Macroeconomic Dynamics, **22**, 2018, 470–500. Printed in the United States of America.
doi:10.1017/S1365100516000286

SOVEREIGN RESTRUCTURING VS. FISCAL ADJUSTMENT IN A MONETARY UNION: MACROECONOMIC EFFECTS FROM MODEL-BASED SIMULATIONS

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We assess the macroeconomic effects of a sovereign restructuring in a small economy belonging to a monetary union by simulating a dynamic general equilibrium model. We compare the macroeconomic outcome of restructuring with scenarios where the debt reduction is achieved via fiscal adjustment. In line with the empirical evidence, we assume that the sovereign debt is held by domestic agents and by agents in the rest of the monetary union; after the restructuring the sovereign borrowing rate increases and the increase is fully transmitted to the domestic households' borrowing rate; and the government cannot discriminate between domestic and foreign agents when restructuring. We also assume that the small economy does not exit from the monetary union after the restructuring and that the restructuring does not have systemic effects on the rest of the union. Our results suggest that the restructuring can imply persistent and large reduction of output, especially if the share of public debt held domestically is large, the private foreign debt is high, and the spread paid by the government and the households does increases.

Keywords: Fiscal Policy, DSGE Modeling, Sovereign Restructuring

1. INTRODUCTION

Following a few years of weak economic activity, the fiscal position of some Euro Area member states is now particularly strained. Greece has undergone two debt restructurings since 2010, and opened the way to the possibility of a sovereign debt restructuring by a Euro Area member. Although officials have repeatedly

We thank for useful comments C. Cottarelli, C. Kamps, A. Locarno, D. Muir, M. Guerguil, P. Manasse, A. Notarpietro, and participants at the ECB Workshop "Challenges for Sovereign Debt Management in the EU" (October 2011) and the Bank of Poland "Central Bank Macroeconomic Modeling Workshop" (September 2012) and in seminars at the IMF Fiscal Affair Department (November 2011) and the University of Bologna (December 2011). We are solely responsible for any errors. The opinions expressed in this paper do not necessarily reflect those of the Bank of Italy or the Eurosystem or the International Monetary Fund. Address correspondence to: Lorenzo Forni, Departments of Economics, Università di Padova, Via del Santo 33 - I-35123 Padova, Italy; e-mail: lorenzo.forni@unipd.it.

 1365-1005/18

stated that Greece is a "special case," there is speculation about the economic implications of a sovereign restructuring by a member of the monetary union (MU). Moreover, the outcome being so unclear, it is difficult to assess whether sovereign restructuring would be preferable (from a social welfare perspective) to fiscal consolidation as a mean to reduce the debt.

This paper addresses these issues by simulating, in a rather standard New Keynesian general equilibrium model of a monetary union, the macroeconomic impact of a small region sovereign restructuring and comparing the obtained results with those of a fiscal adjustment that reduces the debt by a similar amount.

Our analysis highlights three important factors that determine the macroeconomic costs and benefits of a restructuring: first, the share of sovereign bonds held by households resident in the country as compared to the share held by foreign residents; second, the response of international financial investors to the sovereign restructuring; third, the private sector net foreign asset position (NFA) at the moment of the restructuring.

Regarding the distribution of government bond holdings between domestic and foreign residents, let us consider, for the sake of argument, two extreme cases. Suppose that the government bonds are held by domestic households only. Moreover, suppose that households have infinite lifetime horizon and taxes are lump-sum. In this case the restructuring would not have any macroeconomic effect, as the public debt is not considered net wealth by its holders. Indeed, its reduction would be fully offset by the expectation of lower future taxes, leaving households' permanent income unchanged. In other terms, the Ricardian equivalence holds. Even if financial markets are incomplete at the international level, the financial markets' completeness holds within each country. In fact, in each country there is a representative household, because of the assumptions of risk-sharing of country-specific risks and the same initial conditions across households (resident in the country). Domestically held public debt and lump-sum taxes do not have redistributive and hence real effects. Instead, suppose that foreign investors are the only holders of government bonds and, moreover, that they do not "punish" the government and its citizens by increasing the country's borrowing cost after the restructuring. In this case the country implementing the restructuring would get a positive capital gain associated with the improvement of its NFA position.

Second, interest rates may increase around restructuring instances. Indeed, usually defaulting governments have to pay a premium to reenter the capital market, as they are perceived as riskier borrowers. This premium or spread can therefore reflect the loss of reputation as a reliable borrower that the country faces after the restructuring.

Finally, the private sector's NFA position at the time of the sovereign restructuring is relevant as well. The larger the foreign liabilities, the larger is the likely increase in the interest payments that the higher borrowing costs would imply, and hence the negative income effect faced by residents.

The overall macroeconomic implications of a restructuring would therefore depend on the combined effects of, on one hand, the capital gain coming from lowering the foreign debt and, on the other hand, the costs of rolling over the (post-haircut) public and private external debt at possibly higher interest rates. The capital gain induces a positive wealth effect, as it corresponds to a lump-sum tax on foreign investors. A positive spread, on the other hand, would induce a negative substitution effect (today's consumption is more expensive than future consumption) and a negative income effect (the interest payment on the new after-restructuring foreign asset position of the country as a whole increases).

The restructuring scenario is compared with the fiscal adjustment scenario that would achieve the same debt reduction. The fiscal adjustment entails two main differences. The first is that the burden of the adjustment falls entirely on domestic taxpayers even if a relevant share of sovereign debt might be held abroad. The second is that the fiscal adjustment might entail an increase in distortionary taxes, which add costs (in terms of distortions) to those of the fiscal consolidation.

Turning to the model, it is composed of two regions, Home and Foreign, of different size. Home is a relatively small country of the MU, whereas Foreign represents the rest of the MU (RMU). The Home government is assumed to restructure its debt. We consider the case of a relatively small Home country, so that the restructuring does not greatly affect the RMU. Thus, the restructuring does not have systemic implications for the union.[1] The MU setup makes it possible to take two specific features into account. First, monetary policy is conducted at union level, through a standard Taylor rule. Hence, it does not fully react to the changing macroeconomic conditions in the Home country after the restructuring. Second, fiscal policy is managed at the regional level.

On the financial side, the model features two types of bonds, both denominated in the currency of the MU. The first is exchanged between the domestic and foreign private sectors only. The second is issued by the two sovereign states and is bought by both domestic and foreign households. Each bond is in zero net supply at MU-wide level. We follow Broner et al. (2010) and assume that the domestic government cannot discriminate between domestic and foreign debt holders.[2]

For the spread, we follow the most recent and more comprehensive (in terms of the episodes covered) results of Cruces and Trebesh (2013) and assume in our baseline simulations that after the sovereign restructuring both the government and the private sector have to pay a spread above the risk-free rate when issuing bonds (the risk-free rate is equal to the interest rate set by the central bank of the MU). The spread is proportional to the size of the haircut. Specifically, for a 40% haircut, the spreads are estimated to jump by 250 basis points (b.p.) on impact and to 0 b.p. after five years. Moreover, we assume they move in parallel for private and public borrowing, consistent with evidence that spreads on the sovereigns are quickly passed on to the private sector. This is a deliberately parsimonious way to capture the "price" paid by the country for the loss of reputation as a reliable borrower and the related financial distress that characterize both the private and public sectors after a sovereign restructuring. In particular, it follows approaches

used in the literature on New Keynesian models, where defaults are typically assumed to be exogenous.[3] We acknowledge that the literature is quite divided regarding how big and how persistent the increase in the premium is. Cruces and Trebesh (2013) show that spreads are positively correlated with the size of the haircut.[4] Other papers point to relatively short periods of exclusion from the international financial market and moderate increase in spreads (Panizza et al. 2009). Given the intrinsic uncertainty regarding the behavior of spreads around default, we will present a sensitivity analysis.

The Home country is calibrated to broadly resemble a generic small open economy belonging to a MU. In the baseline simulation it is assumed that the small economy is loaded with a very high level of sovereign debt, [equal to 150% of yearly gross domestic product (GDP)]. We will start off assuming that Home households hold 100% of Home government debt (we will relax this assumption later on to check how important it is to allow for a share of external debt). Finally, it is assumed that the private sector's net foreign debt prior to the restructuring is equal to 100% of GDP. Given this background, the restructuring is modeled as an unexpected write-off (haircut) of the public debt equal to 40% of its nominal value. As a ratio to yearly GDP, this corresponds to a large reduction in the public debt, from 150% to 90%. Moreover, we assume that after the restructuring, net taxes are adjusted by the government to stabilize the debt at the new (post-haircut) level according to a fiscal rule. These results are in turn compared with those of a hypothetical fiscal adjustment that would achieve the same debt reduction. The fiscal adjustment will be in the first instance achieved by reducing transfers and increasing labor income taxes.

The results are as follows. First, in our baseline simulation after the haircut, the GDP shows a decrease that is rather persistent and is associated with a reduction in consumption and investment by domestic residents. The recovery is slow, as it takes about four years for the GDP to return close to its baseline level (and many more to completely get back to baseline). Second, the GDP loss is relatively large if the share of public debt held domestically is large, the private foreign debt is large, and the spreads increase substantially. We do find that the sovereign restructuring induces a rather persistent reduction in macroeconomic activity even under more favorable initial financial conditions (when the initial share of domestically held sovereign bonds and the level of foreign debt by households are relatively low). In comparison, the fiscal adjustment will take much longer to achieve a similar debt reduction, and thus it will have a much more persistent, but less dramatic, effect on GDP. Our baseline simulation for fiscal adjustment entails a five-percentage-point (p.p.)-of-GDP fiscal adjustment achieved over five years, partly by increasing labor income taxes and partly by reducing transfers. Based on this calibration, we find that the discounted loss of GDP from the fiscal adjustment correspond roughly to that obtained by a restructuring with a 40% haircut when about 60% of the public debt is held domestically. That is, in our baseline simulations, the fiscal adjustment dominates the restructuring when more than 60% of the debt is held domestically (using as a metric the discounted value of GDP losses).

We stress that our analysis is based on a number of assumptions, some of which are rather determinant for the results. Obviously, the problem is complicated and subject to many complexities, so our simulations cannot be taken as predictions of a likely outcome. They should be taken instead as a way to highlight what are some important dimensions that have to be taken into account when trying to assess these trade-offs. A sovereign restructuring by an advanced economy is a rare event and therefore it is difficult to study it from an empirical point of view. Although there have been a number of sovereign restructuring episodes in low-income and developing economies in the past, experience regarding advanced economies is extremely limited. Advanced economies differ from low-income and developing economies in many ways. They tend to have a larger share of their public debt held domestically, as they tend to have deeper financial systems. Moreover, MU member countries display a high degree of financial integration, with significant cross-country holdings of public and private debt. A sovereign restructuring by a monetary union member would therefore happen in a very different context than previous instances of sovereign restructuring.[5]

To the best of our knowledge, few studies have assessed the macroeconomic impact of sovereign distress in a MU.

