Scientific paper reporting the final results of the model specification, parameterization and calibration of model extended to multi-country setting

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Contents

Project Information Summary

Table 1: Project Information Summary

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Deliverable Documentation Sheet

Table 2: Deliverable Documentation Sheet

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Title	Scientific paper reporting the final results of the model specification, parameterization and calibration of model extended to multi-country setting
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Author(s)	Francesco Bianchi (Duke, CEPR, NBER), Diego Comin (Dartmouth, CEPR, NBER), Thilo Kind (LBS), Howard Kung (LBS, CEPR)
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Quality Control Assessment Sheet

Table 3: Quality Control Assessment Sheet

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V0.1	26.06.2017	First draft	author 1
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Executive Summary

This paper examines the impact of fiscal consolidations on economic recoveries through an endogenous technology margin in an open economy framework. We build and estimate a two-country model that features technology adoption, trade in goods, and capital flows from the transaction of sovereign bonds. To capture salient features of observed fiscal reforms implemented in the Eurozone, we model a rich fiscal sector in each country that includes, government expenditures, countercyclical fiscal rules for distortionary taxation of labor, capital, and consumption, in addition to subsidies to the adoption of new technologies. Fiscal stress generated by rising costs of government financing are captured through stochastic demand shocks on sovereign debt which allow the model to match the observed dynamics of sovereign bond spreads. We show that the austerity measures imposed in the Euro area in the presence of the high yields contributed to significantly slower recoveries in the aftermath of the recession due to the adverse effects on capital accumulation and technology adoption.

1 Introduction

The great recession has staged the tensions between two views on fiscal policy. The traditional Keynesian view advocated for expansionary fiscal policy to make up for the decline in aggregate demands. An opposite view advocated for contractionary fiscal policy in response to the increase in government deficits and sovereign bond spreads (See Figures 1 and 2). Proponents of fiscal austerity argued that the low productivity problems were as important for the downturn as aggregate demand and that structural reforms that alleviated these supply side problems could restore economic activity.

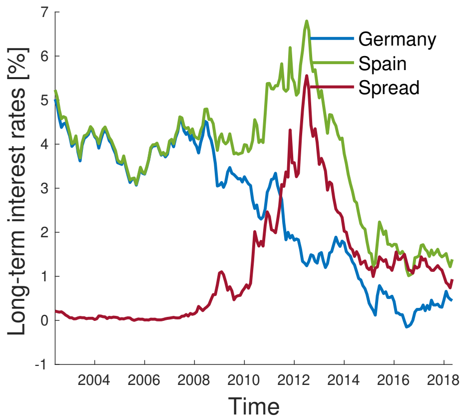

Figure 1: Long-term interest rates of Germany and Spain, as well as their difference in annualized percentage points.

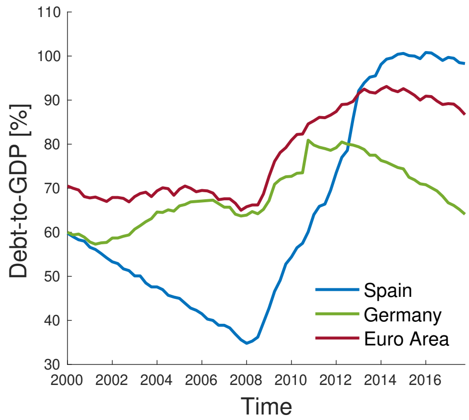

Figure 2: The ratio of government debt to the gross domestic product.

These divergent views on fiscal policy were reflected by the implementation of different fiscal policies across countries. As illustrated in Figure 3, countries in the euro area adopted a more austere fiscal policy than the US. Some have argued that this difference in fiscal policy explains the faster recovery experienced by the US economy.

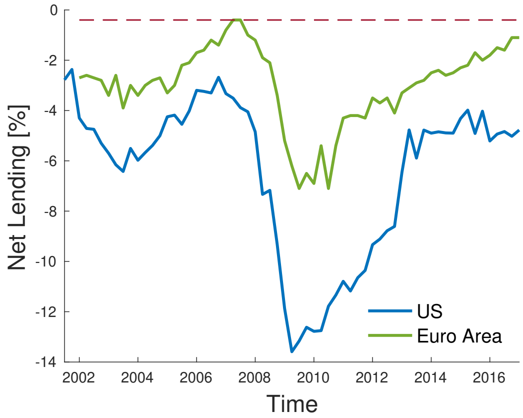

Figure 3: The government's net lending as a fraction of the gross domestic product.

Any exercise that aims at accurately evaluate alternative fiscal policies needs to rely on a rich enough model that captures two elements that we consider key. First, the interconnections between national economies which are both deep and widespread in the euro area. Second, the inter-relation between business cycle conditions and the current and future productive capacity of the economy.

The goal of this paper is to develop a setting that captures these key components and to use it to evaluate the impact of a rich array of fiscal policies in the euro area during the great recession. Our framework contains two open economies that interact through international trade and capital flows derived from the transaction of sovereign bonds. Financial rigidities are introduced through a stochastic cost to the acquisition of government bonds which results in time-varying bond spreads across countries. The world technology frontier grows at a stochastic rate, but domestic productivity is determined by the endogenous range of technologies adopted by producers. The adoption margin connects local supply conditions to local and foreign economic and financial conditions. A rich set of fiscal details that include explicit fiscal policy rules for tax rates, government expenditures and transfers, and distortionary taxation of labor income, capital, consumption, as well as subsidies to the adoption of new technologies. Finally, we envision one economy to be more efficient in the adoption of new technologies and, as a result, closer to the technological frontier. In Europe, it is reasonable to think about Germany as the country closer to the technological frontier with respect to countries in southern Europe, such as Spain. In what follows, we think about Spain as the domestic country, and Germany the foreign country.

We use a calibration to explore the properties of the model. We differentiate between three types of parameters. (i) standard parameters in macro DSGE models, (ii) parameters related to the innovation process and (iii) parameters related to international trade. For the first group, we draw information from WP1, that covers a literature survey on DSGE models. We use WP6 as guidance for the parameters related that characterize innovation activities. To calibrate the parameters related to international trade, we refer to the literature on open economies in a DSGE setting.

Our key findings are as follows. We consider the effects of a financial shock that makes the cost of financing domestic debt larger. This shock can be thought as a change in the risk appetite of international investors. We call this shock domestic liquidity demand shock. We compare the effects of robust and non-robust fiscal policies to a domestic financial shock. The robust fiscal policy rule reacts aggressively to an increase debt-to-GDP ratio, and as a result the government's increase in taxes is more pronounced. As a result of the higher taxes, the adoption rate declines more under the robust rule leading to a significantly larger decline in GDP over the medium term. This suggests that an aggressive fiscal consolidation can have unwanted consequences in the long run. For a given fiscal stance, we also compare the effects of using different distortionary tax instruments after. In particular, we consider taxes to capital, consumption and labor that yield similar levels of debt-to-GDP ratio after 25 years. We find that labor income tax leads to the most severe recessions, while capital taxes lead to the least severe recessions.

We then extend the model to consider the realistic possibility that the cost of financing depends on the level of debt. In this case, a trade-off arises. On the one hand, fiscal consolidations reduce the fiscal burden and the cost of financing debt. This has beneficial effects on adoption. On the other hand, the increase in distortionary taxation can also lead to a large reduction in adoption. Thus, our results show that the long-run effects of fiscal consolidations vary significantly depending on the fiscal instrument used by policymakers. This results echoes similar results in the empirical literature, but it brings a new dimension to the debate, given the focus on the long run consequences of fiscal interventions.

Interestingly, we find that for realistic parameter values, a domestic recession caused by a liquidity demand shock also affects negatively the foreign country. In particular, we observe a drop in foreign consumption and investment s well as in the rate of technology adoption. This is because the contraction in demand in the domestic country also reduces real activity in the foreign country. Given that adoption depends on the state of the economy, a recession in the domestic country has long run consequences for the foreign country.

The rest of the paper is organized as follows. Section 1.1 presents the related literature. Section 2 develops the model. Section 3 conducts a quantitative evaluation of the fiscal policy responses to liquidity demand shocks and section 4 concludes.

2 Related Literature

The endogenous technology growth margin in this paper builds on Comin and Gertler (2006), Comin et al. (2009), Comin and Hobijn (2004), Comin et al. (2014), Anzoategui et al. (2016), Bianchi et al. (2018). These papers show that this margin provides a strong growth propagation mechanism for explaining medium-term fluctuations in the macroeconomy. We differ from these papers by considering an open economy setting with a rich fiscal sector. We feature this margin to quantitatively assess the impact of various fiscal reforms implemented in the Euro zone at lower-than-business-cycle frequencies.

The two-country open economy framework with trade in goods and financial assets builds on Heathcote and Perri (2002) and Heathcote and Perri (2013). We distinguish ourselves from this work by incorporating the endogenous technology margin to reconcile the slow recoveries experienced in the euro area. Also we model rich fiscal rules to capture salient features of the fiscal reforms.

Our paper also relates to papers examining fiscal consolidations. These papers present a broad range of results. For example, Alesina and Perotti (1997) and Alesina and Ardagna (2010) find that fiscal consolidations can be expansionary, especially if implemented with a reduction in spending, while Guajardo et al. (2014) reach the opposite conclusion. Given that we analyze the spillover effects of fiscal consolidations in an open economy setting, our work connects with the literature on fiscal consolidations in open economy DSGE models (e.g., Erceg and Lindé (2012)). More broadly, our paper connects to the literature that studies fiscal policy in a DSGE setting, such as Zubairy (2014) and Leeper et al. (2010). Our paper complements but differs from this literature by featuring the endogenous technology margin, which allows us to consider the medium- and long-run effects of fiscal consolidations that are relevant for addressing the slow recoveries observed in the euro area that implemented more austere measures compared to the US in the aftermath of the Great Recession.

3 A Two Country Model

The model consists of two open economies which the variables are denoted as (X_t, X_t^*). The final goods are produced competitively and is tradable between both countries. The differentiated intermediate goods are produced by a monopolist and non-tradable, while all prices are denoted in the same currency. A representative agent consumes a consumption index, consisting of the final goods of each country. The household owns the domestic capital, all domestic firms, and holds a portfolio of domestic and foreign government bonds. Besides issuing bonds, the government finances expenditures through distortionary taxes to labor income, capital income, and on consumption goods, in addition to lump-sum transfers. Further, there is an exogenously evolving world technology frontier. Firms of each country independently invest to adopt technology using the final goods such that the intermediate goods variety for producing the final good expands. Furthermore, markets are incomplete and only non-state-contingent government bonds are traded. We describe the set of equations for the home country, however, the foreign country's problem is characterized in the same way.

3.1 Representative Household

The household's preferences over the consumption goods index $\mathcal{C}_t$, and total labor supply L_t are given by

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{\mathcal{C}_t^{1-\sigma}}{1-\sigma} - \varphi_0 Z_t^{1-\sigma} \frac{{L_t}^{1+\varphi}}{1+\varphi} \right) \right] \tag{1}$$

$$\tag{2}$$

$$\mathcal{C}_t = \left((1-\upsilon)^{\frac{1}{\eta}} (C_{Ht})^{\frac{\eta-1}{\eta}} + \upsilon^{\frac{1}{\eta}} (C_{Ft})^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{3}$$

$$\mathcal{P}_t = \left((1-\upsilon) (P_{Ht})^{1-\eta} + \upsilon (P_{Ft})^{1-\eta} \right)^{\frac{1}{1-\eta}}, \tag{4}$$

where we scale the disutility of labor by the level of the world technological frontier Z_t[1]. Here, the representative household accumulates the capital stock K_t according to:

$$K_{t+1} = (1-\delta) K_t + I_t \left[1 - \Psi \left(\iota_t \frac{I_t}{I_{t-1}} \right) \right] \tag{5}$$

$$\log \iota_t = \rho_\iota \log \iota_{t-1} + \sigma_\iota \varepsilon_t^\iota, \tag{6}$$

where the convex function Ψ has the property that $\Psi(\cdot)_{|ss} = \Psi'(\cdot)_{|ss} = 0$ and ι_t is a mean one shock to the marginal efficiency to investment. Then, the household's budget constraint reads

$$(1+\tau_t^c) \mathcal{P}_t \mathcal{C}_t = \left(1-\tau_t^l\right) W_t L_t + \Omega_t + \left(1-\tau_t^k\right) R_{kt} K_t - P_{Ht} I_t + T_t \tag{7}$$

$$- \mathcal{P}_t \left((\kappa_{Ht} + \eta_{Ht} B_{Ht}) B_{Ht} - R^r_{B,t-1} B_{Ht-1} \right) \tag{8}$$

$$- \mathcal{P}_t^* \left((\kappa_{Ft} + \eta_{Ft} B_{Ft}) B_{Ft} - R^{r*}_{B,t-1} B_{Ft-1} \right), \tag{9}$$

where R^r_{Bt} is the return on a government bond and R_{kt} is the return on physical capital. Ω_t represents the total domestic profits[2] and T_t are the lump-sum transfers from the government. τ_t^l and τ_t^k are tax rates on labor income and capital income, whereas τ_t^c is the domestic tax rate on consumption goods of domestic and foreign goods. In addition, the household pays a fee $\kappa_{Ht} + \eta_{Ht} B_{Ht} - 1$ per unit of bond traded[3]. The corresponding first order conditions with respect to domestic and foreign bonds are

[1] The corresponding demand functions for the domestic and foreign final good are $C_{Ht} = (1-\upsilon)(P_{Ht}/\mathcal{P}_t)^{-\eta} \mathcal{C}_t$ and $C_{Ft} = \upsilon (P_{Ft}/\mathcal{P}_t)^{-\eta} \mathcal{C}_t$.

