^k \Xi_{t,t+k} \left[\frac{P_t^{\#}}{P_{t+k}^H} \right]^{-\phi} y_{t+k}^H mc_{t+k} \frac{P_{t+k}}{P_t} \tag{85}$$

Using these two auxiliary variables, z_t^1, z_t^2, and equation (83), we come up with two new equations which enter the dynamic system and allows a recursive representation of (83).

Thus, in what follows, we replace equation (71) with:

$$z_t^1 = \frac{\phi}{(\phi - 1)} z_t^2 \tag{86}$$

where:

$$z_t^1 = \Theta_t^{1-\phi} y_t TT_t^{\nu-1} + \beta\theta E_t \frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}} \frac{1+\tau_t^c}{1+\tau_{t+1}^c} \left(\frac{\Theta_t}{\Theta_{t+1}} \right)^{1-\phi} \left(\frac{1}{\Pi_{t+1}^H} \right)^{1-\phi} z_{t+1}^1 \tag{87}$$

$$z_t^2 = \Theta_t^{-\phi} y_t mc_t + \beta\theta E_t \frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}} \frac{1+\tau_t^c}{1+\tau_{t+1}^c} \left(\frac{\Theta_t}{\Theta_{t+1}} \right)^{-\phi} \left(\frac{1}{\Pi_{t+1}^H} \right)^{-\phi} z_{t+1}^2 \tag{88}$$

11.4 Lifetime utility written as a first-order dynamic equation

Since we want to compute social welfare, we follow Schmitt-Grohé and Uribe (2007) by defining a new endogenous variable, V_t, whose motion is given by:

$$V_t = \frac{c_t^{1-\sigma}}{1-\sigma} - \chi_n \frac{n_t^{1+\phi}}{1+\phi} + \chi_m \frac{m_t^{1-\mu}}{1-\mu} + \chi_g \frac{\left(s_t^g y_t^H\right)^{1-\zeta}}{1-\zeta} + \beta E_t V_{t+1} \tag{89}$$

where V_t is household's expected discounted lifetime utility at time t.

Thus, in what follows, we add equation (89) and the new variable V_t to the equilibrium system. Note that in the welfare computations reported, we add a constant number, 2, to each period's utility. This makes the welfare numbers easier to read.

11.5 Equilibrium equations transformed

Using the above, the transformed DE is summarized by the following equations.

$$V_t = \frac{c_t^{1-\sigma}}{1-\sigma} - \chi_n \frac{n_t^{1+\phi}}{1+\phi} + \chi_m \frac{m_t^{1-\mu}}{1-\mu} + \chi_g \frac{\left(s_t^g y_t^H\right)^{1-\zeta}}{1-\zeta} + \beta E_t V_{t+1} \tag{90}$$

$$\begin{gathered} \beta E_t \; c_{t+1}^{-\sigma} \tfrac{1}{\left(1+\tau_{t+1}^c\right)} R_t \tfrac{1}{\Pi_{t+1}} = \\ = c_t^{-\sigma} \tfrac{1}{\left(1+\tau_t^c\right)} \end{gathered} \tag{91}$$

$$\begin{gathered} \beta E_t \; c_{t+1}^{-\sigma} \tfrac{1}{\left(1+\tau_{t+1}^c\right)} Q_t TT_{t+1}^{v^*+\nu-1} \tfrac{1}{\Pi_{t+1}^*} = \\ = c_t^{-\sigma} \tfrac{1}{\left(1+\tau_t^c\right)} TT_t^{v^*+\nu-1} \left[1 + \phi^p \left(TT_t^{\nu^*+\nu-1} f_t^h - TT^{\nu^*+\nu-1} f^h\right)\right] \end{gathered} \tag{92}$$

$$\begin{gathered} \beta c_{t+1}^{-\sigma} TT_{t+1}^{\nu-1} \left\{1 - \delta - \tfrac{\xi}{2}\left(\tfrac{k_{t+1}}{k_t} - 1\right)^2 + \xi\left(\tfrac{k_{t+1}}{k_t} - 1\right)\tfrac{k_{t+1}}{k_t} + \left(1 - \tau_{t+1}^k\right) r_{t+1}^k\right\} = \\ = c_t^{-\sigma} TT_t^{\nu-1} \tfrac{1}{\left(1+\tau_t^c\right)} \left[1 - \xi\left(\tfrac{k_t}{k_{t-1}} - 1\right)\right] \end{gathered} \tag{93}$$