Mendoza and Yue (2012) construct a small open economy model of sovereign default and business cycles. Corsetti et al. (2012) propose a closed economy model where a high level of public debt affects the private sector via the effect that the debt level has on the spread paid by the private sector. Guerrieri et al. (2013) address the issue of the international spillover of a default in a MU model with banks. Our focus is on the domestic impact of a restructuring depending on the NFA position of the country prior to the default, including the distribution of government bond holdings between residents and nonresidents and the private sector external borrowing position, and how this compares to a fiscal adjustment delivering a similar debt reduction.

The paper is organized as follows. Section 2 describes the main equations of the model (with a focus on those related to the model's financial and fiscal structure; the remaining ones are reported in the Appendix) and the calibration. Section 3 discusses the results. Section 4 concludes.

2. THE MODEL

2.1. Setup

The basic structure of the (quarterly) model is New Keynesian and akin to the International Monetary Fund's Global Economy Model (GEM) and the European Central Bank's New Area Wide Model (NAWM).[6] We divide the MU into two regions, the Home country and the RMU.

On the production side, we assume that in each country there are firms producing nontraded final goods under perfect competition. The goods are used for private and public consumption as well as for investment. They are produced

https://doi.org/10.1017/S1365100516000286 Published online by Cambridge University Press

by combining traded and nontraded intermediate goods. Intermediate goods are produced under monopolistic competition. Firms in the sector are price setters (each of them is able to set the price of the produced variety, taking into account the demand). In particular, firms producing tradables are able to price-discriminate between domestic and export markets (hence they set two country-specific prices). Intermediate goods are produced by combining domestic labor and capital.

We assume that households accumulate capital (which they rent to domestic firms) and, more importantly, trade two nominal bonds at the union level. Both bonds are denominated in the currency of the monetary union. One bond is traded among households only. The other is the government bond, traded between households and governments. Households are wage setters (each of them offers differentiated labor services to domestic firms under monopolistic competition).

Monetary and fiscal authorities behave according to feedback rules. A standard Taylor rule holds for monetary policy, which is common to the Home and Foreign regions. The monetary policy rate reacts to monetary unionwide inflation rates and output growth. It is set in an inertial way, to capture gradualism in the conduct of monetary policy. Fiscal policy is conducted at the country level. On the expenditure side, we distinguish between spending on final goods and services produced by the private sector, public wages, and transfers to families. On the revenue side, we distinguish between lump-sum and distortionary taxation of labor income, capital income, and consumption.[7] The fiscal sector is closed by a fiscal rule that stabilizes the public debt using lump-sum transfers.

Finally, the model features the standard real and nominal frictions, such as habit in consumption, adjustment costs related to investment changes, adjustment costs related to nominal prices and wages, and wage and price indexation to a weighted average of previous period inflation and the central bank's inflation target.

Fiscal policy. Fiscal policy is set at the country level. The discussion in this section applies to the Home region. The Appendix gives a more detailed description of the model. The government budget constraint is

$$B_t^{\text{gov}} - B_{t-1}^{\text{gov}}\left(1 - \text{Loss}_t^{B^{\text{gov}}}\right) = B_{t-1}^{\text{gov}}\left(1 - \text{Loss}_t^{B^{\text{gov}}}\right)\left(r_{t-1} + \phi_{t-1}^{\text{gov}}\right) + (1 + \tau_t^c) P_t C_t^{\text{gov}} + W_t L_t^{\text{gov}} + \text{Tr}_t - T_t, \quad (\mathbf{1})$$

where B_{t-1}^{gov}, $B_t^{\text{gov}} \geq 0$ are the levels of nominal public debt at the beginning and end of period t, respectively.[8] The bond is issued in the unionwide market and pays a (net) nominal interest rate $(r + \phi^{\text{gov}})$. The latter is equal to the sum of the risk-free rate set by the central bank of the monetary union, r, and the spread ϕ^{gov} that the government has to pay after a restructuring. The (net) nominal rate r_t is paid at the beginning of period $t + 1$ and is known at time t. Similarly, the spread ϕ_t^{gov} is paid at the beginning of period $t + 1$ and is known at time t (immediately after the restructuring). The term $\text{Loss}_t^{B^{\text{gov}}}$ represents the haircut associated with the restructuring, leading to a sudden reduction (measured in percent) in the initial value of sovereign debt. In other words, $\text{Loss}_t^{B^{\text{gov}}}$ is greater than zero at $t = 1$ (the initial period of the simulation) and zero subsequently. The first term on the

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right-hand side of equation (1) corresponds to the amount of interest expenditure on the new post-restructuring level of public debt. It depends on the new level of debt and the response of the interest rate, in particular the spread component.

Other variables in the equation are standard. The variable C^{gov} stands for government purchases of goods and services, WL^{gov} for compensation for public employees, and $\text{Tr} > 0$ are lump-sum transfers to households ($\text{Tr} < 0$ are lump-sum taxes). We assume that C^{gov} has the same composition as private consumption. Hence it is multiplied by the private consumption price index P. Total government revenues T are given by the identity

$$T_t \equiv \tau_t^l W_t L_t + \tau_t^c \left(P_t C_t + P_t C_t^{\text{gov}}\right) + \tau_t^k \left(r_t^k K_{t-1} + \Pi_t^P\right), \tag{2}$$

where τs are tax rates on labor income (τ_t^l), capital income (τ_t^k), and consumption (τ_t^c), L_t is employment, r_t^k is the rental rate of physical capital K_{t-1}, and Π_t^P stands for dividends from ownership of domestic monopolistic firms.

For the Home region, we assume a policy rule that uses as instrument the net transfers as a proportion of GDP, tr_t. The instrument responds to the discrepancy of the beginning-of-period public debt-to-GDP ratio, b_{t-1}^{gov}, from its long-run target $b^{\text{gov,targ}}$, to the change in the public debt-to-GDP ratio and to the GDP growth:

$$\frac{\text{tr}_t}{\text{tr}_{t-1}} = \left(\frac{b_{t-1}^{\text{gov}}}{b^{\text{gov,targ}}}\right)^{\phi_1} \left(\frac{b_t^{\text{gov}}}{b_{t-1}^{\text{gov}}}\right)^{\phi_2} \left(\frac{\text{GDP}_t}{\text{GDP}_{t-1}}\right)^{\phi_3}. \tag{3}$$

$\phi_1, \phi_2, \phi_3 < 0$ are parameters. In the simulations, the Home target $b^{\text{gov,targ}}$ is reset in order to stabilize the sovereign debt at the new (post-haircut) level. Lump-sum transfers are not distortionary and therefore make the simulations more transparent, but at the same time less realistic, as usually fiscal adjustments involve some distortionary taxation. This is a second-order issue for the restructuring scenarios, where the fiscal rule will have to move slightly in order to stabilize the debt at the post-haircut value. For the fiscal adjustment scenarios, instead, we move Home labor income taxes exogenously based on realistic assumptions and we fill in the rest of the required adjustment, letting the fiscal rule defined on lump-sum transfers operate.

For the RMU, it is assumed that the lump-sum transfers adjust according to a fiscal rule similar to equation (3).

Households. In each region there is a continuum of households having symmetric preferences, initial conditions, and budget constraint. They are indexed by $j \in (0; s)$ (Foreign households by $j \in [s; 1]$), where s is the size of the Home region and $1 - s$ is the size of the RMU. Households' preferences are additively separable in consumption C and labor effort L. The expected value of household j lifetime utility is

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(C_t(j) - hC_{t-1}\right)^{1-\sigma}}{(1-\sigma)} - \frac{\kappa}{\tau} L_t(j)^{\tau} \right] \right\},$$

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where E_0 denotes the expectation conditional on information set at date 0, β is the discount factor ($0 < \beta < 1$), h is the external habit in consumption ($0 < h < 1$), $1/\sigma$ is the elasticity of intertemporal substitution ($\sigma > 0$), and $1/(\tau - 1)$ is the labor Frisch elasticity ($\tau > 0$).

The budget constraint of household j is

$$\begin{aligned} & B_t(j) - B_{t-1}(j) + B_t^g(j) - B_{t-1}^g(j)\left(1 - \text{Loss}_t^{B^{\text{gov}}}\right) \\ & \leq B_{t-1}(j)\left(r_{t-1} + \phi_{t-1}^b\right) + B_{t-1}^g(j)\left(1 - \text{Loss}_t^{B^{\text{gov}}}\right)\left(r_{t-1} + \phi_{t-1}^{\text{gov}}\right) \\ & + (1 - \tau_t^k)\left[\Pi_t^P(j) + r_t^K K_{t-1}(j)\right] \\ & + (1 - \tau_t^l) W_t(j) L_t(j) - (1 + \tau_t^c) P_t C_t(j) - P_t^I I_t(j) \\ & + \text{Tr}_t(j) - \text{AC}_t^W(j). \end{aligned}$$

Home households hold two bonds B and B^g denominated in the currency of the monetary union. Both bonds are in zero net supply at the monetary union level (we report the market-clearing conditions in the next section). The bond B is exchanged with Foreign households only. It pays a (net) interest rate $(r_t + \phi_t^b)$ at the beginning of period $t + 1$ and known at time t. The bond B^g is the government bond, exchanged between households and governments in the monetary unionwide government bond market. The term $\text{Loss}_t^{B^{\text{gov}}}$ is the same shock as the one in the government budget constraint (1). As said, it measures the (percent) reduction in the value of the government bond at the beginning of period $t = 1$ (the initial period in the simulation horizon).

After the restructuring, the Home government pays a higher spread not only to the Foreign households but also to the domestic ones. As such, the spread ϕ^{gov} is added on top of the risk-free rate r also in the households' budget constraint. Moreover, we assume that the spread paid by the government after the haircut is fully transmitted to domestic households. The latter, after the initial sovereign haircut, face an increase in the spread ϕ^b on their foreign debt position, B, in the households' bond market. In this (deliberately) stylized way we characterize the (ex post) sovereign haircut channel to the Home economy. Specifically, after the sovereign restructuring, credit conditions for the private sector become as stringent as for the government. So the same spread $\phi^{\text{gov}} = \phi^b = \phi$ applies to Home households when borrowing from foreign households and to the home government when borrowing from domestic and foreign households. It is defined as

$$\phi_t = \phi_{b1}\left(\exp\left(\text{Loss}_t^{B^{\text{gov}}}\right) - 1\right) + \rho_\phi \phi_{t-1} + \phi_{b2}\frac{\exp\left(\phi_{b3}\left(b_t - \bar{b}\right)\right) - 1}{\exp\left(\phi_{b3}\left(b_t - \bar{b}\right)\right) + 1}. \quad (4)$$

The first two terms are related to the effects of the sovereign restructuring on Home's borrowing costs in international markets. The larger the restructuring (so the larger $\text{Loss}_t^{B^{\text{gov}}}$), the higher the spread [first term on the right-hand side of equation (4)], where ϕ_{b1} is a parameter larger than zero. In this way financial

https://doi.org/10.1017/S1365100516000286 Published online by Cambridge University Press

markets impose a cost on Home households and government for the implied loss of reputation as reliable borrowers. Moreover, the increase in the spread is persistent over time [second term on the right-hand side of equation (4), where $0 \leq \rho_\phi \leq 1$]. Finally, the third term on the right-hand side of equation (4) guarantees, as in the Global Economy Model [see Pesenti (2008)], that the foreign asset position of households as a proportion of GDP, b_t, converges to its steady-state value, $\bar{b}$. We set the parameters $\phi_{b2}, \phi_{b3} > 0$ to rather low values to limit the impact of the third term on the dynamics and keep the model stationary.[9]

As we will demonstrate later, the combination of post-haircut spread, share of public debt held by domestic households, and households' foreign borrowing position is crucial for assessing the macroeconomic effects of the restructuring on the domestic economy.