[2] $\Omega_t = \Omega_{At} + \Omega_{Bt}$ where Ω_{At} are firms' profits. Implicitly, Ω_{At} in the consumer's budget constraint accounts for when a new technology is developed; consumers must pay J to get the option to adopt it. Then, after successfully investing in adoption, the technology's value becomes V. Ω_{Bt} are the total trading fees on the domestic government bond payed by the domestic and foreign household.

[3] For constant coefficients, this specification can be mapped to Benigno (2009) or Ghironi, Lee, Rebucci (2006). There, a quadratic cost in changes in the real asset position when trading in the foreign bond market is incurred. The cost of moving the holdings of foreign assets serves for the purpose of determining the steady-state value of the foreign-asset position

$$1+\underbrace{2\frac{\eta_{Ht}}{\kappa_{Ht}}}_{\equiv(\tilde{\eta}_{Ht}-\bar{\eta}_H)/Z_t}B_{Ht}=\frac{R^r_{B,t}}{\kappa_{Ht}}\mathbb{E}_t\left[\Lambda_{t,t+1}\left(\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\right)\right] \tag{10}$$

$$1+\frac{(\tilde{\eta}_{Ft}-\bar{\eta}_F)}{Z_t}B_{Ft}=\frac{R^{r*}_{B,t}}{\kappa_{Ft}}\mathbb{E}_t\left[\Lambda_{t,t+1}\left(\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\right)\left(\frac{\mathcal{Q}_t}{\mathcal{Q}_{t+1}}\right)\right] \tag{11}$$

where $\mathcal{Q}_t=\frac{\mathcal{P}_t}{\mathcal{P}^*_t}$ is the real exchange rate between the two countries and $\Lambda_{t,t+1}=\beta\left(\frac{\mathcal{C}_{t+1}}{\mathcal{C}_t}\right)^{-\sigma}$ is the real stochastic discount factor. We model the trading costs, κ_t and $\tilde{\eta}_t$, in reduced-form according to

$$\log\kappa_t=(1-\rho_\kappa)\,\bar{\kappa}+\rho_\kappa\log\kappa_{t-1}+\sigma_\kappa\varepsilon^\kappa_t \tag{12}$$

$$\log\tilde{\eta}_t=(1-\rho_{\tilde{\eta}})\,\bar{\tilde{\eta}}+\rho_{\tilde{\eta}}\log\tilde{\eta}_{t-1}+\sigma_{\tilde{\eta}}\varepsilon^{\tilde{\eta}}_t. \tag{13}$$

The spread between the two countries is given by

$$R^r_{B,t}-R^{r*}_{B,t}=\frac{\kappa_{Ht}+\kappa_{Ht}\left(\tilde{\eta}_{Ht}-\bar{\eta}_H\right)B_{Ht}}{\mathbb{E}_t\left[\Lambda_{t,t+1}\left(\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\right)\right]}-\frac{\kappa_{Ft}+\kappa_{Ft}\left(\tilde{\eta}_{Ft}-\bar{\eta}_F\right)B_{Ft}}{\mathbb{E}_t\left[\Lambda_{t,t+1}\left(\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\right)\left(\frac{\mathcal{Q}_t}{\mathcal{Q}_{t+1}}\right)\right]} \tag{14}$$

Other optimality conditions for labor supply, investment, and the return on capital are

$$Z_t^{1-\sigma}\varphi_0\mathcal{C}_t^\sigma L_t^\varphi=\left(\frac{1-\tau^l_t}{1+\tau^c_t}\right)\frac{W_t}{\mathcal{P}_t} \tag{15}$$

$$\frac{P_{Ht}}{\mathcal{P}_t}\frac{\mathcal{C}_t^{-\sigma}}{(1+\tau^c_t)}=\mu_t\left(1-\iota_t\frac{I_t}{I_{t-1}}\Psi'(\cdot)-\Psi\left(\frac{I_t}{I_{t-1}}\right)\right)+\beta\mathbb{E}_t\left[\mu_{t+1}\iota_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2\Psi'(\cdot)\right] \tag{16}$$

$$\mu_t=\beta\mathbb{E}_t\left[\mu_{t+1}(1-\delta)+\frac{\mathcal{C}_t^{-\sigma}}{\mathcal{P}_{t+1}}\left(\frac{1-\tau^k_{t+1}}{1+\tau^c_{t+1}}\right)R_{kt+1}\right] \tag{17}$$

where μ_t is the Lagrange multiplier on the capital accumulation equation.

3.2 Final Good

The competitive final good producer faces a constant elasticity production function which nests all differentiated domestic goods

$$Y_{Ht}=\left(\int_0^{A_t}\left(Y_t(j)\right)^{\frac{\varepsilon-1}{\varepsilon}}dj\right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{18}$$

$$P_{Ht}=\left(\int_0^{A_t}\left(P_t(j)\right)^{1-\varepsilon}dj\right)^{\frac{1}{1-\varepsilon}} \tag{19}$$

and the corresponding demand function reads

$$Y_t(j)=\left(\frac{P_t(j)}{P_{Ht}}\right)^{-\varepsilon}Y_{Ht} \tag{20}$$

3.3 Intermediate Goods

Each differentiated domestic good $j \in [0, A_t]$ is produced by a monopolist that uses labor and capital as factor inputs subject to the demand function of the final good producer in each country. The production technology of monopolist j is characterized by

$$Y_t(j) = \xi_t (K_t(j))^{\alpha} (L_t(j))^{1-\alpha} \tag{21}$$

$$\log \xi_t = \rho_\xi \log \xi_{t-1} + \sigma_\xi \varepsilon_t^\xi \tag{22}$$

where ξ_t is the stationary productivity process for the intermediate production technology. Using profit maximization, the optimality conditions read

$$W_t = \frac{\epsilon - 1}{\epsilon} P_t(j)(1-\alpha)\frac{Y_t(j)}{L_t(j)} \tag{23}$$

$$R_{kt} = \frac{\epsilon - 1}{\epsilon} P_t(j)\,\alpha \frac{Y_t(j)}{K_t(j)} \tag{24}$$

$$\pi_t(j) = \frac{1}{\epsilon} P_t(j)\, Y_t(j) \tag{25}$$

3.4 Technology

As in Comin et al. (2009), the world technological frontier, Z_t, evolves exogenously and according to

$$Z_{t+1} = \left(\bar{\chi}\chi_t^{\zeta} + \phi\right) Z_t \tag{26}$$

$$\log(\chi_t) = \rho_\chi \log(\chi_{t-1}) + \sigma_\chi \varepsilon_t^\chi \tag{27}$$

An adoption firm k tries to make a technology $k \in Z_t \cap A_t$ usable by investing the final domestic good. The firm is owned by the domestic representative household and can sell the adopted technology on the open market. Let $J_t(k)$ be the value of an unadopted innovation. Then, the optimization problem and the corresponding optimality conditions read

$$J_t(k) = \max_{H_t(k)} \mathbb{E}_t \left\{ -P_{Ht} H_t(k) + \phi \Lambda_{t,t+1} \frac{\mathcal{P}_t}{\mathcal{P}_{t+1}} \left[\lambda_t(k) V_{t+1}(k) + (1-\lambda_t(k)) J_{t+1}(k)\right] \right\} \tag{28}$$

$$P_{Ht} = \rho_\lambda \frac{\lambda_t(k)}{H_t(k)} \phi \mathbb{E}_t \left\{ \Lambda_{t,t+1} \frac{\mathcal{P}_t}{\mathcal{P}_{t+1}} (V_{t+1}(k) - J_{t+1}(k)) \right\} \tag{29}$$

$$V_t(k) = \pi_t(k) + \phi \mathbb{E}_t \left\{ \Lambda_{t,t+1} \frac{\mathcal{P}_t}{\mathcal{P}_{t+1}} V_{t+1}(k) \right\} \tag{30}$$

$$\lambda_t(k) = \bar{\lambda} (F_t H_t(k))^{\rho_\lambda} \tag{31}$$

$$F_t = \frac{Z_t}{K_t}. \tag{32}$$

where $\Lambda_{t,t+1}$ is the real stochastic discount factor. Given that the solution is symmetric, the total cost of adoption and the time evolution of adopted technologies is given by

$$H_t^T = H_t(Z_t - A_t) \tag{33}$$

$$A_{t+1} = \lambda_t \phi [Z_t - A_t] + \phi A_t \tag{34}$$

3.5 Government

The government finances expenditures, G_t, by issuing real bonds (to domestic and foreign investors), lump-sum transfers, and taxes on consumption, labor, and capital income:

$$\frac{P_{Ht}}{\mathcal{P}_t}G_t = B_t - R^r_{Bt-1}B_{t-1} + \tau^l_t W^r_t L_t - T^r_t + \tau^c_t \mathcal{C}_t + \tau^k_t R^r_{kt} K_t, \tag{35}$$

where R^r_{Bt} is the real interest rate on real government bond holdings. We model the fiscal policy rules for expenditures, tax rates, and transfers as in Leeper et al. (2010). Their log-deviations from the steady state follow

$$\hat{u}^x_t = \rho_x \hat{u}^x_{t-1} + \sigma_x \varepsilon^x_t, \quad x \in \{g, l, c, k, T\} \tag{36}$$
$$\hat{G}_t = -\varphi_g \hat{Y}^{HW}_{Ht} - \zeta_g \hat{b}_{t-1} + \hat{u}^g_t \tag{37}$$
$$\hat{T}_t = -\varphi_T \hat{Y}^{HW}_{Ht} - \zeta_T \hat{b}_{t-1} + \hat{u}^T_t \tag{38}$$
$$\hat{\tau}^k_t = \varphi_k \hat{Y}^{HW}_{Ht} + \zeta_k \hat{b}_{t-1} + \varphi_{kl}\hat{u}^l_t + \varphi_{kc}\hat{u}^c_t + \hat{u}^k_t \tag{39}$$
$$\hat{\tau}^l_t = \varphi_l \hat{Y}^{HW}_{Ht} + \zeta_l \hat{b}_{t-1} + \varphi_{lk}\hat{u}^k_t + \varphi_{lc}\hat{u}^c_t + \hat{u}^l_t \tag{40}$$
$$\hat{\tau}^c_t = \varphi_c \hat{Y}^{HW}_{Ht} + \zeta_c \hat{b}_{t-1} + \varphi_{ck}\hat{u}^k_t + \varphi_{cl}\hat{u}^l_t + \hat{u}^c_t. \tag{41}$$

The government reacts to the log-output gap which is smoothed by the Holt-Winters filter and to the previous deviation from the non-stochastic steady state of the log Debt-to-GDP ratio $\hat{b}_{t-1}$:

$$\log Y^{HW}_{Ht} = \tau^g_{HW} \log Y^{HW}_{Ht-1} + (1 - \tau^g_{HW})(\log Y_{Ht} - \log Y_{Hss}) \tag{42}$$
$$\hat{B}_{t-1} = \log\left(\frac{\mathcal{P}_{t-1}B_{t-1}}{P_{Ht-1}Y_{Ht-1}}\right) - \log\left(\frac{\mathcal{P}_{ss}B_{ss}}{P_{Hss}Y_{Hss}}\right) \tag{43}$$