$$\chi_m m_t^{-\mu} = c_t^{-\sigma} \frac{1}{\left(1+\tau_t^c\right)} - \beta E_t c_{t+1}^{-\sigma} \frac{1}{\left(1+\tau_{t+1}^c\right)} \frac{1}{\Pi_{t+1}} \tag{94}$$

$$\chi n_t^{\eta} = \left(1 - \tau_t^n\right) w_t c_t^{-\sigma} \frac{1}{\left(1+\tau_t^c\right)} \tag{95}$$

$$\frac{c_t^H}{c_t^F} = \frac{\nu}{1-\nu} TT_t \tag{96}$$

$$k_t = (1-\delta) k_{t-1} + x_t - \frac{\xi}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1} \tag{97}$$

$$c_t \equiv \frac{\left(c_t^H\right)^{\nu} \left(c_t^F\right)^{1-\nu}}{(\nu)^{\nu} (1-\nu)^{1-\nu}} \tag{98}$$

$$w_t = mc_t (1-a) A_t k_{t-1}^a n_t^{-a} \tag{99}$$

$$\frac{1}{TT_t^{1-v}} r_t^k = mc_t a A_t k_{t-1}^{a-1} n_t^{1-a} \tag{100}$$

$$\widetilde{\omega}_t = \frac{1}{TT_t^{1-v}} y_t^H - \frac{1}{TT_t^{1-v}} r_t^k k_{t-1} - w_t n_t \tag{101}$$

$$z_t^1 = \frac{\phi}{(\phi - 1)} z_t^2 \tag{102}$$

$$y_t^H = \frac{1}{\Delta_t} A_t k_{t-1}^a n_t^{1-a} \tag{103}$$

$$\begin{aligned} d_t + m_t = {} & \tfrac{\phi^g}{2}[(1-s_t)d_t - (1-s)d]^2 + R_{t-1}\tfrac{1}{\Pi_t} s_{t-1}d_{t-1} + \tfrac{1}{\Pi_t} m_{t-1} + \\ & + Q_{t-1} TT_t^{v+v^*-1} \tfrac{1}{\Pi_t^*} \tfrac{1}{TT_{t-1}^{v+v^*-1}} (1-s_{t-1})d_{t-1} + TT_t^{\nu-1} s_t^g y_t^H - \\ & - \tau_t^c (\tfrac{1}{TT_t^{1-v}} c_t^H + TT_t^v c_t^F) - \tau_t^k (r_t^k \tfrac{1}{TT_t^{1-v}} k_{t-1} + \widetilde{\omega}_t) - \tau_t^n w_t n_t - TT_t^{\nu-1} s_t^l y_t^H \end{aligned} \tag{104}$$

$$y_t^H = c_t^H + x_t + s_t^g y_t^H + c_t^{F*} \tag{105}$$

$$\begin{aligned} (1-s_t)d_t - TT_t^{\nu^*+\nu-1} f_t^h = {} & -TT_t^{\nu-1} c_t^{F*} + TT_t^{\nu} c_t^F + \\ & Q_{t-1} TT_t^{\nu^*+\nu-1} \tfrac{1}{\Pi_t^*} \left(\tfrac{1}{TT_{t-1}^{v+v^*-1}} (1-s_{t-1})d_{t-1} - f_{t-1}^h \right) \\ & + \tfrac{\phi^p}{2} \left(TT_t^{\nu^*+\nu-1} f_t^h - TT^{\nu^*+\nu-1} f^h \right)^2 + \tfrac{\phi^g}{2} \left((1-s_t)d_t - (1-s)d \right)^2 \end{aligned} \tag{106}$$

$$\left(\Pi_t^H\right)^{1-\phi} = \theta + (1-\theta) \left(\Theta_t \Pi_t^H\right)^{1-\phi} \tag{107}$$

$$\frac{\Pi_t}{\Pi_t^H} = \left(\frac{TT_t}{TT_{t-1}} \right)^{1-\nu} \tag{108}$$

$$\frac{TT_t}{TT_{t-1}} = \frac{\epsilon_t \Pi_t^{H*}}{\Pi_t^H} \tag{109}$$

$$\frac{\Pi_t^*}{\Pi_t^{H*}} = \left(\frac{TT_{t-1}}{TT_t} \right)^{1-\nu^*} \tag{110}$$

$$\Delta_t = \theta \Delta_{t-1} \left(\Pi_t^H\right)^{\phi} + (1-\theta) \left(\Theta_t\right)^{-\phi} \tag{111}$$

$$Q_t = Q_t^* + \psi \left(e^{\left(\frac{d_t}{TT_t^{\nu-1} y_t^H} - \overline{d}\right)} - 1 \right) \tag{112}$$