We also assume that households own all Home firms and there is no international trade in claims on firms' profits, represented by $\Pi^P(j)$. Each Home agent j is a wage setter, being a monopolistic supplier of a single labor variety. The nominal wage $W_t(j)$ is sticky given the presence of the adjustment cost AC_t^W:

$$\mathrm{AC}_t^W(j) \equiv \frac{\kappa_W}{2}\left(\frac{W_t(j)/W_{t-1}(j)}{\pi_{W,t-1}^{\alpha_W}\bar{\pi}^{1-\alpha_W}} - 1\right)^2 W_t L_t,$$

where $\kappa_W > 0$ is a parameter and $W_t L_t$ is the average Home wage income. The term $\pi_{W,t-1}^{\alpha_W}\bar{\pi}^{1-\alpha_W}$ represents the indexation of wages to the previous period's gross (average) wage inflation $\pi_{W,t-1}$ and to the gross consumer price inflation target of the central bank $\bar{\pi}$, with weights α_W and $1-\alpha_W$, respectively ($0 \leq \alpha_W \leq 1$). Finally, each household rents physical capital to domestic firms at the nominal rate R^k. The law of motion of physical capital is

$$K_t(j) = (1-\delta)K_{t-1}(j) + \left(1 - \mathrm{AC}_t^I(j)\right) I_t(j), \tag{5}$$

where $0 \leq \delta \leq 1$ is the depreciation rate. The adjustment cost on investment $I_t(j)$, AC_t^I, is given by

$$\mathrm{AC}_t^I(j) \equiv \frac{\phi_I}{2}\left(\frac{I_t(j)}{I_{t-1}(j)} - \delta\right)^2, \tag{6}$$

where $\phi_I > 0$ is a parameter. Similar relations hold in the Foreign country.

2.2. Bond Market Clearing Conditions

To clarify the financial structure of the model, we report the two bond-market-clearing conditions. For the bond traded between Home and Foreign households, we have (using the assumption of symmetric households in each country)[10]

$$sB_t + (1-s)B_t^* = 0, \tag{7}$$

where, as previously said, $0 < s < 1$ is the size of the Home economy (the size of the union is normalized to 1). For the government bond, the market-clearing

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condition is

$$s B_t^g - B_t^{\text{gov}} + (1-s) B_t^{g*} - B_t^{\text{gov}*} = 0, \tag{8}$$

where $B_t^{\text{gov}} \geq 0$ and $B_t^{\text{gov}*} \geq 0$ represent Home and Foreign government debt, respectively. The Home NFA position (NFA_t) is given by the sum of Home households and government positions against the RMU:

$$\text{NFA}_t = s B_t + s B_t^g - B_t^{\text{gov}}, \tag{9}$$

where the sum $s B_t + s B_t^g$ represents the total asset position of the Home households. The current account CA_t and the trade balance TB_t of the Home economy are, respectively,

$$\text{CA}_t = \text{NFA}_t - \text{NFA}_{t-1}, \tag{10}$$

$$\text{TB}_t = \text{CA}_t - (s B_{t-1} + s B_{t-1}^g - B_{t-1}^{\text{gov}}) \left(r_{t-1} + \phi_{t-1}^{\text{gov}}\right). \tag{11}$$

The Home current account is the change in the Home NFA. The trade balance is the current account net of the interest payment on the foreign asset position.

Given the preceding equations and the spread in (4), we are able to assess the impact of the Home sovereign restructuring on the Home foreign asset position and hence on the Home economy.

2.3. Calibration

The model is calibrated at quarterly frequency to a generic small peripheral country of a monetary union and the RMU. For most parameters we resort to previous studies and estimates available in the literature.[11]

Table 1 reports the steady-state macroeconomic aggregates (% of GDP) and tax rates under our baseline calibration. Tax rates are calibrated using 2012 data on effective average tax rates in the Euro Area from Eurostat (2014). The tax rate on wage income τ^l is set to 35% in both Home and the RMU. Similarly, the tax rate on capital income τ^k is set to 27.4%, and the tax rate on consumption τ^c to 20.5%. The public debt-to-yearly GDP ratio is calibrated at 150% for Home and at 60% for the RMU. Finally, Home households have a foreign debt equal to 100% of Home annualized GDP.

Table 2 reports the calibration of the spread paid by the public and private sector [see equation (3)]. Consistent with evidence provided by Cruces and Trebesch (2013), sovereign bond spreads for a country that imposes a 40% haircut on creditors are estimated at about 250 b.p. above those prevailing for a country with similar characteristics (including the post-haircut debt level) during the first year after restructuring. Subsequently, spreads decrease over time in a gradual way to reach about the zero level after five years.

Table 3 contains parameters related to preferences and technology. Parameters with a "$*$" are related to the RMU. We assume that discount rates and elasticities of substitution have the same value across the two regions. The discount factor

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TABLE 1. Great ratios and tax rates

	Home	RMU
Macro variables		
Private consumption C	60.4	61.7
Investment I	16.1	18.7
Imports	21.4	—
Foreign debt (% annualized GDP)	100.0	—
Fiscal variables		
Public purchases C^g	10.0	10.0
Wage bill WL^g	10.2	9.8
Interests	4.8	1.9
Tax Rates		
On wages	35.0	35.0
On rental rate of capital	27.4	27.4
On price of consumption	20.5	20.5
Debt (ratio to annual GDP)	150	60.0

Note: RMU = rest of monetary union.

TABLE 2. Home country spread

Parameter	Value
ϕ_{b1}	−0.0154
ϕ_{b2}	0.002
ϕ_{b3}	0.002
ρ_{ϕ}	0.92

β is set to 0.992, so that the steady-state real interest rate is equal to 3.3% on an annual basis. The intertemporal elasticity of substitution, $1/\sigma$, is set to 1, the Frisch labor elasticity to 0.5, and the depreciation rate of capital δ to 0.025. For the production of traded intermediate goods, the elasticity of substitution between labor and capital is set to 0.9 in both regions. For the production functions of nontraded intermediate goods, the elasticity is set to 0.9. The bias toward capital is set close to 0.6 in both regions. In the final consumption and investment goods the elasticity of substitution between domestic and imported tradable is set to 1.5, whereas the elasticity of substitution between tradables and nontradables is set to 0.5. In the consumption sector the bias for the composite tradable is set to 0.5 for the Home region as well as for the RMU. In the investment sector it is set to 0.75. The population size of Home, s, is set to 0.003 (the population of the monetary union is normalized to 1).

Table 4 reports gross markups in the traded and nontraded intermediate goods sectors and in the labor markets. Markups are higher in the nontraded goods

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TABLE 3. Parameterization

Parameter ("*" refers to RMU)	Home	RMU
Rate of time preference $(1/\beta^4 - 1) \times 100$	3.3	3.3
Intertemporal elasticity of substitution $1/\sigma$	1.0	1.0
Habit h	0.45	0.45
Frisch elasticity of labor $1/(\tau - 1)$	0.5	0.5
Depreciation rate of capital δ, δ^*	0.025	0.025
Tradable intermediate goods		
Substitution between factors of production ξ_T, ξ_T^*	0.9	0.9
Bias toward capital α_T, α_T^*	0.6	0.6
Nontradable intermediate goods		
Substitution between factors of production ξ_N, ξ_N^*	0.9	0.9
Bias toward capital α_N	0.7	0.7
Final consumption goods		
Substitution between domestic and imported goods ϕ_A, ϕ_A^*	1.5	1.5
Bias toward domestic tradable goods a_H, a_F^*	0.5	0.9
Substitution between domestic tradables and non tradables ρ_A, ρ_A^*	0.5	0.5
Bias toward tradable goods a_T, a_T^*	0.5	0.5
Final investment goods		
Substitution between domestic and imported goods ϕ_E, ϕ_E^*	1.5	1.5
Bias toward domestic tradable goods υ_H, υ_F^*	0.4	0.9
Substitution between domestic tradables and non tradables ρ_E, ρ_E^*	0.5	0.5
Bias toward tradable goods υ_T, υ_T^*	0.75	0.75
Size s and $(1 - s)$	0.003	0.997

Note: RMU = rest of monetary union.

TABLE 4. Gross markups

	Markups and elasticities of substitution		
	Tradables	Nontradables	Wages
Home	1.2 ($\theta_T = 6$)	1.3 ($\theta_N = 4.3$)	1.3 ($\psi = 4.3$)
RMU	1.2 ($\theta_T^* = 6$)	1.3 ($\theta_N^* = 4.3$)	1.3 ($\psi^* = 4.3$)

Note: RMU = rest of monetary union.

sectors and labor markets. Markups are obtained by calibrating the sector-specific elasticities of substitution between different varieties of goods.[12]

Table 5 contains parameters that regulate the dynamics. Adjustment costs on investment changes are set to 2.8. Nominal wage and price quadratic adjustment costs are set to obtain an average frequency of price adjustment in line with the NAWM.

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TABLE 5. Real and nominal adjustment costs

Parameter ("*" refers to RMU)	Home	RMU
Real adjustment costs		
Investment ϕ_I, ϕ_I^*	2.80	2.80
Nominal adjustment costs		
Wages κ_W, κ_W^*	400	400
Price of domestically produced tradables κ_H, k_F^*	600	600
Price of nontradables κ_N, κ_N^*	600	600
Price of imported intermediate goods κ_F, κ_H^*	600	600
Indexation to past inflation α, α^*	0.5	0.5

Note: RMU = rest of monetary union.

TABLE 6. Fiscal and monetary policy rules

Parameter ("*" refers to RMU)	Home	RMU	MU
Fiscal policy rule			
Public debt deviation from long run level ϕ_1, ϕ_1^*	−0.5	−0.5	—
Public debt change ϕ_2, ϕ_2^*	−25	−25	—
GDP growth ϕ_3, ϕ_3^*	−25	−25	—
Common monetary policy rule			
Lagged interest rate at t-1 ρ_i	—	—	0.85
Inflation ρ_Π	—	—	1.9
GDP growth ρ_{GDP}	—	—	0.4

Note: RMU = rest of monetary union.