3.6 Resource Constraints

$$\underbrace{P_{Ft}C_{Ft} - P_{Ht}C^*_{Ft}}_{-\mathrm{NX}_t} = \mathcal{P}_t\left(B^*_{Ft} - R^r_{Bt-1}B^*_{Ft-1}\right) - \mathcal{P}^*_t\left(B_{Ft} - R^{r*}_{B,t-1}B_{Ft-1}\right) \tag{44}$$
$$- \mathcal{P}^*_t\left(\left(\kappa_{Ft} + \eta_{Ft}B_{Ft} - 1\right)B_{Ft} - \frac{\mathcal{P}_t}{\mathcal{P}^*_t}\left(\kappa^*_{Ft} + \eta^*_{Ft}B^*_{Ft} - 1\right)B^*_{Ft}\right) \tag{45}$$
$$Y_{Ht} = C_{Ht} + C^*_{Ft} + H^T_t + I_t + G_t \tag{46}$$
$$B_t = B_{Ht} + B^*_{Ft} \tag{47}$$
$$L_t = \int_0^{A_t} L_t(j)\,dj \tag{48}$$
$$K_t = \int_0^{A_t} K_t(j)\,dj \tag{49}$$

3.7 International Identities

The terms-of-trade is defined as the price ratio of imported to exported goods of the home country. The real exchange rate is defined as the price ratio of the two price indices.

$$\mathcal{S}_t = \frac{P_{Ft}}{P_{Ht}} = \frac{P^*_{Ht}}{P_{Ht}} \tag{50}$$

$$\mathcal{Q}_t = \frac{\mathcal{P}_t}{\mathcal{P}^*_t} \tag{51}$$

Competition in the final sector insures that the law of one price holds for the tradable goods, i.e.

$$P_{Ft} = P^*_{Ht} \tag{52}$$

$$P_{Ht} = P^*_{Ft} \tag{53}$$

4 Results

In this section, we analyze the responses to fiscal stress under different regimes. First, we highlight the transmission of a financial shock in a model with adoption and the effect of different tax policies. We then examine the response to a deficit shock when investors believe that the default probability of government bonds depends on the level of debt.

4.1 Financial Shock

Technology Adoption

We show the transmission of a liquidity shock to bonds issued by the home country over a horizon of 25 years. Figure 4 plots the impulse response functions for government Debt-to-GDP, the interest rate spread between the two countries, adoption probability, physical investment, GDP, and consumption of the home country. The IRFs compare an economy with and without adoption, holding everything else equal. While the effect on fiscal distress is small, the endogenous adoption margin amplifies the dynamics of the macroeconomic variables, particularly at medium-term frequencies. Adoption-related investment activities decrease with respect to a liquidity shock which ultimately leads to a deeper and longer recession. Capital investment, GDP, and consumption all decline more strongly and persistently with endogenous technology adoption.

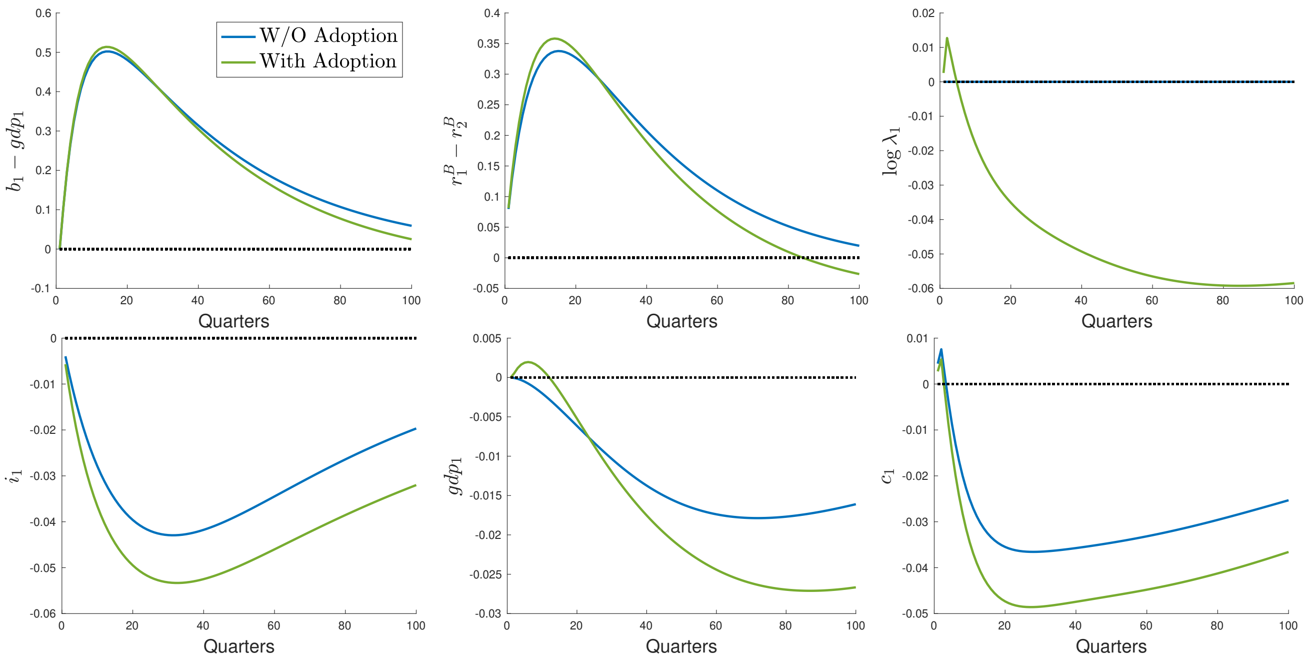

Figure 4: Home country's impulse response functions to a liquidity shock to bonds issued by the home country: Debt-to-GDP, Spread, Adoption, Investment, GDP, and Consumption.

Fiscal Robustness

Figure 5 compares two different government responses to a liquidity shock to the home country. The robust fiscal policy rule reacts aggressively to an increase in the Debt-to-GDP ratio. The government's increase in taxes is more pronounced in the robust case. In contrast, the non robust fiscal policy government increases taxes only slightly. Crucially, figure 5 highlights the potential cost of a tight fiscal policy in the light of endogenous technology adoption. A strong fiscal reaction to fiscal distress leads to a strong and persistent decline in GDP.

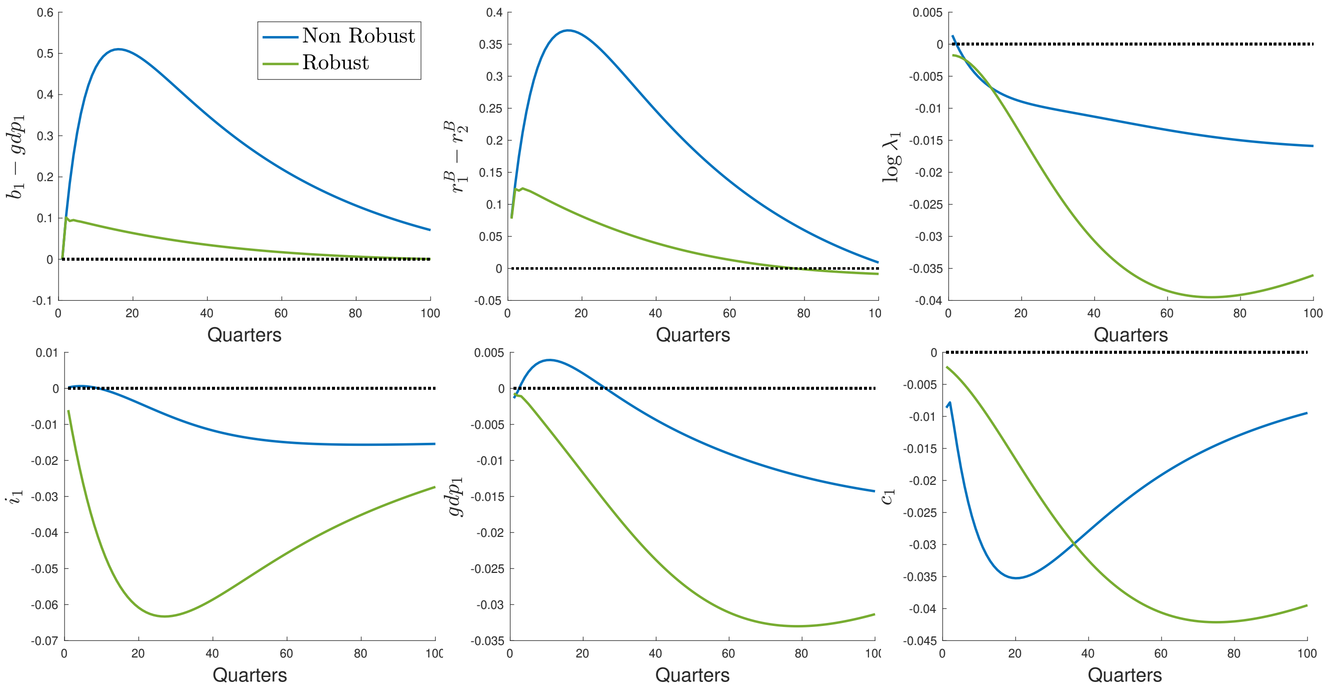

Figure 5: Home country's impulse response functions to a liquidity shock to bonds issued by the home country: Debt-to-GDP, Spread, Adoption, Investment, GDP, and Consumption.

Taxation

We compare different government tax instruments. Figure 6 shows the home country's impulse response functions to a liquidity shock to bonds issued by the home country for various tax policies. We compare three different regimes in which the government stabilizes debt by either raising capital tax, consumption tax, or labor tax. Each of those instruments distorts the optimal equilibrium outcome. However, labor tax has the strongest effect and leads to the most severe recession as it distorts the household's optimal consumption leisure decision. Capital tax on the other hand, which distorts the optimal investment decision of the household, has the most moderate effect on macroeconomic dynamics. Further, figure 7 shows that the foreign country is adversely affected by a liquidity shock to the home country. Similarly, the two key ingredients, adoption in conjunction with different fiscal policy instruments, have strong effects on growth. It indicates that not only the response to fiscal stress in the first country is important. In perspective, Germany's fiscal choice to a reaction to financial distress in Spain has also strong implications on macroeconomic fluctuations in Germany.

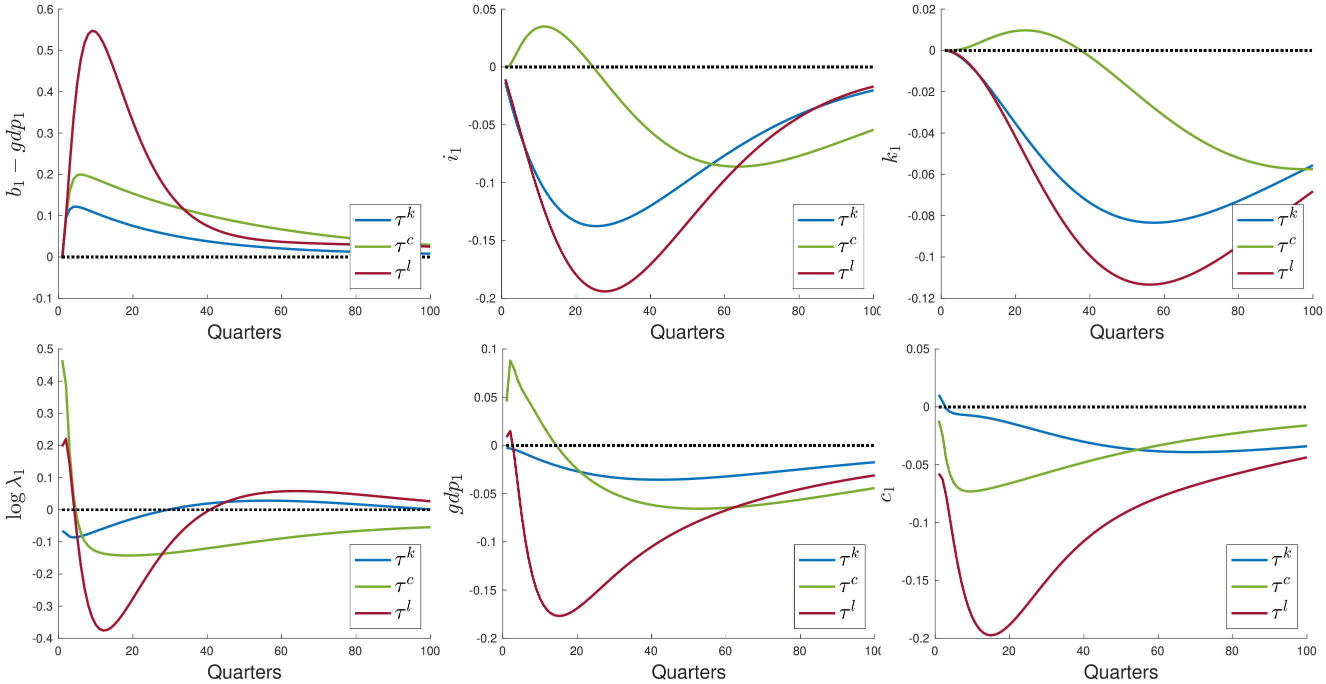

Figure 6: Home country's impulse response functions to a liquidity shock to bonds issued by the home country: Debt-to-GDP, Spread, Adoption, Investment, GDP, and Consumption.