$$z_t^1 = \Theta_t^{1-\phi} y_t TT_t^{\nu-1} + \beta\theta E_t \, \frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}} \frac{1+\tau_t^c}{1+\tau_{t+1}^c} \left(\frac{\Theta_t}{\Theta_{t+1}} \right)^{1-\phi} \left(\frac{1}{\Pi_{t+1}^H} \right)^{1-\phi} z_{t+1}^1 \tag{113}$$

$$z_t^2 = \Theta_t^{-\phi} y_t mc_t + \beta\theta E_t \, \frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}} \frac{1+\tau_t^c}{1+\tau_{t+1}^c} \left(\frac{\Theta_t}{\Theta_{t+1}} \right)^{-\phi} \left(\frac{1}{\Pi_{t+1}^H} \right)^{-\phi} z_{t+1}^2 \tag{114}$$

$$l_t = \frac{R_t s_t d_t + Q_t \epsilon_{t+1} (1-s_t) d_t}{TT_t^{\nu-1} y_t^H} \tag{115}$$

We thus have 26 equations in 26 endogenous variables, $\{V_t,\ y_t^H,\ c_t,\ c_t^H,\ c_t^F,\ n_t,\ x_t,\ k_t,\ f_t^h,\ m_t,\ TT_t,\ \Pi_t,\ \Pi_t^H,\ \Theta_t,\ \Delta_t,\ w_t,\ mc_t,\ \widetilde{\omega}_t,\ r_t^k,\ Q_t,\ d_t,\ \Pi_t^*,\ z_t^1,\ z_t^2,\ R_t,\ l_t\}_{t=0}^{\infty}$. This is given the independently set policy instruments, $\{\epsilon_t,\ \tau_t^c,\ \tau_t^k,\ \tau_t^n,\ s_t^g,\ s_t^l,\ \lambda_t\}_{t=0}^{\infty}$, the rest-of-the-world variables, $\{c_t^{F*}, Q_t^*,\ \Pi_t^{H*}\}_{t=0}^{\infty}$, technology, $\{A_t\}_{t=0}^{\infty}$, and initial conditions for the state variables.

11.6 Final equilibrium system (given feedback policy coefficients)

We can now define the equilibrium system. It consists of the 26 equations of the transformed DE presented in the previous subsection, the 4 policy rules in subsection 2.8 in the main text, and the equation for domestic exports in subsection 2.9 in the main text. Thus, we have a system of 31 equations. By using 2 auxilliary variables, we transform it to a first-order,[25] so we end up with 33 equations in 33 variables, $\{y_t^H,\ c_t,\ c_t^H,\ c_t^F,\ x_t,\ n_t,\ m_t,\ f_t^h,\ d_t,\ k_t,\ \widetilde{\omega}_t,\ mc_t,\ \Pi_t,\ \Pi_t^H,\ \Pi_t^*,\ \Theta_t,\ \Delta_t,\ TT_t,\ w_t,\ r_t^k,\ Q_t,\ l_t,\ z_t^1,\ z_t^2,\ V_t;\ R_t,\ \tau_t^c,\ s_t^g,\ \tau_t^k,\ \tau_t^n;\ klead_t,\ TTlag_t,\ c_t^{F*}\}_{t=0}^{\infty}$. This is given the exogenous variables, $\{Q_t^*, \Pi_t^{H*}, A_t, \epsilon_t,\ s_t^l,\ \lambda_t\}_{t=0}^{\infty}$, and initial condistions for the state variables. The 33 endogenous variables are distinguished in 24 control variables, $\{y_t^H,\ c_t,\ c_t^H,\ c_t^F,\ x_t,\ n_t,\ \widetilde{\omega}_t,\ mc_t,\ \Pi_t,\ \Pi_t^H,\ \Pi_t^*,\ \Theta_t,\ TT_t,\ w_t,\ r_t^k,\ z_t^1,\ z_t^2,\ V_t,\ klead_t, c_t^{F*},\ \tau_t^c,\ s_t^g,\ \tau_t^k,\ \tau_t^n\}_{t=0}^{\infty}$, and 9 state variables, $\{m_{t-1},\ f_{t-1}^h,\ d_{t-1},\ k_{t-1},\ \Delta_{t-1},\ Q_{t-1},\ R_{t-1},\ l_{t-1},\ TTlag_t\}_{t=0}^{\infty}$. All this is given the values of feedback policy coefficients in the policy rules, which are chosen optimally in the computational part of the paper.

[25] In particular, we add 2 auxiliary endogenous variables, *klead* and *TTlag*, to reduce the dynamic system into a first-order one.