Finally, parameterizations of the systematic feedback rules followed by the fiscal and monetary authorities are reported in Table 6. For each country-specific fiscal policy rule (3) we set ϕ_1, ϕ_2, and ϕ_3, respectively, to −0.5, −25, and −25. The central bank of the monetary union targets the contemporaneous monetary-union-wide consumer price inflation (the corresponding parameter is set to 1.9) and the output growth (the parameter is set to 0.4).[13] The interest rate is set in an inertial way. Its previous-period value enters the rule with a weight equal to 0.85.

3. RESULTS

We evaluate next the domestic macroeconomic effects of a sovereign restructuring and in turn we simulate a fiscal adjustment that achieves a similar reduction in sovereign debt. We consider perfect foresight scenarios, where there is no uncertainty regarding the future path of policies. We show the macroeconomic implications of restructuring change according to (1) the reaction of sovereign spreads, (2) different initial (before the restructuring) shares of public debt held

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by domestic and foreign residents, and (3) different initial private sector foreign debt positions.

3.1. Sovereign Restructuring

Our baseline simulation can be described as follows. We assume that the economy starts off from the steady state. At the beginning of the first period the haircut is implemented and hence the spread increases. In the baseline simulation the public debt of the Home country is reduced from 150 to 90% of annualized GDP. This corresponds to a 40% reduction in nominal value. After the first period, transfers move according to the fiscal rule [see equation (3)] to stabilize the debt-to-GDP ratio at the new value (90%).[14] Moreover, for illustration purposes, we start by assuming that 100% of the debt is held by domestic agents and that the Home private sector has an initial debt position toward foreign residents equal to 100% of annualized GDP.

Figures 1 and 2 report the baseline results. Both the Home government and the private sector face an increase in the spread paid for borrowing in the international financial market (Figure 2). The spread increases by 250 (annualized) b.p. on impact. Subsequently, it gradually decreases over time to 0 b.p. after 5 years. As previously said, the increase in the spread captures the loss of reputation of the country as a reliable borrower.

GDP decreases by 4% of the initial steady state level after one year, and returns at its initial level after three years (Figure 1). The increase in spreads leads to an increase in the real interest rate faced by Home households,[15] inducing a large reduction in consumption and investment, by 5% and 15%, respectively, by the end of the first year. After about three years consumption and investment both return to the baseline levels.

Regarding the other macroeconomic variables, gross exports increase and imports decrease.[16] The increase in exports is associated with the reduction in the prices of traded goods produced in the Home country, which become more competitive than RMU-produced goods. The lower prices are due to the lower Home aggregate demand, which in turn reduces Home imports from the RMU as well. Employment decreases by about 5%. The decrease is driven by the lower labor demand by firms (the real wage, not reported, also decreases over time). The Home CPI inflation rate initially falls by about 1.0 (annualized) percentage point, driven by the reduction in aggregate demand. We do not report spillovers to the RMU, as they are relatively small.[17]

As reported in Figure 2 (third panel), the overall foreign asset position of the Home country deteriorates slightly, as there is an increase in Home households' private borrowing to smooth consumption. The Home current account (as aproportion of GDP) deteriorates, because of the higher interest payments on the increased foreign asset position of the country.

Overall, results suggest that the restructuring can have sizable negative effects on economic activity when all debt is held domestically. The main reason is the

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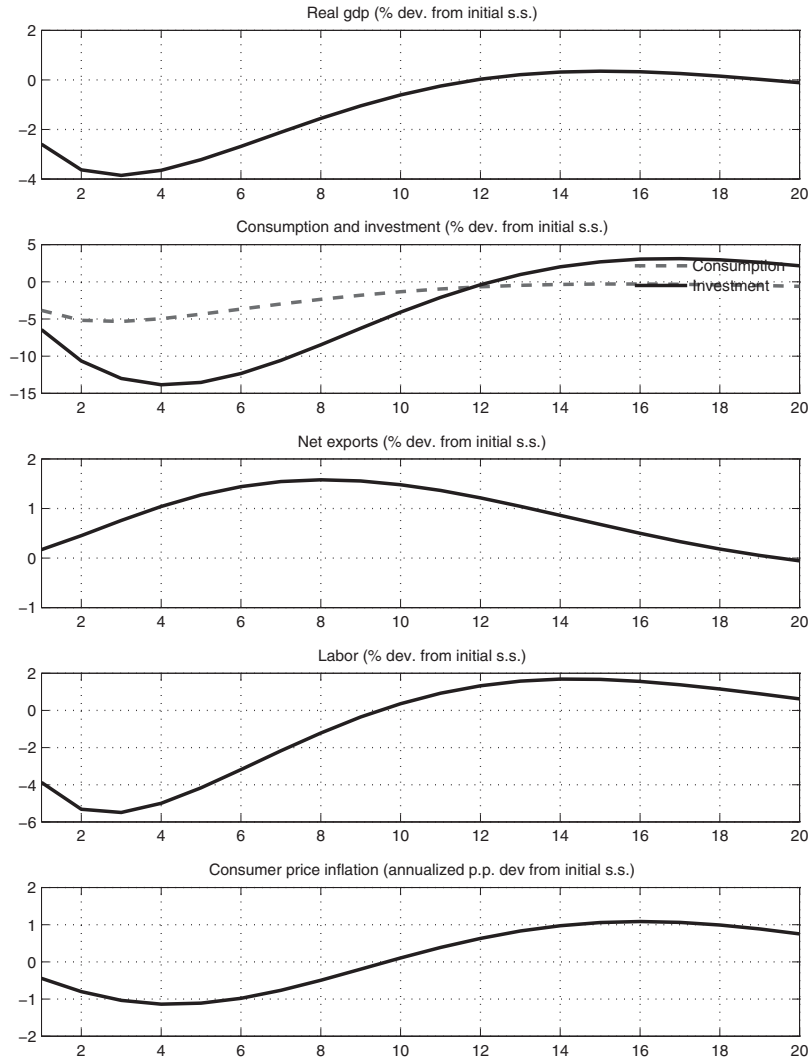

FIGURE 1. 40% restructuring of sovereign debt: real variables and inflation. Horizontal axis: quarters.

wide and persistent increase in the spreads paid by both the public and private sector.

3.2. Comparing Debt Restructuring and Fiscal Consolidation

In this section we compare the macroeconomic effects of the sovereign default with those of fiscal consolidation. In both cases, the public debt is reduced by 40%

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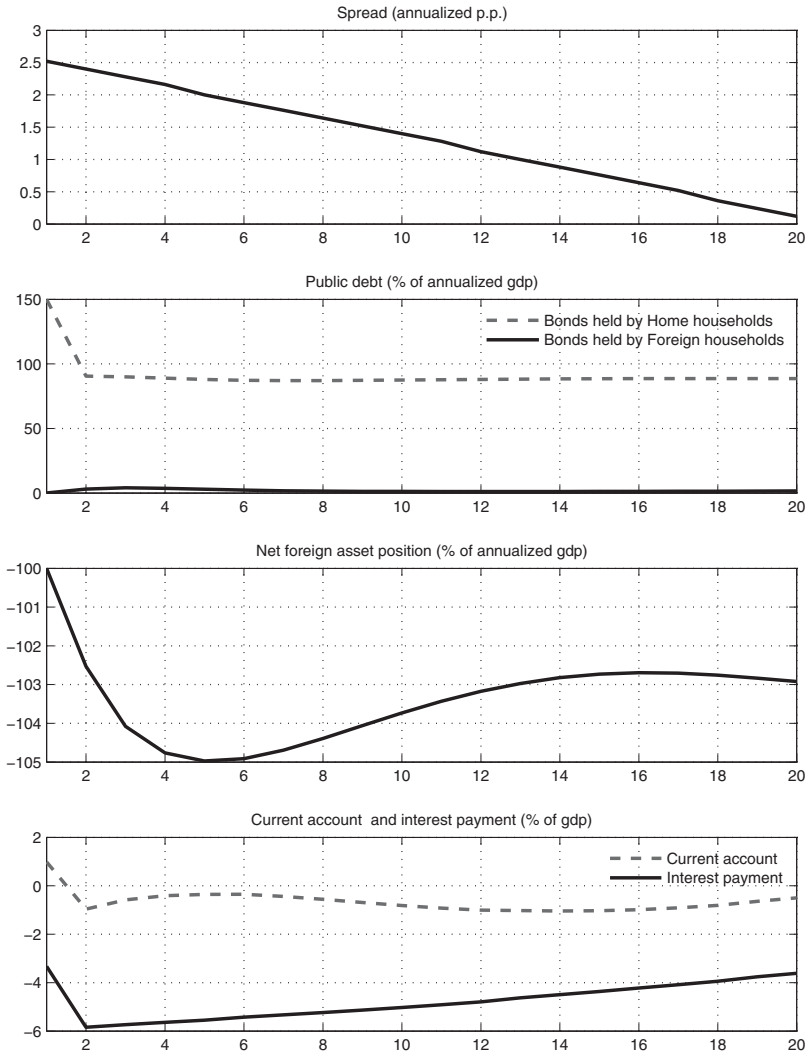

FIGURE 2. 40% restructuring of sovereign debt: asset positions. Horizontal axis: quarters.

of its initial value. Under fiscal consolidation, the public debt is reduced by 40% in a gradual way over 20 years. We assume that the labor income tax rate increases from 35% to 40% during the initial five years and comes back to the steady state during the sixth year. Lump-sum transfers (endogenously) change following the fiscal rule.

We have calibrated the fiscal adjustment using evidence on past fiscal adjustments. In particular, Escolano et al. (2014), using a sample of 91 adjustment

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episodes of countries during 1945–2012 that needed and wanted to adjust in order to stabilize the debt-to-GDP ratio, show that countries improved their cyclically adjusted primary balances by close to 5% of GDP (median value). We assume that about half of this adjustment is achieved by adjusting distortionary labor income taxes. Differently from the case of restructuring, we now assume no increase in the spread (it is equal to zero).

Our simulations show (Figure 3) that a fiscal consolidation has lower macroeconomic costs on impact as compared with a haircut scenario when the whole sovereign debt is held domestically, but that the effect is more persistent. Under fiscal consolidation, GDP falls by about 1% after five years. Consumption and investment fall in a gradual way because of, respectively, consumption habit and adjustment cost on investment change.

The discounted value of the GDP losses (discounted using the households' discount factor) is about 13% for the restructuring scenario and about 9% for the fiscal adjustment. Therefore, the results suggest that the deterioration of the economic activity is greater under the restructuring episode than under the consolidation of public debt, as the increase in spreads triggered by the default has dire effects on private sector consumption and investment (also considering that the initial net foreign asset position is large and negative). In the case of fiscal adjustment, instead, the macroeconomic cost is related to the initial increase in distortionary (labor income) taxes. Absent these, the consolidation would be based on lump-sum taxes only. Thus, it would not have any significant macroeconomic effect, as in our setup agents are Ricardian (we assume that the spread, which is distortionary, is zero).