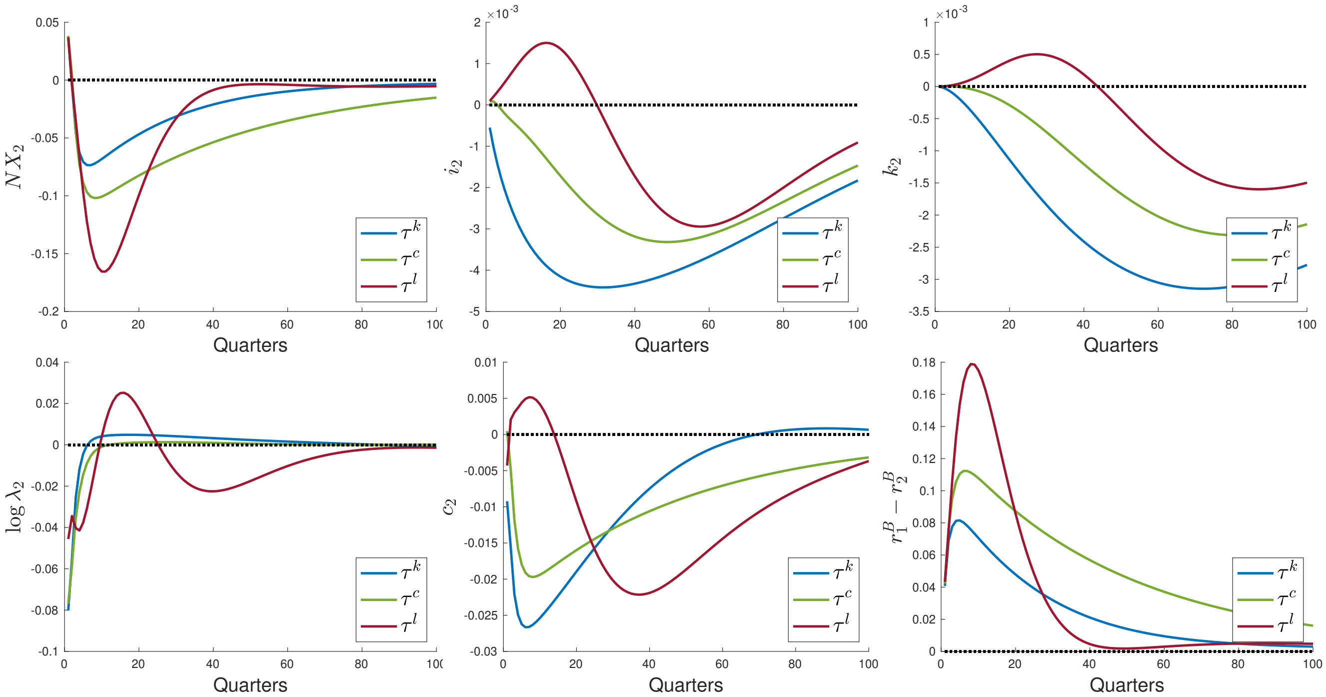

Figure 7: Foreign country's impulse response functions to a liquidity shock to bonds issued by the home country: Net-Exports, Investment, Capital, Adoption, Consumption, and the spread.

4.2 Fiscal Uncertainty

This section investigates the effects of fiscal uncertainty that arises with an increase in the Debt-to-GDP level. A high level of debt can create ambiguity about a country's ability to repay its obligations. In anticipation, investors rebalance their portfolio to the safer sovereign bonds. As a consequence, the spread between a high level debt and low level debt country increases. First, we show that when interest rates respond to the level of debt, a deficit shock is more severe. And second, we show that fiscal austerity in response to a deficit shock can be beneficial to mitigate the effects of the increased spread.

Flight to Safety

Figure 8 shows the response to a one time lump sum taxation shock to country one under two different scenarios. In the case of fiscal uncertainty, the interest rate of the government bond depends on the level of debt which reflects the investors' flight-to-safety behavior, i.e. investors command higher interest rates to hold sovereign bonds that are associated with higher level of debt as they believe that it reflects information about the country's ability to repay its debt. The second scenario abstracts from the direct uncertainty channel, however, spreads are still effected through the quadratic trading fees that depend on total debt outstanding. Nevertheless, the exercise highlights the potential costs of high level of debt if one accounts for the direct link to the investors' perceived risk of default.

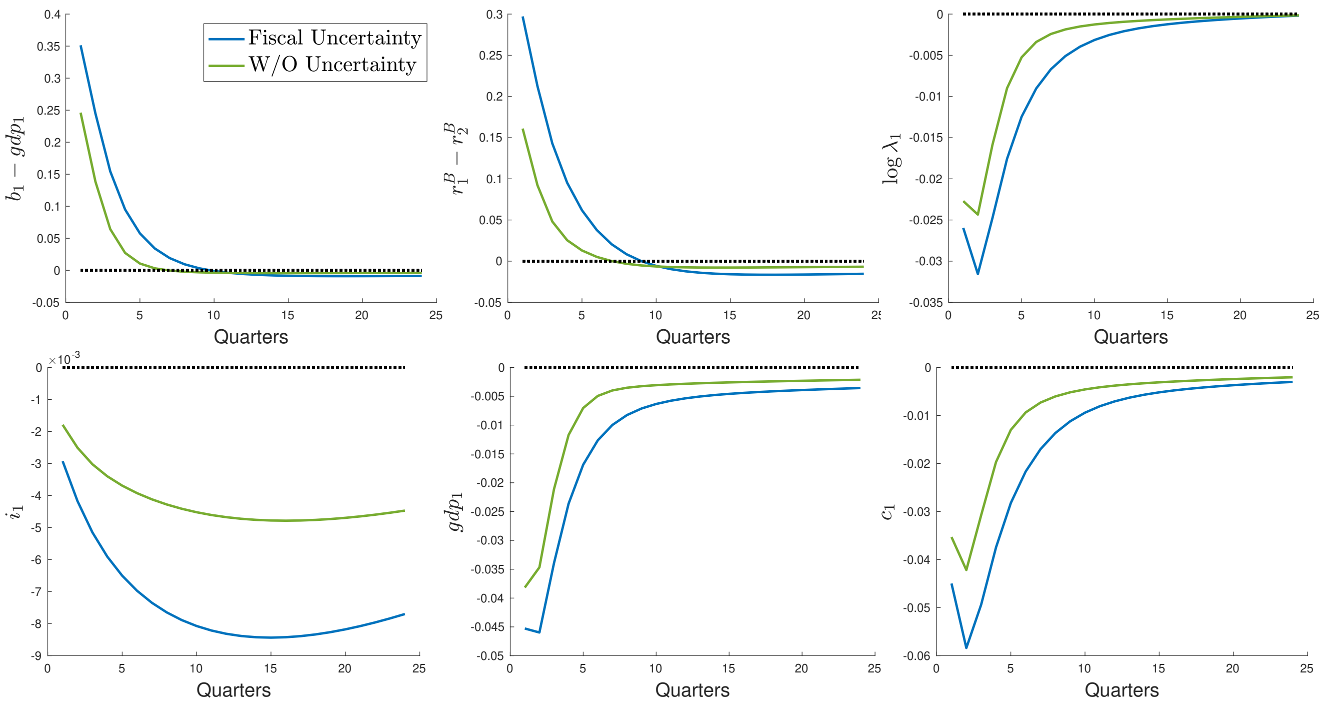

Figure 8: Home country's impulse response functions to a lump sum taxation one time shock that increases the Debt-to-GDP level: Debt-to-GDP, Spread, Adoption, Investment, GDP, and Consumption.

Fiscal Robustness

Figure 9 shows the response to a one time lump sum taxation shock to country one where the interest rates of government bonds depends on the level of debt. Here, we compare two different fiscal policy regimes. Policy one (non-robust) raises taxes less aggressive than policy two (robust). Usually, an increase in distortionary taxes is associated with prolonged recovery periods. However, raising taxes now mitigates the additional fiscal uncertainty channel, and as a consequence, spreads increase less in a regime with tighter fiscal policy. As a result, fiscal austerity can lead to a quicker recovery.

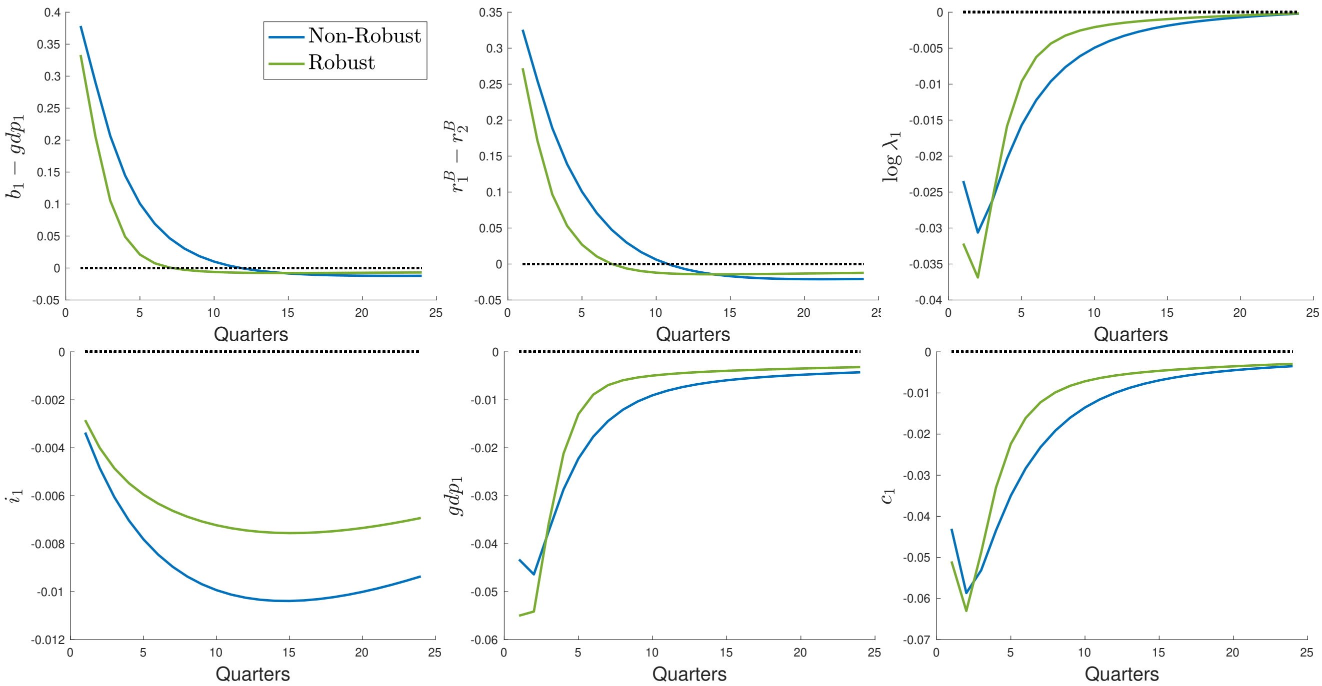

Figure 9: Home country's impulse response functions to a lump sum taxation one time shock that increases the Debt-to-GDP level: Debt-to-GDP, Spread, Adoption, Investment, GDP, and Consumption.