3.3. Alternative Initial Shares of Domestically Held Public Debt

Figure 4 assumes that Home households hold 50% of domestic public debt, as opposed to 100% in the previous section. As in the baseline case, we consider a cut equal to 40% of the initial nominal value of public debt. On impact, the fall in GDP and domestic demand is about half as much as the fall in the case of debt entirely held by domestic agents.

The key trade-off of the restructuring works as follows. After the sovereign restructuring, Home households pay a lower amount of current and expected taxes, as the stock of public debt is reduced. The cut in the nominal value of the sovereign bond they hold is smaller than the reduction in the expected stream of taxes they have to pay, as 50% of the sovereign bonds are held by foreign residents. From this perspective, Home households benefit from the haircut. In other words, the sovereign debt held by foreign households is a foreign liability that Home households sooner or later have to repay (through taxes). Thus, the sovereign restructuring implies a reduction in this foreign liability, and hence a positive wealth effect for the Home households. On the other hand, the spread paid by Home households increases after the restructuring. This induces a negative income

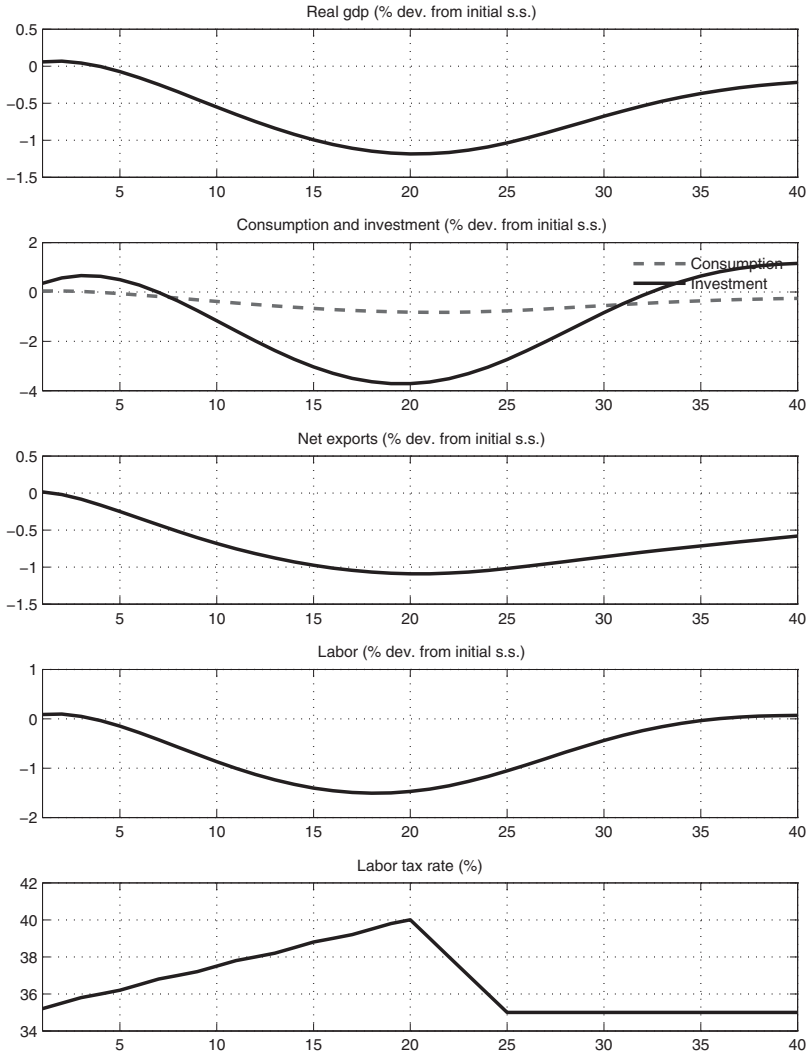

FIGURE 3. Consolidation of sovereign debt: real variables and inflation. Horizontal axis: quarters.

effect, because of the higher interest payments, and a negative substitution effect that induces agents to postpone consumption, because of the higher interest rate.

Overall, the macroeconomic effects of the sovereign restructuring depend in a relevant way on the initial share of public debt held by domestic residents. When Home households hold a relatively small share of government debt (or, conversely, when foreign residents hold a relatively large share of government debt), the Home

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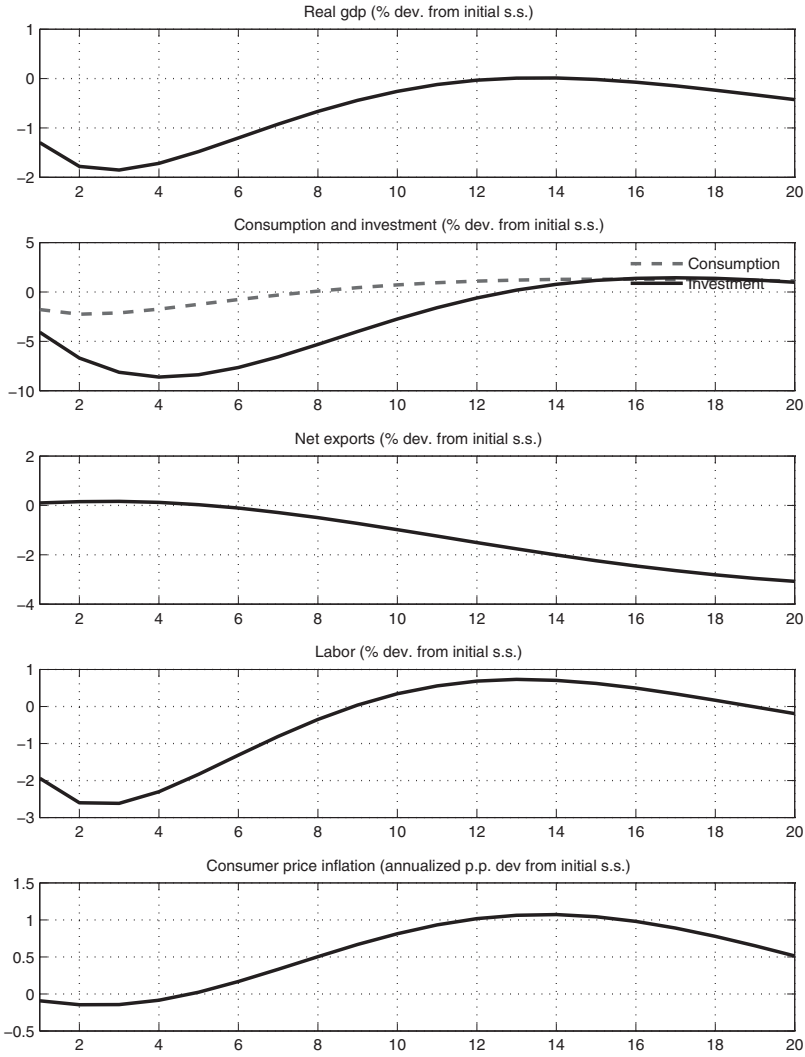

FIGURE 4. Restructuring: 50% of sovereign debt held abroad. Horizontal axis: quarters.

macroeconomic costs of a restructuring are lower, and the favorable income and wealth effects on Home households larger.

In Figure 5 we repeat the simulation of Figure 4 assuming that "only" 40% of the sovereign debt is held abroad. GDP falls by a little more than 2% and comes back to baseline in the fourth year. The results imply that the discounted value of the Home GDP losses (discounted using the households' discount factor) is now about 11%, a value similar to that of the fiscal adjustment. Therefore, with 40% of the

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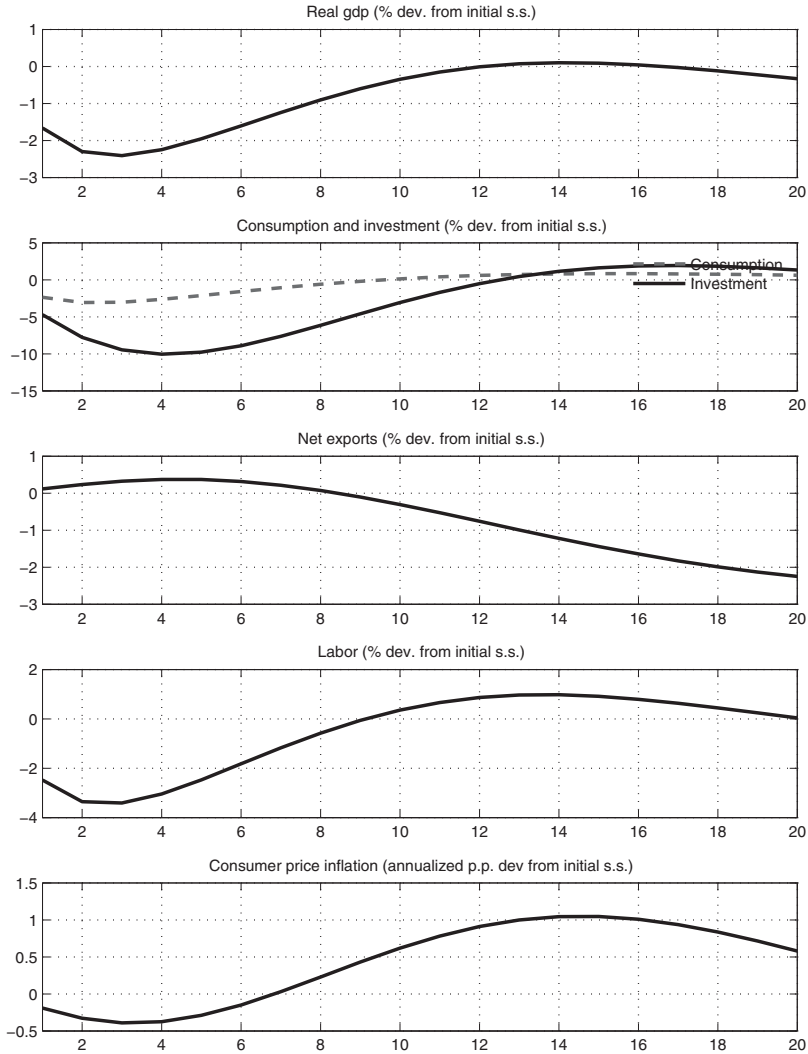

FIGURE 5. Restructuring: 40% of sovereign debt held abroad. Horizontal axis: quarters.

debt held abroad, the impact of the restructuring on the macroeconomic variables is very close to that of the fiscal adjustment reported in Figure 3. Clearly, this result is conditional on how other parameters have been calibrated (in particular the increase in spreads after the restructuring, discussed later), but shows that for a reasonable calibration a country that holds more than about 60% of sovereign debt domestically is likely to be better off reducing the sovereign debt through fiscal consolidation as opposed via a restructuring.

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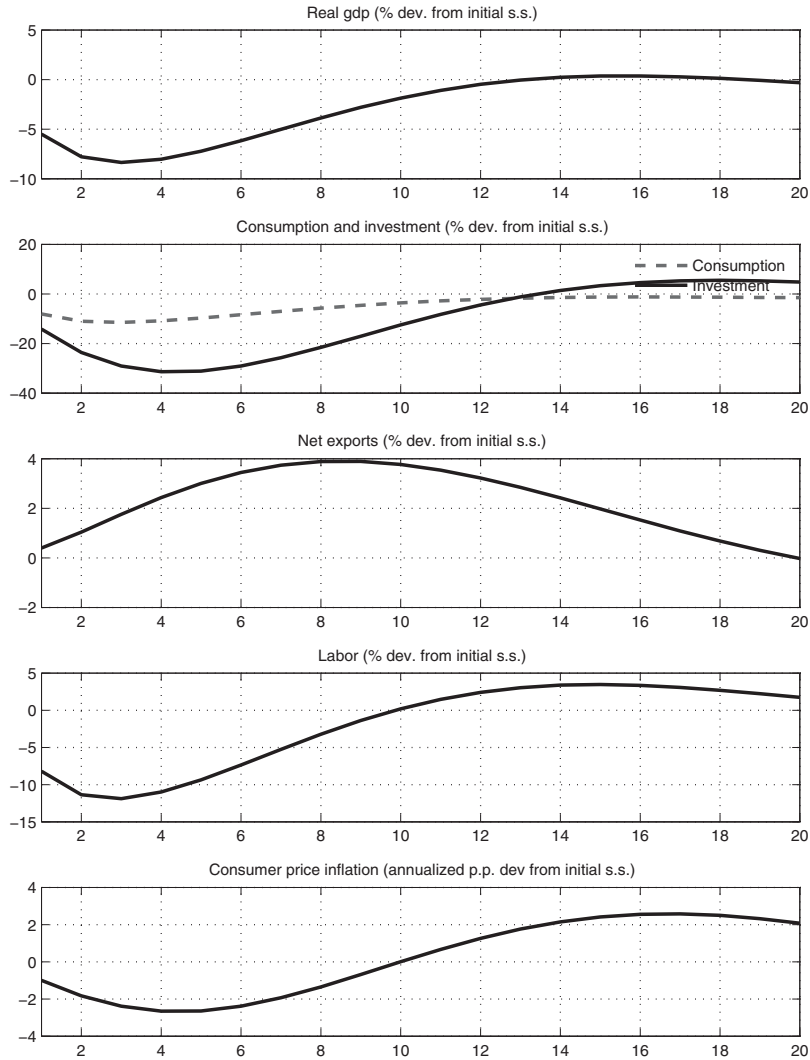

FIGURE 6. Sensitivity: restructuring and larger spread. Horizontal axis: quarters.

3.4. Sensitivity: The Role of Spreads and of the Households' Initial Foreign Asset Position

To further provide intuition on the effects of a restructuring, we show in Figures 6 and 7 results obtained assuming the spread jumps more (up to 400 b.p.) or less (about 100 b.p.) after a restructuring. In Figure 8 instead we consider an initial foreign asset position of the domestic private sector equal to zero. In all these cases we assume that 100% of the debt is held domestically.

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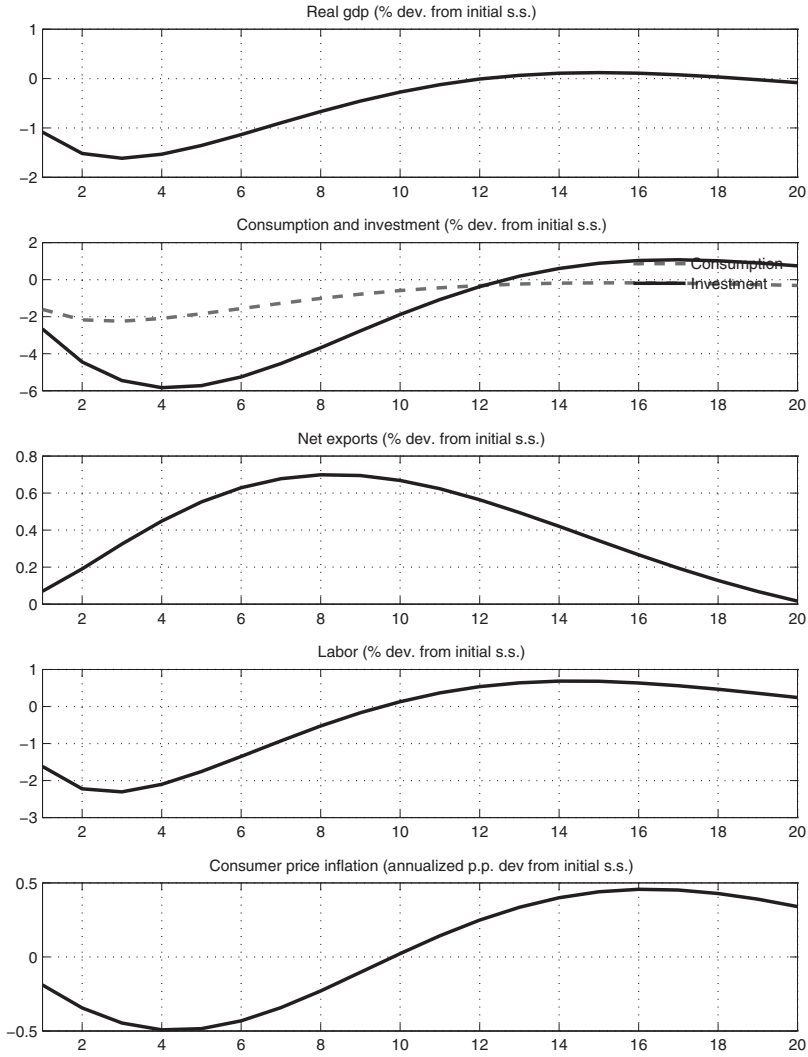

FIGURE 7. Sensitivity: restructuring and smaller spread. Horizontal axis: quarters.

Larger spreads are accompanied by a larger (about twice as large) fall in GDP and in the components of domestic demand. Similarly, smaller spreads bring about a more muted response after the restructuring. All in all, this shows how important are the assessments of the quantitative results for the amount of increase in spreads.

Of course, the effects of spreads not only matter through the standard intertemporal substitution effect, but also are magnified by the initial foreign asset position, as private agents will have to roll over these positions at higher rates after the restructuring. In Figure 8 we address this issue and make the extreme

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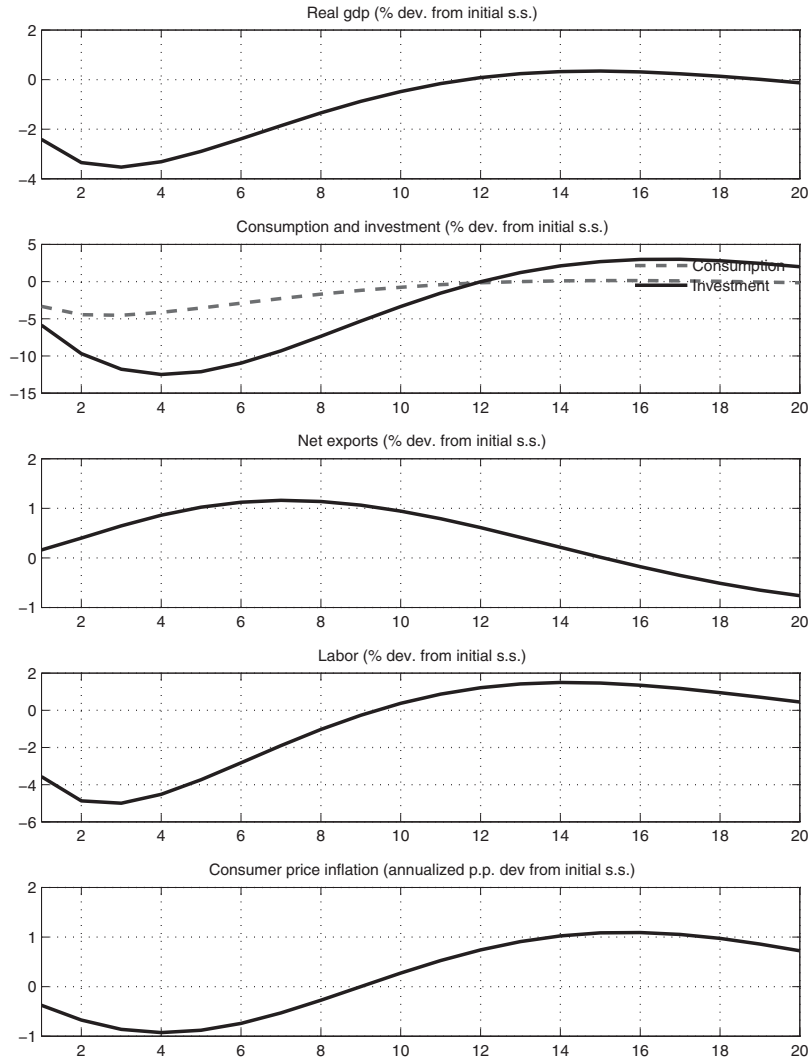

FIGURE 8. Sensitivity: restructuring and initial asset position. Horizontal axis: quarters.

assumption that the initial foreign asset position of the domestic private sector is equal to zero. The decrease in GDP and its main components is somewhat lower than in the baseline case.[18] As the initial private sector NFA position is zero, the negative income effect (coming from the cost of rolling over the private debt at a higher interest rate) on Home households is smaller than in the baseline case. The reason is that now Home households have to pay (indirectly) through taxes only the higher interest on the stock of public debt held by Foreign households after the restructuring. In this case, Home households do not have direct financial liability

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toward Foreign households. Thus, they do not face over time an increase in the associated financial cost as large as in the baseline case.

4. CONCLUSIONS

This paper has assessed the domestic macroeconomic effects of a sovereign restructuring using a monetary union model and has compared its effects with those of a fiscal adjustment scenario. Assuming an increase in spreads after the write-off, our baseline simulation suggests a negative impact on domestic economic activity. We have also compared the simulated effects of a restructuring with those of a smooth fiscal consolidation. In the case of fiscal consolidation the adjustment path does not depend on how much public debt is held abroad, as the entire amount of the debt has to be repaid. On the other hand, the country avoids an increase in spreads. We find that in our baseline parameterization the country would be better off reducing the debt via fiscal adjustment if it held more than 60% of the debt domestically. If instead it held less, then the lump-sum tax that a restructuring would impose on foreign debt holders would make the restructuring less painful than the fiscal adjustment for the domestic residents.

NOTES

1. Contagion and systemic crises are not the object of the analysis.

2. As long as there is a functioning secondary market for the debt, foreign holders always have the opportunity to sell their debt on the secondary market. Therefore, if the fiscal authority, when restructuring its debt, tried to discriminate and imposed the haircut only on foreign holders, the latter would sell their bonds on the secondary market to the domestic residents (who should be willing to buy at a price close to the face value).