5 Conclusion

This paper builds a quantitative two-country model that features rich fiscal sectors and endogenous technology adoption that allows us to shed light on the debate regarding fiscal austerity measures implemented in the Euro area following the Global Recession. A novel dimension of our model is that the endogenous technology margin allows us to link fiscal policy to medium- and low-frequency macroeconomic dynamics. As such, our model is able to provide an explanation for the slow recoveries experienced in the Eurozone. In particular, we find that in the presence of fiscal stress – captured through high government financing costs from observed sovereign spreads – austerity measures generate large and persistent contractions in capital accumulation and technology adoption, which subsequently lead to slow recoveries. However, in the presence of fiscal uncertainty, a robust tax policy can counter high interest spreads between countries and lead to faster recoveries. The interconnectedness of countries through trade in goods and financial assets lead to strong spillover effects of such fiscal reforms and financial shocks.

A Real Symmetric Conditions

- Exogenous processes

$$Z_{t+1} = \left(\bar{\chi}\chi_t^{\zeta} + \phi\right) Z_t \tag{54}$$
$$\log\left(\chi_t\right) = \rho_\chi \log\left(\chi_{t-1}\right) + \sigma_\chi \varepsilon_t^\chi \tag{55}$$
$$\log \kappa_t = \left(1-\rho_\kappa\right)\bar{\kappa} + \rho_\kappa \log \kappa_{t-1} + \sigma_\kappa \varepsilon_t^\kappa \tag{56}$$
$$\log \tilde{\eta}_t = \left(1-\rho_{\tilde{\eta}}\right)\bar{\tilde{\eta}} + \rho_{\tilde{\eta}} \log \tilde{\eta}_{t-1} + \sigma_{\tilde{\eta}} \varepsilon_t^{\tilde{\eta}} \tag{57}$$
$$\log \xi_t = \rho_\xi \log \xi_{t-1} + \sigma_\xi \varepsilon_t^\xi \tag{58}$$
$$\log \iota_t = \rho_\iota \log \iota_{t-1} + \sigma_\iota \varepsilon_t^\iota \tag{59}$$
$$\varsigma_t = \varsigma_0 + \varsigma_1\left(\hat{b}_t - \bar{\hat{b}}\right) + \sigma_\varsigma \varepsilon_t^\varsigma \tag{60}$$
$$\hat{u}_t^x = \rho_x \hat{u}_{t-1}^x + \sigma_x \varepsilon_t^x, \quad x \in \{g, l, c, k, T\} \tag{61}$$

- Price relations

$$\frac{\mathcal{P}_t}{P_{Ht}} = \left(\left(1-\upsilon\right) + \upsilon\left(\mathcal{S}_t\right)^{1-\eta}\right)^{\frac{1}{1-\eta}} \equiv h\left(\mathcal{S}_t\right) \tag{62}$$
$$\frac{\mathcal{P}_t}{P_{Ft}} = \frac{h\left(\mathcal{S}_t\right)}{\mathcal{S}_t} \tag{63}$$
$$\mathcal{Q}_t = \frac{\mathcal{P}_t}{\mathcal{P}_t^*} = \frac{\mathcal{P}_t}{P_{Ht}}\frac{P_{Ht}}{\mathcal{P}_t^*} = \frac{\mathcal{P}_t}{P_{Ht}}\frac{P_{Ht}}{P_{Ft}}\frac{P_{Ft}}{\mathcal{P}_t^*} = \frac{1}{\mathcal{S}_t}\frac{h\left(\mathcal{S}_t\right)}{f\left(\mathcal{S}_t\right)} \tag{64}$$
$$\mathcal{S}_t = \frac{P_{Ft}}{P_{Ht}} = \frac{P_{Ht}^*}{P_{Ht}} \tag{65}$$
$$P_{Ft} = P_{Ht}^* \tag{66}$$
$$P_{Ht} = P_{Ft}^* \tag{67}$$
$$\frac{P_{Ht}}{P_t} = A_t^{\frac{1}{1-\varepsilon}} \tag{68}$$

- Household

$$\mathcal{C}_t = \left(\left(1-\upsilon\right)^{\frac{1}{\eta}}\left(C_{Ht}\right)^{\frac{\eta-1}{\eta}} + \upsilon^{\frac{1}{\eta}}\left(C_{Ft}\right)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{69}$$
$$C_{Ht} = \left(1-\upsilon\right)\left(\frac{P_{Ht}}{\mathcal{P}_t}\right)^{-\eta}\mathcal{C}_t \tag{70}$$
$$C_{Ft} = \upsilon\left(\frac{P_{Ft}}{\mathcal{P}_t}\right)^{-\eta}\mathcal{C}_t \tag{71}$$
$$K_{t+1} = \left(1-\delta\right)K_t + I_t\left[1 - \Psi\left(\iota_t\frac{I_t}{I_{t-1}}\right)\right] \tag{72}$$
$$Z_t^{1-\sigma}\varphi_0 \mathcal{C}_t^\sigma L_t^\varphi = \left(\frac{1-\tau_t^l}{1+\tau_t^c}\right)\frac{W_t}{\mathcal{P}_t} \tag{73}$$
$$\frac{P_{Ht}}{\mathcal{P}_t}\frac{\mathcal{C}_t^{-\sigma}}{\left(1+\tau_t^c\right)} = \mu_t\left(1 - \iota_t\frac{I_t}{I_{t-1}}\Psi'\left(\cdot\right) - \Psi\left(\iota_t\frac{I_t}{I_{t-1}}\right)\right) + \beta\mathbb{E}_t\left[\mu_{t+1}\iota_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2\Psi'\left(\cdot\right)\right] \tag{74}$$

- Returns

$$\mu_t = \beta \mathbb{E}_t \left[\mu_{t+1} (1-\delta) + \frac{\mathcal{C}_t^{-\sigma}}{\mathcal{P}_{t+1}} \left(\frac{1-\tau_{t+1}^k}{1+\tau_{t+1}^c} \right) R_{kt+1} \right] \tag{75}$$

$$1 + \frac{(\tilde{\eta}_{Ht} - \bar{\eta}_H)}{Z_t} B_{Ht} = \frac{R_{B,t}^r}{\kappa_{Ht}} \mathbb{E}_t \left[\Lambda_{t,t+1} \left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c} \right) (1 - \mathbb{I}_{Dt+1} \gamma_{t+1}) \right] \tag{76}$$

$$1 + \frac{(\tilde{\eta}_{Ft} - \bar{\eta}_F)}{Z_t} B_{Ft} = \frac{R_{B,t}^{r*}}{\kappa_{Ft}} \mathbb{E}_t \left[\Lambda_{t,t+1} \left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c} \right) \left(\frac{\mathcal{Q}_t}{\mathcal{Q}_{t+1}} \right) (1 - \mathbb{I}_{Dt+1}^* \gamma_{t+1}^*) \right] \tag{77}$$

$$p_{Dt} = \frac{1}{1+e^{-\varsigma_t}} \tag{78}$$

$$\Lambda_{t,t+1} = \beta \left(\frac{\mathcal{C}_{t+1}}{\mathcal{C}_t} \right)^{-\sigma} \tag{79}$$

- Final good

$$Y_{Ht} = A_t^{\frac{\varepsilon}{\varepsilon-1}} Y_t \tag{80}$$

$$Y_t = \left(\frac{P_t}{P_{Ht}} \right)^{-\epsilon} Y_{Ht} \tag{81}$$

- Intermediate goods

$$Y_t = \frac{1}{A_t} \xi_t K_t^{\alpha} L_t^{1-\alpha} \tag{82}$$

$$W_t^r = \frac{\epsilon - 1}{\epsilon} \frac{P_t}{\mathcal{P}_t} (1-\alpha) A_t \frac{Y_t}{L_t} \tag{83}$$

$$R_{kt}^r = \frac{\epsilon - 1}{\epsilon} \frac{P_t}{\mathcal{P}_t} \alpha A_t \frac{Y_t}{K_t} \tag{84}$$

$$\pi_t^r = \frac{1}{\epsilon} \frac{P_t}{\mathcal{P}_t} Y_t \tag{85}$$

- Technology

$$J_t^r = \max_{H_t} \mathbb{E}_t \left\{ -\frac{P_{Ht}}{\mathcal{P}_t} H_t + \phi \Lambda_{t,t+1} \left[\lambda_t V_{t+1}^r + (1-\lambda_t) J_{t+1}^r \right] \right\} \tag{86}$$

$$\frac{P_{Ht}}{\mathcal{P}_t} = \rho_\lambda \frac{\lambda_t}{H_t} \phi \mathbb{E}_t \left\{ \Lambda_{t,t+1} \left(V_{t+1}^r - J_{t+1}^r \right) \right\} \tag{87}$$

$$V_t^r = \pi_t^r + \phi \mathbb{E}_t \left\{ \Lambda_{t,t+1} V_{t+1}^r \right\} \tag{88}$$

$$\lambda_t = \bar{\lambda} (F_t H_t)^{\rho_\lambda} \tag{89}$$

$$F_t = \frac{Z_t}{K_t} \tag{90}$$

$$H_t^T = H_t (Z_t - A_t) \tag{91}$$

$$A_{t+1} = \lambda_t \phi [Z_t - A_t] + \phi A_t \tag{92}$$

- Government

$$\frac{P_{Ht}}{\mathcal{P}_t}G_t = B_t - R^r_{Bt-1}\left(1-\mathbb{I}_{Dt}\gamma_t\right)B_{t-1} + \tau^l_t W^r_t L_t - T^r_t + \tau^c_t \mathcal{C}_t + \tau^k_t R^r_{kt} K_t, \quad (93)$$

$$\text{GDP}_t = P_{Ht} Y_{Ht} \quad (94)$$

$$\hat{G}_t = -\varphi_g \hat{Y}^{HW}_{Ht} - \zeta_g \hat{b}_{t-1} + \hat{u}^g_t \quad (95)$$

$$\hat{T}_t = -\varphi_T \hat{Y}^{HW}_{Ht} - \zeta_T \hat{b}_{t-1} + \hat{u}^T_t \quad (96)$$

$$\hat{\tau}^k_t = \varphi_k \hat{Y}^{HW}_{Ht} + \zeta_k \hat{b}_{t-1} + \varphi_{kl}\hat{u}^l_t + \varphi_{kc}\hat{u}^c_t + \hat{u}^k_t \quad (97)$$

$$\hat{\tau}^l_t = \varphi_l \hat{Y}^{HW}_{Ht} + \zeta_l \hat{b}_{t-1} + \varphi_{lk}\hat{u}^k_t + \varphi_{lc}\hat{u}^c_t + \hat{u}^l_t \quad (98)$$

$$\hat{\tau}^c_t = \varphi_{ck}\hat{u}^k_t + \varphi_{cl}\hat{u}^l_t + \hat{u}^c_t \quad (99)$$