3. For example, Corsetti et al. (2012) use a closed economy New Keynesian model to stress the role of the sovereign risk channel of fiscal policy. In their model the risk of sovereign default depends on the level of public debt. Kollman et al. (2013) model default assuming that at a given time the government writes off a given amount of debt. Similarly, Iacoviello et al. (2012) assume that negative income shocks drive governments to hit their borrowing constraint and therefore to default.

4. The empirical result of Cruces and Trebesch (2013) is consistent with the classical work of Eaton and Gersovitz (1981), where it is argued that sovereign borrowing can be supported as long as a restructuring is costly. Therefore, nonrepayments have to be followed by punishments (in the form of high spreads or exclusion from international borrowing), and larger nonrepayments by larger punishments.

5. We do not consider some other factors that could have important implications during a restructuring, such as the roles played by financial frictions, by banks' balance sheets, and by possible contagion effects (especially relevant in a financially integrated monetary union). Moreover, in our baseline simulations, we will assume that the budget balance is in equilibrium in the initial steady state and that fiscal policy will aim at stabilizing the debt after the restructuring. This assumption does not match the recent experience of countries that have faced sovereign stress while at the same time undergoing considerable fiscal consolidations. All in all, therefore, our results cannot easily be applied to the experience of any specific country.

6. For descriptions of the GEM and NAWM see Pesenti (2008) and Coenen et al. (2008), respectively. A detailed description of our model is reported in the Appendix.

7. For a model with similar fiscal features, see Forni et al. (2010a).

8. As is standard in this class of models, bonds are one-period securities and each period is equal to one quarter. The actual average maturity of sovereign debt is usually longer than one quarter. The largest Euro Area countries have an average term to maturity of outstanding marketable bonds between 6 and 8 years [see OECD (2014, p. 29)]. Therefore, the transmission of the increase in spreads to higher interest spending will depend on the average maturity of the public debt, whereas the model assumes that the entire stock of debt is rolled over every period. Although we think that the model assumption is rather extreme (and therefore likely a ceiling on the potential cost), we still believe it is a reasonable approximation. In fact, countries that have restructured in the past tended to enter the restructuring with a very short maturity structure. The reason is that, as the fiscal position of the country deteriorates over time, creditors are willing to lend only short-term (or said in a different way, it would be too costly for the sovereign to borrow long-term). See, among the many papers that address this issue, Fernández and Martin (2014).

9. There is only one (minor) difference between ϕ^{gov} and ϕ^{b}. It corresponds to the third term on the right-hand side of equation (4), which in the case of the government spread depends on the current and steady-state values of the government bonds held by Home households. As said, the difference is quantitatively small, as we minimize the impact of that term on the dynamics. Finally, all revenues from the imposition of the spread are rebatedas a lump sum to Foreign households [see Benigno (2009)]. For the latter, the spread does not enter either in the government budget constraint or in the Euler equations.

10. Foreign (RMU) variables have a "*."

11. See Forni et al. (2009, 2010a) and Gomes et al. (2010).

12. For an analysis of the macroeconomic effects of different degree of markups in a model similar to the one used in this paper, see Forni et al. (2010b).

13. The monetary-union-wide consumer price inflation rate is the weighted (by the country size) geometric average of the corresponding regional variables. The monetary union GDP is the sum of regional GDPs.

14. Because we assume that fiscal policy is managed by changing lump-sum transfers and that agents are Ricardian, results are not very different if we allow the debt level to increase after the restructuring and the spread to be zero.

15. The nominal interest rate set by the monetary authority does not greatly change, given the low weight of the Home country in monetary union and hence in the Taylor rule.

16. Real exporst and imports are evaluated at the initial steady state prices.

17. As said, we assume that the Home country is relatively small compared to the RMU and that there is no financial contagion.

18. As illustrated in the calibration section, in the baseline simulation it is assumed that Home households have an initial financial liability against the Foreign households equal to 100% of Home annualized GDP.

19. For a detailed description of the main features of the model, see also Pesenti (2008).

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APPENDIX

In this Appendix we report a detailed description of the model, excluding the fiscal policy part, the description of the households' optimization problem, which is reported in the main text.[19]

There are two countries, the Home country and the rest of the monetary union (RMU), having different sizes and sharing the currency and the central bank. In each region there are households and firms. Each household consumes a final composite good made of nontradable, domestic tradable, and imported intermediate goods from the RMU. Households have access to financial markets and smooth consumption by trading a risk-free one-period nominal bond. They also own domestic firms and capital stock, which is rented to domestic firms in a perfectly competitive market. Households supply differentiated labor services to domestic firms and act as wage setters in monopolistically competitive markets by charging a markup over their marginal rate of substitution. A fraction of households, as said in the text, do not optimize over time but simply consume the overall wage income available in each period.

On the production side, there are perfectly competitive firms that produce the final goods and monopolistic firms that produce the intermediate goods. The three final goods (a private consumption, a private investment, and a public consumption good) are produced by combining all available intermediate goods in a constant-elasticity-of-substitution manner. Tradable and nontradable intermediate goods are produced by combining capital and labor in the same way. Tradable intermediate goods are split into domestically consumed and

export goods. Because intermediate goods are differentiated, firms have market power and restrict output to create excess profits. We assume that Home and the RMU are segmented markets and the law of one price for tradables does not hold. Hence, each firm producing a tradable good sets two prices, one for the domestic market and the other for the export market. Because the firm faces the same marginal costs regardless of the scale of production in each market, the different price-setting problems are independent of each other.

To capture the empirical persistence of the aggregate data and generate realistic dynamics, we include costs of adjustment to real and nominal variables, ensuring that, in response to a shock, consumption and production do not immediately jump to a new long-term equilibrium. On the real side, quadratic costs prolong the adjustment of the capital stock. On the nominal side, quadratic cost make wages and prices sticky.

Imperfect competition in product and labor markets is reflected in markups over marginal costs. The elasticity of substitution between products of different firms determines the market power of each profit-maximizing firm. The setup in the labor market is similar. Each worker offers a differentiated kind of labor services that is an imperfect substitute for services offered by other workers. The lower the degree of substitutability, for example because of skill differences or anticompetitive regulation, the higher is the markup and the lower the employment in terms of hours. Hence, markups are modeled by a single parameter.

In what follows we illustrate the Home economy. The structure of the Foreign economy (the RMU) is similar and to save on space we do not report it.

A.1. FINAL CONSUMPTION AND INVESTMENT GOODS

There is a continuum of symmetric Home firms producing Home final nontradable consumption goods under perfect competition. Each firm producing the consumption good is indexed by $x \in (0, s]$, where the parameter $0 < s < 1$ is a measure of country size. Foreign firms producing the Foreign final consumption goods are indexed by $x^* \in (s, 1]$ (the size of the monetary union is normalized to 1). The CES production technology used by firm x is

$$A_t(x) \equiv \left(a_T^{\frac{1}{\phi_A}} \left(a_H^{\frac{1}{\rho_A}} Q_{\mathrm{HA},t}(x)^{\frac{\rho_A-1}{\rho_A}} + (1-a_H)^{\frac{1}{\rho_A}} Q_{\mathrm{FA},t}(x)^{\frac{\rho_A-1}{\rho_A}} \right)^{\frac{\rho_A}{\rho_A-1}\frac{\phi_A-1}{\phi_A}} + (1-a_T)^{\frac{1}{\phi_A}} Q_{\mathrm{NA},t}(x)^{\frac{\phi_A-1}{\phi_A}} \right)^{\frac{\phi_A}{\phi_A-1}},$$

where Q_{HA}, Q_{FA}, and Q_{NA} are bundles of, respectively, Home tradable, Foreign tradable, and Home nontradable intermediate goods, $\rho > 0$ is the elasticity of substitution between tradables, and $\phi > 0$ is the elasticity of substitution between tradable and nontradable goods. The parameter a_H $(0 < a_H < 1)$ is the weight of domestic tradable, a_T $(0 < a_T < 1)$ the weight of tradable goods.

The production of the investment good is similar. There are symmetric Home firms under perfect competition indexed by $y \in (0, s]$ and symmetric Foreign firms indexed by

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$y^* \in (s, 1]$. The output of Home firm y is

$$E_t(y) \equiv \left(v_T^{\frac{1}{\phi_E}} \left(v_H^{\frac{1}{\rho_E}} Q_{\mathrm{HE},t}(y)^{\frac{\rho_E-1}{\rho_E}} + (1-v_H)^{\frac{1}{\rho_E}} Q_{\mathrm{FE},t}(y)^{\frac{\rho_E-1}{\rho_E}} \right)^{\frac{\rho_E}{\rho_E-1}\frac{\phi_E-1}{\phi_E}} + (1-v_T)^{\frac{1}{\phi_E}} Q_{\mathrm{NE},t}(y)^{\frac{\phi_E-1}{\phi_E}} \right)^{\frac{\phi_E}{\phi_E-1}}.$$

Finally, we assume that public expenditure C^g has the same composition as private consumption.

A.2. INTERMEDIATE GOODS

Demand. Bundles used to produce the final consumption goods are CES indices of differentiated intermediate goods, each produced by a single firm under conditions of monopolistic competition:

$$Q_{\mathrm{HA}}(x) \equiv \left[\left(\frac{1}{s}\right)^{\theta_T} \int_0^s Q(h,x)^{\frac{\theta_T-1}{\theta_T}} dh \right]^{\frac{\theta_T}{\theta_T-1}}, \tag{A.1}$$

$$Q_{\mathrm{FA}}(x^*) \equiv \left[\left(\frac{1}{1-s}\right)^{\theta_T} \int_s^1 Q(f,x)^{\frac{\theta_T-1}{\theta_T}} df \right]^{\frac{\theta_T}{\theta_T-1}}, \tag{A.2}$$

$$Q_{\mathrm{NA}}(x) \equiv \left[\left(\frac{1}{s}\right)^{\theta_N} \int_0^s Q(n,x)^{\frac{\theta_N-1}{\theta_N}} dn \right]^{\frac{\theta_N}{\theta_T-1}}, \tag{A.3}$$

where firms in the Home tradable and nontradable intermediate sectors and in the Foreign intermediate tradable sector are, respectively, indexed by $h \in (0, s)$, $n \in (0, s)$, and $f \in (s, 1]$. Parameters $\theta_T, \theta_N > 1$ are, respectively, the elasticity of substitution between brands in the tradable and nontradable sector. The prices of the nontradable intermediate goods are denoted as $p(n)$. Each firm x takes these prices as given when minimizing the production costs of the final good. The resulting demand for nontradable intermediate input n is

$$Q_{A,t}(n,x) = \left(\frac{1}{s}\right)\left(\frac{P_t(n)}{P_{N,t}}\right)^{-\theta_N} Q_{\mathrm{NA},t}(x), \tag{A.4}$$

where $P_{N,t}$ is the cost-minimizing price of one basket of local intermediates:

$$P_{N,t} = \left[\int_0^s P_t(n)^{1-\theta_N} dn \right]^{\frac{1}{1-\theta_N}}. \tag{A.5}$$

We can derive $Q_A(h,x)$, $Q_A(f,x)$, $C_A^g(h,x)$, $C_A^g(f,x)$, P_H, and P_F in a similar way. Firms y producing the final investment goods have similar demand curves. Aggregating over x and y, it can be shown that total demand for nontradable intermediate good n is

$$\int_0^s Q_{A,t}(n,x)\,dx + \int_0^s Q_{E,t}(n,y)\,dy + \int_0^s C_t^g(n,x)\,dx = \left(\frac{P_t(n)}{P_{N,t}}\right)^{-\theta_N} \left(Q_{\mathrm{NA},t} + Q_{\mathrm{NE},t} + C_{N,t}^g\right),$$

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where C_N^g is the nontradable component of public sector consumption. Home demand for Home and Foreign tradable intermediate goods can be derived in a similar way.