- Budget and resource constraints

$$\frac{P_{Ft}}{\mathcal{P}_t}C_{Ft} - \frac{P_{Ht}}{\mathcal{P}_t}C^*_{Ft} = \left(B^*_{Ft} - R^r_{Bt-1}\left(1-\mathbb{I}_{Dt}\gamma_t\right)B^*_{Ft-1}\right) - \frac{1}{\mathcal{Q}_t}\Big(B_{Ft} - R^{r*}_{B,t-1}\left(1-\mathbb{I}^*_{Dt}\gamma^*_t\right)B_{Ft-1}\Big) \quad (100)$$

$$-\frac{1}{\mathcal{Q}_t}\left(\left(\kappa_{Ft} + \eta_{Ft}B_{Ft} - 1\right)B_{Ft} - \mathcal{Q}_t\left(\kappa^*_{Ft} + \eta^*_{Ft}B^*_{Ft} - 1\right)B^*_{Ft}\right) \quad (101)$$

$$Y_{Ht} = C_{Ht} + C^*_{Ft} + H^T_t + I_t + G_t + \boldsymbol{\vartheta_t \mathbb{I}_{Dt}} \quad (102)$$

$$B_t = B_{Ht} + B^*_{Ft} \quad (103)$$

B Stationary Representation

Non-stationary variables are scaled by Z_t, i.e. $\tilde{X}_t = \frac{X_t}{Z_t}$ with the corresponding rate $\Gamma_{t+1} = \frac{Z_{t+1}}{Z_t}$. Stationarity requires

$$Y_{Ht} = A_t^{\frac{\varepsilon}{\varepsilon-1}} \frac{\xi_t}{A_t} K_t^{\alpha} L_t^{1-\alpha} \sim A_t^{\frac{\varepsilon}{\varepsilon-1}-1+\alpha} \tag{104}$$

$$\Rightarrow 2 = \frac{\epsilon}{\epsilon-1} + \alpha \tag{105}$$

- Exogenous processes

$$\Gamma_{t+1} = \left(\bar{\chi}\chi_t^{\zeta} + \phi\right) \tag{106}$$

$$\log(\chi_t) = \rho_{\chi} \log(\chi_{t-1}) + \sigma_{\chi}\varepsilon_t^{\chi} \tag{107}$$

$$\log\kappa_t = (1-\rho_{\kappa})\,\bar{\kappa} + \rho_{\kappa}\log\kappa_{t-1} + \sigma_{\kappa}\varepsilon_t^{\kappa} \tag{108}$$

$$\log\tilde{\eta}_t = (1-\rho_{\tilde{\eta}})\,\bar{\tilde{\eta}} + \rho_{\tilde{\eta}}\log\tilde{\eta}_{t-1} + \sigma_{\tilde{\eta}}\varepsilon_t^{\tilde{\eta}} \tag{109}$$

$$2\frac{\eta_t}{\kappa_t} = \frac{\tilde{\eta}_t - \bar{\eta}}{Z_t} \tag{110}$$

$$\log\xi_t = \rho_{\xi}\log\xi_{t-1} + \sigma_{\xi}\varepsilon_t^{\xi} \tag{111}$$

$$\varsigma_t = \varsigma_0 + \varsigma_1\left(\hat{b}_t - \bar{\hat{b}}\right) + \sigma_{\varsigma}\varepsilon_t^{\varsigma} \tag{112}$$

$$\hat{u}_t^x = \rho_x\hat{u}_{t-1}^x + \sigma_x\varepsilon_t^x, \quad x \in \{g, l, c, k, T\} \tag{113}$$

- Price relations

$$\frac{\mathcal{P}_t}{P_{Ht}} = \left((1-\upsilon) + \upsilon\,(\mathcal{S}_t)^{1-\eta}\right)^{\frac{1}{1-\eta}} \equiv h\,(\mathcal{S}_t) \tag{114}$$

$$\mathcal{P}_t^* = \left((1-\upsilon)\,(P_{Ht}^*)^{1-\eta} + \upsilon\,(P_{Ft}^*)^{1-\eta}\right)^{\frac{1}{1-\eta}} = P_{Ft}\left((1-\upsilon) + \upsilon\left(\frac{1}{\mathcal{S}_t}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}} \equiv P_{Ft} f\,(\mathcal{S}_t) \tag{115}$$

$$\frac{\mathcal{P}_t}{P_t} = \frac{\mathcal{P}_t}{P_{Ht}}\frac{P_{Ht}}{P_t} = h\,(\mathcal{S}_t)\,A_t^{\frac{1}{1-\varepsilon}} \tag{116}$$

$$\frac{\mathcal{P}_t}{P_{Ft}} = \frac{h\,(\mathcal{S}_t)}{\mathcal{S}_t} \tag{117}$$

$$\mathcal{Q}_t = \frac{\mathcal{P}_t}{\mathcal{P}_t^*} = \frac{\mathcal{P}_t}{P_{Ht}}\frac{P_{Ht}}{\mathcal{P}_t^*} = \frac{\mathcal{P}_t}{P_{Ht}}\frac{P_{Ht}}{P_{Ft}}\frac{P_{Ft}}{\mathcal{P}_t^*} = \frac{1}{\mathcal{S}_t}\frac{h\,(\mathcal{S}_t)}{f\,(\mathcal{S}_t)} \tag{118}$$

$$\mathcal{S}_t = \frac{P_{Ft}}{P_{Ht}} = \frac{P_{Ht}^*}{P_{Ht}} \tag{119}$$

$$P_{Ft} = P_{Ht}^* \tag{120}$$

$$P_{Ht} = P_{Ft}^* \tag{121}$$

$$\frac{P_{Ht}}{P_t} = A_t^{\frac{1}{1-\varepsilon}} \tag{122}$$

- Household

$$\tilde{C}_H = (1-\upsilon)\left(h\left(\mathcal{S}_t\right)\right)^{\eta}\tilde{\mathcal{C}}_t \tag{123}$$

$$\tilde{C}_F = \upsilon\left(\frac{h\left(\mathcal{S}_t\right)}{\mathcal{S}_t}\right)^{\eta}\tilde{\mathcal{C}}_t \tag{124}$$

$$\Gamma_{t+1}\tilde{K}_{t+1} = (1-\delta)\tilde{K}_t + \tilde{I}_t\left[1-\Psi\left(\Gamma_t\iota_t\frac{\tilde{I}_t}{\tilde{I}_{t-1}}\right)\right] \tag{125}$$

$$\varphi_0\tilde{\mathcal{C}}_t^{\sigma}L_t^{\varphi} = \left(\frac{1-\tau_t^l}{1+\tau_t^c}\right)\tilde{W}_t^r \tag{126}$$

$$\frac{1}{h\left(\mathcal{S}_t\right)}\frac{\tilde{\mathcal{C}}_t^{-\sigma}}{\left(1+\tau_t^c\right)} = \frac{\mu_t}{Z_t^{-\sigma}}\left(1-\Gamma_t\iota_t\frac{\tilde{I}_t}{\tilde{I}_{t-1}}\Psi'\left(\Gamma_t\iota_t\frac{\tilde{I}_t}{\tilde{I}_{t-1}}\right)-\Psi\left(\Gamma_t\iota_t\frac{\tilde{I}_t}{\tilde{I}_{t-1}}\right)\right) \tag{127}$$

$$+\beta\mathbb{E}_t\left[\Gamma_{t+1}^{-\sigma}\frac{\mu_{t+1}}{Z_{t+1}^{-\sigma}}\iota_{t+1}\left(\Gamma_{t+1}\frac{\tilde{I}_{t+1}}{\tilde{I}_t}\right)^2\Psi'\left(\Gamma_{t+1}\iota_{t+1}\frac{\tilde{I}_{t+1}}{\tilde{I}_t}\right)\right] \tag{128}$$

- Returns

$$\frac{\mu_t}{Z_t^{-\sigma}} = \beta\mathbb{E}_t\left[\Gamma_{t+1}^{-\sigma}\frac{\mu_{t+1}}{Z_{t+1}^{-\sigma}}(1-\delta)+\Gamma_{t+1}^{-\sigma}\tilde{\mathcal{C}}_{t+1}^{-\sigma}\left(\frac{1-\tau_{t+1}^k}{1+\tau_{t+1}^c}\right)R_{kt+1}^r\right] \tag{129}$$

$$1+\left(\tilde{\eta}_{Ht}-\bar{\eta}_H\right)\tilde{B}_{Ht} = \frac{R_{B,t}^r}{\kappa_{Ht}}\mathbb{E}_t\left[\beta\left(\Gamma_{t+1}\frac{\tilde{\mathcal{C}}_{t+1}}{\tilde{\mathcal{C}}_t}\right)^{-\sigma}\left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\right)\left(1-\mathbb{I}_{Dt+1}\gamma_{t+1}\right)\right] \tag{130}$$

$$1+\left(\tilde{\eta}_{Ft}-\bar{\eta}_F\right)\tilde{B}_{Ft} = \frac{R_{B,t}^{r*}}{\kappa_{Ft}}\mathbb{E}_t\left[\beta\left(\Gamma_{t+1}\frac{\tilde{\mathcal{C}}_{t+1}}{\tilde{\mathcal{C}}_t}\right)^{-\sigma}\left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\right)\left(\frac{\mathcal{Q}_t}{\mathcal{Q}_{t+1}}\right)\left(1-\mathbb{I}_{Dt+1}^*\gamma_{t+1}^*\right)\right] \tag{131}$$

$$p_{Dt} = \frac{1}{1+e^{-\varsigma_t}} \tag{132}$$

$$\Lambda_{t,t+1} = \beta\left(\Gamma_{t+1}\frac{\tilde{\mathcal{C}}_{t+1}}{\tilde{\mathcal{C}}_t}\right)^{-\sigma} \tag{133}$$

- Goods

$$\tilde{Y}_{Ht} = \tilde{A}_t^{\frac{1}{\varepsilon-1}}\xi_t\tilde{K}_t^{\alpha}L_t^{1-\alpha} \tag{134}$$

$$\tilde{W}_t^r = \frac{\epsilon-1}{\epsilon}\frac{1}{h\left(\mathcal{S}_t\right)}\tilde{A}_t^{\frac{1}{\varepsilon-1}}(1-\alpha)\xi_t\left(\frac{\tilde{K}_t}{L_t}\right)^{\alpha} \tag{135}$$

$$R_{kt}^r = \frac{\epsilon-1}{\epsilon}\frac{1}{h\left(\mathcal{S}_t\right)}\tilde{A}_t^{\frac{1}{\varepsilon-1}}\alpha\xi_t\left(\frac{L_t}{\tilde{K}_t}\right)^{1-\alpha} \tag{136}$$

$$\pi_t^r = \frac{1}{\epsilon}\frac{1}{h\left(\mathcal{S}_t\right)}\tilde{A}_t^{\frac{1}{\varepsilon-1}-1}\xi_t\tilde{K}_t^{\alpha}L_t^{1-\alpha} \tag{137}$$

- Technology

$$J_t^r = \max_{H_t} \mathbb{E}_t \left\{ -\frac{1}{h(\mathcal{S}_t)} H_t + \phi\beta \left(\Gamma_{t+1} \frac{\tilde{\mathcal{C}}_{t+1}}{\tilde{\mathcal{C}}_t} \right)^{-\sigma} \left[\lambda_t V_{t+1}^r + (1-\lambda_t) J_{t+1}^r \right] \right\} \tag{138}$$

$$\frac{1}{h(\mathcal{S}_t)} = \rho_\lambda \frac{\lambda_t}{H_t} \phi \mathbb{E}_t \left\{ \beta \left(\Gamma_{t+1} \frac{\tilde{\mathcal{C}}_{t+1}}{\tilde{\mathcal{C}}_t} \right)^{-\sigma} \left(V_{t+1}^r - J_{t+1}^r \right) \right\} \tag{139}$$

$$V_t^r = \pi_t^r + \phi \mathbb{E}_t \left\{ \beta \left(\Gamma_{t+1} \frac{\tilde{\mathcal{C}}_{t+1}}{\tilde{\mathcal{C}}_t} \right)^{-\sigma} V_{t+1}^r \right\} \tag{140}$$

$$\lambda_t = \bar{\lambda} (F_t H_t)^{\rho_\lambda} \tag{141}$$

$$F_t = \frac{1}{\tilde{K}_t} \tag{142}$$

$$\tilde{H}_t^T = H_t \left(1 - \tilde{A}_t \right) \tag{143}$$

$$\Gamma_{t+1} \tilde{A}_{t+1} = \lambda_t \phi \left[1 - \tilde{A}_t \right] + \phi \tilde{A}_t \tag{144}$$