Supply. The supply of each Home nontradable intermediate good n is denoted by

$$N_t^S(n) = \left((1-\alpha_N)^{\frac{1}{\xi_N}} L_{N,t}(n)^{\frac{\xi_N-1}{\xi_N}} + \alpha^{\frac{1}{\xi_N}} K_{N,t}(n)^{\frac{\xi_N-1}{\xi_N}}\right)^{\frac{\xi_N}{\xi_N-1}}. \tag{A.6}$$

Firm n uses labor $L_{N,t}^p(n)$ and capital $K_{N,t}(n)$ with constant elasticity of input substitution $\xi_N > 0$ and capital weight $0 < \alpha_N < 1$. Firms producing intermediate goods take the prices of labor inputs and capital as given. Denoting by W_t the nominal wage index and by R_t^K the nominal rental price of capital, cost minimization implies that

$$L_{N,t}^p(n) = (1-\alpha_N)\left(\frac{W_t}{\mathrm{MC}_{N,t}(n)}\right)^{-\xi_N} N_t^S(n) \tag{A.7}$$

$$K_{N,t}(n) = \alpha\left(\frac{R_t^K}{\mathrm{MC}_{N,t}(n)}\right)^{-\xi_N} N_t^S(n)$$

where $\mathrm{MC}_{N,t}(n)$ is the nominal marginal cost:

$$\mathrm{MC}_{N,t}(n) = \left((1-\alpha)W_t^{1-\xi_N} + \alpha\left(R_t^K\right)^{1-\xi_N}\right)^{\frac{1}{1-\xi_N}}. \tag{A.8}$$

The production of each Home tradable good, $T^S(h)$, is similarly characterized.

Price setting in the intermediate sector. Consider now profit maximization in the Home country's nontradable intermediate sector. Each firm n sets the price $p_t(n)$ by maximizing the present discounted value of profits subject to demand constraint (A.6) and the quadratic adjustment costs:

$$\mathrm{AC}_{N,t}^p(n) \equiv \frac{\kappa_N^p}{2}\left(\frac{P_t(n)}{P_{t-1}(n)} - 1\right)^2 Q_{N,t} \quad \kappa_N^p \geq 0.$$

paid in unit of sectorial product $Q_{N,t}$ and where κ_N^p measures the degree of price stickiness. The resulting first-order condition, expressed in terms of domestic consumption, is

$$p_t(n) = \frac{\theta_N}{\theta_N - 1}\mathrm{mc}_t(n) - \frac{A_t(n)}{\theta_N - 1} \tag{A.9}$$

where $\mathrm{mc}_t(n)$ is the real marginal cost and $A(n)$ contains terms related to the presence of price adjustment costs:

$$A_t(n) \approx \kappa_N^p \frac{P_t(n)}{P_{t-1}(n)}\left(\frac{P_t(n)}{P_{t-1}(n)} - 1\right) - \beta\kappa_N^p \frac{P_{t+1}(n)}{P_t(n)}\left(\frac{P_{t+1}(n)}{P_t(n)} - 1\right)\frac{Q_{N,t+1}}{Q_{N,t}}.$$

These equations clarify the link between imperfect competition and nominal rigidities. As emphasized by Bayoumi et al.(2004), when the elasticity of substitution θ_N is very large and hence the competition in the sector is high, prices closely follow marginal costs, even though adjustment costs are large. To the contrary, it may be optimal to maintain stable

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prices and accommodate changes in demand through supply adjustments when the average markup over marginal costs is relatively high. If prices were flexible, optimal pricing would collapse to the standard pricing rule of constant markup over marginal costs (expressed in units of domestic consumption):

$$p_t(n) = \frac{\theta_N}{\theta_N - 1}\mathrm{mc}_{N,t}(n). \tag{A.10}$$

Firms operating in the intermediate tradable sector solve a similar problem. We assume that there is market segmentation. Hence the firm producing the brand h chooses $p_t(h)$ in the Home market and $p_t^*(h)$ in the Foreign market to maximize the expected flow of profits (in terms of domestic consumption units):

$$E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau}\left[p_\tau(h)\, y_\tau(h) + p_\tau^*(h)\, y_\tau^*(h) - \mathrm{mc}_{H,\tau}(h)\left(y_\tau(h) + y_\tau^*(h)\right)\right],$$

subject to quadratic price adjustment costs similar to those considered for nontradables and standard demand constraints. The term E_t denotes the expectation operator conditional on the information set at time t, $\Lambda_{t,\tau}$ is the appropriate discount rate, and $\mathrm{mc}_{H,t}(h)$ is the real marginal cost. The first-order conditions with respect to $p_t(h)$ and $p_t^*(h)$ are

$$p_t(h) = \frac{\theta_T}{\theta_T - 1}\mathrm{mc}_t(h) - \frac{A_t(h)}{\theta_T - 1}, \tag{A.11}$$

$$p_t^*(h) = \frac{\theta_T^*}{\theta_T - 1}\mathrm{mc}_t(h) - \frac{A_t^*(h)}{\theta_T - 1}, \tag{A.12}$$

where θ_T^* is the elasticity of substitution of tradable intermediate goods in the Foreign country, whereas $A(h)$ and $A^*(h)$ involve terms related to the presence of price adjustment costs:

$$A_t(h) \approx \kappa_H^p \frac{P_t(h)}{P_{t-1}(h)}\left(\frac{P_t(h)}{P_{t-1}(h)} - 1\right) - \beta\kappa_H^p \frac{P_{t+1}(h)}{P_t(h)}\left(\frac{P_{t+1}(h)}{P_t(h)} - 1\right)\frac{Q_{H,t+1}}{Q_{H,t}},$$

$$A_t^*(h) \approx \theta_T{}^* - 1 + \kappa_H^{p\,*} \frac{P_t^*(h)}{P_{t-1}^*(h)}\left(\frac{P_t^*(h)}{P_{t-1}^*(h)} - 1\right) - \beta\kappa_H^{p\,*} \frac{P_{t+1}^*(h)}{P_t^*(h)}\left(\frac{P_{t+1}^*(h)}{P_t^*(h)} - 1\right)\frac{Q_{H,t+1}^*}{Q_{H,t}^*},$$

where $\kappa_H^p > 0$ ($\kappa_H^{p\,*} > 0$) measures the degree of nominal rigidity in the Home (Foreign) country. If nominal rigidities in the (domestic) export market are highly relevant (that is, if is relatively large), the degree of inertia of Home goods prices in the Foreign market will be high. If prices were flexible ($\kappa_H^p = \kappa_H^{p\,*} = 0$) and $\theta_T = \theta_T^*$, then optimal price setting would be consistent with the cross-border law of one price:

$$p_t(h) = \frac{\theta_T}{\theta_T - 1}\mathrm{mc}_t(h) = p_t^*(h). \tag{A.13}$$

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A.3. LABOR MARKET

In the case of firms in the nontradable intermediate sector, the labor input $L_N(n)$ is a CES combination of differentiated labor inputs supplied by domestic agents and defined over a continuum of mass equal to the country size ($j \in [0, s]$):

$$L_{N,t}(n) \equiv \left(\frac{1}{s}\right)^{\frac{1}{\psi}} \left[\int_0^s L_t(n, j)^{\frac{\psi-1}{\psi}} dj\right]^{\frac{\psi}{\psi-1}}, \tag{A.14}$$

where $L(n, j)$ is the demand for the labor input of type j by the producer of good n and $\psi > 1$ is the elasticity of substitution among labor inputs. Cost minimization implies that

$$L_t^p(n, j) = \left(\frac{1}{s}\right)\left(\frac{W_t(j)}{W_t}\right)^{-\psi} L_{N,t}^p(j), \tag{A.15}$$

where $W(j)$ is the nominal wage of labor input j and the wage index W is

$$W_t = \left[\left(\frac{1}{s}\right)\int_0^s W_t(h)^{1-\psi} dj\right]^{\frac{1}{1-\psi}}. \tag{A.16}$$

Similar equations hold for firms producing intermediate tradable goods. Each household is the monopolistic supplier of a labor input j and sets the nominal wage facing a downward-sloping demand, obtained by aggregating demand across Home firms. The wage adjustment is sluggish because of quadratic costs paid in terms of the total wage bill:

$$\mathrm{AC}_t^W = \frac{\kappa_W}{2}\left(\frac{W_t}{W_{t-1}} - 1\right)^2 W_t L_t, \tag{A.17}$$

where the parameter $\kappa_W > 0$ measures the degree of nominal wage rigidity and L is the total amount of labor in the Home economy.

A.4. MONETARY POLICY

The monetary authority controls the short-term rate according to a Taylor rule of the form

$$\left(\frac{1+i_t}{1+i}\right) = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_i} \left(\Pi_{\mathrm{MU},t}\right)^{(1-\rho_i)\rho_\pi} \left(\frac{\mathrm{GDP}_{\mathrm{MU},t}}{\mathrm{GDP}_{\mathrm{MU},t-1}}\right)^{(1-\rho_i)\rho_{\mathrm{GDP}}}. \tag{A.18}$$

The parameter ρ_i ($0 < \rho_i < 1$) captures inertia in interest rate setting, whereas the parameters ρ_π and ρ_{GDP} are, respectively, the weights of the currency union's CPI inflation rate $\Pi_{\mathrm{MU},t}$ and GDP $\mathrm{GDP}_{\mathrm{MU},t}$. The CPI inflation rate is a geometric average of CPI inflation rates in the Home and Foreign country (respectively, Π_t and Π_t^*) with weights equal to the correspondent country size:

$$\Pi_{\mathrm{MU},t} \equiv (\Pi_t)^s \left(\Pi_t^*\right)^{1-s}. \tag{A.19}$$

The unionwide GDP is the sum of the Home and Foreign GDPs (respectively, GDP_t and GDP_t^*), both evaluated at the initial steady-state prices:

$$\mathrm{GDP}_{\mathrm{MU},t} \equiv \mathrm{GDP}_t + \mathrm{rer} \cdot \mathrm{GDP}_t^*, \tag{A.20}$$

where rer is the Home real exchange rate, defined as the ratio of RMU to Home consumer prices.

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