- Government

$$\frac{1}{h(\mathcal{S}_t)} \tilde{G}_t = \tilde{B}_t - R_{Bt-1}^r (1 - \mathbb{I}_{Dt} \gamma_t) \frac{\tilde{B}_{t-1}}{\Gamma_t} + \tau_t^l \tilde{W}_t^r L_t - \tilde{T}_t^r + \tau_t^c \tilde{\mathcal{C}}_t + \tau_t^k R_{kt}^r \tilde{K}_t, \tag{145}$$

$$\text{GDP}_t^r = \frac{1}{h(\mathcal{S}_t)} Y_{Ht} \tag{146}$$

$$NX_t^r = \frac{1}{h(\mathcal{S}_t)} C_{Ft}^* - \frac{\mathcal{S}_t}{h(\mathcal{S}_t)} C_{Ft} \tag{147}$$

$$\hat{G}_t = -\varphi_g \hat{Y}_{Ht}^{HW} - \zeta_g \hat{b}_{t-1} + \hat{u}_t^g \tag{148}$$

$$\hat{T}_t = -\varphi_T \hat{Y}_{Ht}^{HW} - \zeta_T \hat{b}_{t-1} + \hat{u}_t^T \tag{149}$$

$$\hat{\tau}_t^k = \varphi_k \hat{Y}_{Ht}^{HW} + \zeta_k \hat{b}_{t-1} + \varphi_{kl} \hat{u}_t^l + \varphi_{kc} \hat{u}_t^c + \hat{u}_t^k \tag{150}$$

$$\hat{\tau}_t^l = \varphi_l \hat{Y}_{Ht}^{HW} + \zeta_l \hat{b}_{t-1} + \varphi_{lk} \hat{u}_t^k + \varphi_{lc} \hat{u}_t^c + \hat{u}_t^l \tag{151}$$

$$\hat{\tau}_t^c = \varphi_{ck} \hat{u}_t^k + \varphi_{cl} \hat{u}_t^l + \hat{u}_t^c \tag{152}$$

- Budget and resource constraints

$$\frac{\mathcal{S}_t}{h\left(\mathcal{S}_t\right)}\tilde{C}_{Ft} - \frac{1}{h\left(\mathcal{S}_t\right)}\tilde{C}^*_{Ft} = \left(\tilde{B}^*_{Ft} - \frac{R^r_{Bt-1}}{\Gamma_t}\left(1-\mathbb{I}_{Dt}\gamma_t\right)\tilde{B}^*_{Ft-1}\right) - \frac{1}{\mathcal{Q}_t}\left(\tilde{B}_{Ft} - \frac{R^{r*}_{B,t-1}}{\Gamma_t}\left(1-\mathbb{I}^*_{Dt}\gamma^*_t\right)\tilde{B}_{Ft-1}\right) \tag{153}$$

$$-\frac{1}{\mathcal{Q}_t}\left(\left(\kappa_{Ft}+\kappa_{Ft}\frac{\tilde{\eta}_{Ft}-\bar{\eta}_F}{2}\tilde{B}_{Ft}-1\right)\tilde{B}_{Ft} - \mathcal{Q}_t\left(\kappa^*_{Ft}+\kappa^*_{Ft}\frac{\tilde{\eta}^*_{Ft}-\bar{\eta}^*_F}{2}\tilde{B}^*_{Ft}-1\right)\tilde{B}^*_{F} \tag{154}$$

$$\eta_{Ht} = \frac{\tilde{\eta}_{Ht}-\bar{\eta}_H}{Z_t}\frac{\kappa_{Ht}}{2} \tag{155}$$

$$\eta_{Ft} = \frac{\tilde{\eta}_{Ft}-\bar{\eta}_F}{Z_t}\frac{\kappa_{Ft}}{2} \tag{156}$$

$$\tilde{Y}_{Ht} = \tilde{C}_{Ht} + \tilde{C}^*_{Ft} + \tilde{H}^T_t + \tilde{I}_t + \tilde{G}_t + \tilde{\vartheta}_{\mathbf{t}}\mathbb{I}_{\mathbf{Dt}} \tag{157}$$

$$\tilde{B}_t = \tilde{B}_{Ht} + \tilde{B}^*_{Ft} \tag{158}$$

C Foreign Country

C.1 Real Symmetric Conditions

Most equilibrium conditions are identical with a few exceptions with respect to the price-ratios.

- Exogenous processes

$$Z_{t+1} = \left(\bar{\chi}\chi_t^{\zeta} + \phi\right)Z_t \tag{159}$$

$$\log\left(\chi_t\right) = \rho_\chi \log\left(\chi_{t-1}\right) + \sigma_\chi\varepsilon_t^{\chi} \tag{160}$$

$$\log \kappa^*_t = \left(1-\rho_\kappa\right)\bar{\kappa}^* + \rho_\kappa \log \kappa^*_{t-1} + \sigma_\kappa \varepsilon_t^{\kappa *} \tag{161}$$

$$\log \tilde{\eta}^*_t = \left(1-\rho_{\tilde{\eta}}\right)\bar{\tilde{\eta}}^* + \rho_{\tilde{\eta}} \log \tilde{\eta}^*_{t-1} + \sigma_{\tilde{\eta}}\varepsilon_t^{\tilde{\eta}*} \tag{162}$$

$$\log \xi^*_t = \rho_\xi \log \xi^*_{t-1} + \sigma_\xi \varepsilon_t^{\xi *} \tag{163}$$

$$\log \iota^*_t = \rho_\iota \log \iota^*_{t-1} + \sigma_\iota \varepsilon_t^{\iota *} \tag{164}$$

$$\varsigma^*_t = \varsigma_0 + \varsigma_1\left(\hat{b}^*_t - \bar{\hat{b}}^*\right) + \sigma_\varsigma \varepsilon_t^{\varsigma *} \tag{165}$$

$$\hat{u}^{x*}_t = \rho_x \hat{u}^{x*}_{t-1} + \sigma_x \varepsilon_t^{x*}, \quad x \in \{g, l, c, k, T\} \tag{166}$$

- Price relations

$$\frac{\mathcal{P}_t^*}{P_{Ht}^*} = \left((1-\upsilon) + \upsilon\left(\frac{1}{\mathcal{S}_t}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}} = f\left(\mathcal{S}_t\right) \tag{167}$$

$$\mathcal{S}_t = \frac{P_{Ft}}{P_{Ht}} = \frac{P_{Ht}^*}{P_{Ht}} \tag{168}$$

$$\frac{\mathcal{P}_t^*}{P_t^*} = f\left(\mathcal{S}_t\right) A_t^{*\frac{1}{1-\varepsilon}} \tag{169}$$

$$\frac{P_{Ht}^*}{P_t^*} = A_t^{*\frac{1}{1-\varepsilon}} \tag{170}$$

$$\frac{P_{Ft}^*}{P_{Ht}^*} = \frac{P_{Ht}}{P_{Ft}} = \frac{1}{\mathcal{S}_t} \tag{171}$$

$$\frac{\mathcal{P}_t^*}{P_{Ft}^*} = \mathcal{S}_t f\left(\mathcal{S}_t\right) \tag{172}$$

$$\frac{\mathcal{P}_t^*}{P_{Ft}^*} = \frac{h\left(\mathcal{S}_t\right)}{\mathcal{S}_t} \tag{173}$$

$$\mathcal{Q}_t = \frac{1}{\mathcal{S}_t}\frac{h\left(\mathcal{S}_t\right)}{f\left(\mathcal{S}_t\right)} \tag{174}$$

- Household

$$C_{Ht}^* = (1-\upsilon)\left(f\left(\mathcal{S}_t\right)\right)^{\eta}\mathcal{C}_t^* \tag{175}$$

$$C_{Ft}^* = \upsilon\left(f\left(\mathcal{S}_t\right)\mathcal{S}_t\right)^{\eta}\mathcal{C}_t^* \tag{176}$$

$$K_{t+1}^* = (1-\delta)K_t^* + I_t^*\left[1-\Psi\left(\iota_t\frac{I_t^*}{I_{t-1}^*}\right)\right] \tag{177}$$

$$Z_t^{*1-\sigma}\varphi_0^*\mathcal{C}_t^{*\sigma}L_t^{*\varphi} = \left(\frac{1-\tau_t^{l*}}{1+\tau_t^{c*}}\right)W_t^{*r} \tag{178}$$

$$\frac{1}{f\left(\mathcal{S}_t\right)}\frac{\mathcal{C}_t^{-\sigma*}}{(1+\tau_t^{c*})} = \mu_t^*\left(1-\iota_t\frac{I_t^*}{I_{t-1}^*}\Psi'(\cdot)-\Psi\left(\iota_t\frac{I_t^*}{I_{t-1}^*}\right)\right) + \beta\mathbb{E}_t\left[\mu_{t+1}^*\iota_{t+1}\left(\frac{I_{t+1}^*}{I_t^*}\right)^2\Psi'(\cdot)\right] \tag{179}$$

Returns

$$\mu_t^* = \beta\mathbb{E}_t\left[\mu_{t+1}^*(1-\delta) + \mathcal{C}_t^{*-\sigma}\left(\frac{1-\tau_{t+1}^{k*}}{1+\tau_{t+1}^{c*}}\right)R_{kt+1}^{r*}\right] \tag{180}$$

$$1+\frac{(\tilde{\eta}_{Ht}^*-\bar{\eta}_H^*)}{Z_t}B_{Ht}^* = \frac{R_{B,t}^{r*}}{\kappa_{Ht}^*}\mathbb{E}_t\left[\Lambda_{t,t+1}^*\left(\frac{1+\tau_t^{c*}}{1+\tau_{t+1}^{c*}}\right)(1-\mathbb{I}_{Dt+1}^*\gamma_{t+1}^*)\right] \tag{181}$$

$$1+\frac{(\tilde{\eta}_{Ft}^*-\bar{\eta}_F^*)}{Z_t}B_{Ft}^* = \frac{R_{B,t}^{r}}{\kappa_{Ft}^*}\mathbb{E}_t\left[\Lambda_{t,t+1}^*\left(\frac{1+\tau_t^{c*}}{1+\tau_{t+1}^{c*}}\right)\left(\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}\right)(1-\mathbb{I}_{Dt+1}\gamma_{t+1})\right] \tag{182}$$

$$p_{Dt}^* = \frac{1}{1+e^{-\varsigma_t^*}} \tag{183}$$

$$\Lambda_{t,t+1}^* = \beta\left(\frac{\mathcal{C}_{t+1}^*}{\mathcal{C}_t^*}\right)^{-\sigma} \tag{184}$$

- Final good

$$Y_{Ht}^{*} = A_t^{*\frac{\epsilon}{\varepsilon-1}} Y_t^{*} \tag{185}$$

- Intermediate goods

$$Y_t^{*} = \frac{\xi_t^{*}}{A_t^{*}} K_t^{*\alpha} L_t^{*1-\alpha} \tag{186}$$

$$W_t^{*r} = \frac{\epsilon-1}{\epsilon} \frac{A_t^{*\frac{1}{\varepsilon-1}}}{f\left(\mathcal{S}_t\right)} \left(1-\alpha\right) A_t^{*} \frac{Y_t^{*}}{L_t^{*}} \tag{187}$$

$$R_{kt}^{*r} = \frac{\epsilon-1}{\epsilon} \frac{A_t^{*\frac{1}{\varepsilon-1}}}{f\left(\mathcal{S}_t\right)} \alpha A_t^{*} \frac{Y_t^{*}}{K_t^{*}} \tag{188}$$

$$\pi_t^{*r} = \frac{1}{\epsilon} \frac{A_t^{*\frac{1}{\varepsilon-1}}}{f\left(\mathcal{S}_t\right)} Y_t^{*} \tag{189}$$

- Technology

$$J_t^{*r} = \mathbb{E}_t \left\{ -\frac{H_t^{*}}{f\left(\mathcal{S}_t\right)} + \phi \Lambda_{t,t+1}^{*} \left[\lambda_t^{*} V_{t+1}^{*r} + \left(1-\lambda_t^{*}\right) J_{t+1}^{*r} \right] \right\} \tag{190}$$

$$\frac{1}{f\left(\mathcal{S}_t\right)} = \rho_\lambda \frac{\lambda_t^{*}}{H_t^{*}} \phi \mathbb{E}_t \left\{ \Lambda_{t,t+1}^{*} \left(V_{t+1}^{*r} - J_{t+1}^{*r} \right) \right\} \tag{191}$$

$$V_t^{r*} = \pi_t^{r*} + \phi \mathbb{E}_t \left\{ \Lambda_{t,t+1}^{*} V_{t+1}^{*r} \right\} \tag{192}$$

$$\lambda_t^{*} = \bar{\lambda}^{*} \left(\frac{Z_t}{K_t^{*}} H_t^{*} \right)^{\rho_\lambda} \tag{193}$$

$$H_t^{*T} = H_t^{*} \left(Z_t - A_t^{*} \right) \tag{194}$$

$$A_{t+1}^{*} = \lambda_t^{*} \phi \left[Z_t - A_t^{*} \right] + \phi A_t^{*} \tag{195}$$

- Government

$$\frac{G_t^{*}}{f\left(\mathcal{S}_t\right)} = B_t^{*} - R_{Bt-1}^{r*} \left(1 - \mathbb{I}_{Dt}^{*} \gamma_t^{*}\right) B_{t-1}^{*} + \tau_t^{l*} W_t^{r*} L_t^{*} - T_t^{r*} + \tau_t^{c*} \mathcal{C}_t^{*} + \tau_t^{k*} R_{kt}^{r*} K_t^{*} \tag{196}$$

$$\text{GDP}_t^{r*} = \frac{Y_{Ht}^{*}}{f\left(\mathcal{S}_t\right)} + NX_t^{r*} \tag{197}$$

$$\hat{G}_t^{*} = -\varphi_g \hat{Y}_{Ht}^{HW*} - \zeta_g \hat{b}_{t-1}^{*} + \hat{u}_t^{g*} \tag{198}$$

$$\hat{T}_t^{*} = -\varphi_T \hat{Y}_{Ht}^{HW*} - \zeta_T \hat{b}_{t-1}^{*} + \hat{u}_t^{T*} \tag{199}$$

$$\hat{\tau}_t^{k*} = \varphi_k \hat{Y}_{Ht}^{HW*} + \zeta_k \hat{b}_{t-1}^{*} + \varphi_{kl} \hat{u}_t^{l*} + \varphi_{kc} \hat{u}_t^{c*} + \hat{u}_t^{k*} \tag{200}$$

$$\hat{\tau}_t^{l*} = \varphi_l \hat{Y}_{Ht}^{HW*} + \zeta_l \hat{b}_{t-1}^{*} + \varphi_{lk} \hat{u}_t^{k*} + \varphi_{lc} \hat{u}_t^{c*} + \hat{u}_t^{l*} \tag{201}$$

$$\hat{\tau}_t^{c*} = \varphi_{ck} \hat{u}_t^{k*} + \varphi_{cl} \hat{u}_t^{l*} + \hat{u}_t^{c*} \tag{202}$$

- Resource constraint

$$Y_{Ht}^{*} = C_{Ht}^{*} + C_{Ft} + H_t^{T*} + I_t^{*} + G_t^{*} + \vartheta_{\mathbf{t}}^{*} \mathbb{I}_{\mathbf{Dt}}^{*} \tag{203}$$

$$B_t^{*} = B_{Ht}^{*} + B_{Ft} \tag{204}$$

C.2 Stationary Representation

- Exogenous processes

$$Z_{t+1} = \left(\bar{\chi}\chi_t^{\zeta} + \phi\right) Z_t \tag{205}$$
$$\log\left(\chi_t\right) = \rho_\chi \log\left(\chi_{t-1}\right) + \sigma_\chi \varepsilon_t^{\chi} \tag{206}$$
$$\log \kappa_t^* = \left(1-\rho_\kappa\right)\bar{\kappa}^* + \rho_\kappa \log \kappa_{t-1}^* + \sigma_\kappa \varepsilon_t^{\kappa *} \tag{207}$$
$$\log \tilde{\eta}_t^* = \left(1-\rho_{\tilde{\eta}}\right)\bar{\tilde{\eta}}^* + \rho_{\tilde{\eta}} \log \tilde{\eta}_{t-1}^* + \sigma_{\tilde{\eta}} \varepsilon_t^{\tilde{\eta} *} \tag{208}$$
$$\log \xi_t^* = \rho_\xi \log \xi_{t-1}^* + \sigma_\xi \varepsilon_t^{\xi *} \tag{209}$$
$$\log \iota_t^* = \rho_\iota \log \iota_{t-1}^* + \sigma_\iota \varepsilon_t^{\iota *} \tag{210}$$
$$\varsigma_t^* = \varsigma_0 + \varsigma_1 \left(\hat{b}_t^* - \bar{\hat{b}}^*\right) + \sigma_\varsigma \varepsilon_t^{\varsigma *} \tag{211}$$
$$\hat{u}_t^{x*} = \rho_x \hat{u}_{t-1}^{x*} + \sigma_x \varepsilon_t^{x*}, \quad x \in \{g, l, c, k, T\} \tag{212}$$

- Price relations

$$\frac{\mathcal{P}_t^*}{P_{Ht}^*} = \left((1-\upsilon) + \upsilon\left(\frac{1}{\mathcal{S}_t}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}} = f\left(\mathcal{S}_t\right) \tag{213}$$
$$\mathcal{S}_t = \frac{P_{Ft}}{P_{Ht}} = \frac{P_{Ht}^*}{P_{Ht}} \tag{214}$$
$$\frac{\mathcal{P}_t^*}{P_t^*} = f\left(\mathcal{S}_t\right) A_t^{*\frac{1}{1-\varepsilon}} \tag{215}$$
$$\frac{P_{Ht}^*}{P_t^*} = A_t^{*\frac{1}{1-\varepsilon}} \tag{216}$$
$$\frac{P_{Ft}^*}{P_{Ht}^*} = \frac{P_{Ht}}{P_{Ft}} = \frac{1}{\mathcal{S}_t} \tag{217}$$
$$\frac{\mathcal{P}_t^*}{P_{Ft}^*} = \mathcal{S}_t f\left(\mathcal{S}_t\right) \tag{218}$$
$$\frac{\mathcal{P}_t^*}{P_{Ft}^*} = \frac{h\left(\mathcal{S}_t\right)}{\mathcal{S}_t} \tag{219}$$
$$\mathcal{Q}_t = \frac{1}{\mathcal{S}_t}\frac{h\left(\mathcal{S}_t\right)}{f\left(\mathcal{S}_t\right)} \tag{220}$$

- Household

$$\tilde{C}^*_{Ht} = (1-\upsilon)\left(f\left(\mathcal{S}_t\right)\right)^{\eta}\tilde{C}^*_t \tag{221}$$

$$\tilde{C}^*_{Ft} = \upsilon\left(f\left(\mathcal{S}_t\right)\mathcal{S}_t\right)^{\eta}\tilde{C}^*_t \tag{222}$$

$$\Gamma_{t+1}\tilde{K}^*_{t+1} = (1-\delta)\tilde{K}^*_t + \tilde{I}^*_t\left[1-\Psi\left(\Gamma_t\iota^*_t\frac{\tilde{I}^*_t}{\tilde{I}^*_{t-1}}\right)\right] \tag{223}$$

$$\varphi^*_0\tilde{C}^{*\sigma}_t L^{*\varphi}_t = \left(\frac{1-\tau^{l*}_t}{1+\tau^{c*}_t}\right)\tilde{W}^{*r}_t \tag{224}$$

$$\frac{1}{f\left(\mathcal{S}_t\right)}\frac{\tilde{C}^{-\sigma*}_t}{\left(1+\tau^{c*}_t\right)} = \frac{\mu^*_t}{Z^{-\sigma}_t}\left(1-\Gamma_t\iota^*_t\frac{\tilde{I}^*_t}{\tilde{I}^*_{t-1}}\Psi'\left(\Gamma_t\iota^*_t\frac{\tilde{I}^*_t}{\tilde{I}^*_{t-1}}\right)-\Psi\left(\Gamma_t\iota^*_t\frac{\tilde{I}^*_t}{\tilde{I}^*_{t-1}}\right)\right) \tag{225}$$

$$+\beta\mathbb{E}_t\left[\mu^*_{t+1}\left(\Gamma_{t+1}\iota^*_t\frac{\tilde{I}^*_{t+1}}{\tilde{I}^*_t}\right)^2\Psi'\left(\Gamma_{t+1}\iota^*_t\frac{\tilde{I}^*_{t+1}}{\tilde{I}^*_t}\right)\right] \tag{226}$$

- Returns

$$\frac{\mu^*_t}{Z^{-\sigma}_t} = \beta\mathbb{E}_t\left[\frac{\mu^*_{t+1}}{Z^{-\sigma}_{t+1}}(1-\delta)+\tilde{C}^{*-\sigma}_t\left(\frac{1-\tau^{k*}_{t+1}}{1+\tau^{c*}_{t+1}}\right)R^{r*}_{kt+1}\right] \tag{227}$$

$$1+\left(\tilde{\eta}^*_{Ht}-\bar{\eta}^*_H\right)\tilde{B}^*_{Ht} = \frac{R^{r*}_{B,t}}{\kappa^*_{Ht}}\mathbb{E}_t\left[\beta\left(\Gamma_{t+1}\frac{\tilde{C}^*_{t+1}}{\tilde{C}^*_t}\right)^{-\sigma}\left(\frac{1+\tau^{c*}_t}{1+\tau^{c*}_{t+1}}\right)\left(1-\mathbb{I}^*_{Dt+1}\gamma^*_{t+1}\right)\right] \tag{228}$$

$$1+\left(\tilde{\eta}^*_{Ft}-\bar{\eta}^*_F\right)\tilde{B}^*_{Ft} = \frac{R^{r}_{B,t}}{\kappa^*_{Ft}}\mathbb{E}_t\left[\beta\left(\Gamma_{t+1}\frac{\tilde{C}^*_{t+1}}{\tilde{C}^*_t}\right)^{-\sigma}\left(\frac{1+\tau^{c*}_t}{1+\tau^{c*}_{t+1}}\right)\left(\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}\right)\left(1-\mathbb{I}_{Dt+1}\gamma_{t+1}\right)\right] \tag{229}$$

$$p^*_{Dt} = \frac{1}{1+e^{-\varsigma^*_t}} \tag{230}$$

$$\Lambda^*_{t,t+1} = \beta\left(\Gamma_{t+1}\frac{\tilde{C}^*_{t+1}}{\tilde{C}^*_t}\right)^{-\sigma} \tag{231}$$

- Final good

$$Y^*_{Ht} = A^{*\frac{\epsilon}{\varepsilon-1}}_t Y^*_t \tag{232}$$

- Intermediate goods

$$\tilde{Y}^*_{Ht} = \tilde{A}^{*\frac{1}{\varepsilon-1}}_t \xi^*_t\tilde{K}^{*\alpha}_t L^{*1-\alpha}_t \tag{233}$$

$$W^{*r}_t = \frac{\epsilon-1}{\epsilon}\frac{1}{f\left(\mathcal{S}_t\right)}(1-\alpha)\xi^*_t\left(\frac{\tilde{K}^*_t}{L^*_t}\right)^{\alpha} \tag{234}$$

$$R^{*r}_{kt} = \frac{\epsilon-1}{\epsilon}\frac{1}{f\left(\mathcal{S}_t\right)}\alpha\tilde{A}^{*\frac{1}{\varepsilon-1}}_t\xi^*_t\left(\frac{L^*_t}{\tilde{K}^*_t}\right)^{1-\alpha} \tag{235}$$

$$\pi^{*r}_t = \frac{1}{\epsilon}\frac{\tilde{A}^{*\frac{1}{\varepsilon-1}-1}_t}{f\left(\mathcal{S}_t\right)}\xi^*_t\tilde{K}^{*\alpha}_t L^{*1-\alpha}_t \tag{236}$$

- Technology

$$J_t^{*r} = \mathbb{E}_t \left\{ -\frac{H_t^*}{f(\mathcal{S}_t)} + \phi\beta \left(\Gamma_{t+1} \frac{\tilde{\mathcal{C}}_{t+1}^*}{\tilde{\mathcal{C}}_t^*} \right)^{-\sigma} \left[\lambda_t^* V_{t+1}^{*r} + (1-\lambda_t^*) J_{t+1}^{*r} \right] \right\} \tag{237}$$

$$\frac{1}{f(\mathcal{S}_t)} = \rho_\lambda \frac{\lambda_t^*}{H_t^*} \phi \mathbb{E}_t \left\{ \beta \left(\Gamma_{t+1} \frac{\tilde{\mathcal{C}}_{t+1}^*}{\tilde{\mathcal{C}}_t^*} \right)^{-\sigma} \left(V_{t+1}^{*r} - J_{t+1}^{*r} \right) \right\} \tag{238}$$

$$V_t^{r*} = \pi_t^{r*} + \phi \mathbb{E}_t \left\{ \beta \left(\Gamma_{t+1} \frac{\tilde{\mathcal{C}}_{t+1}^*}{\tilde{\mathcal{C}}_t^*} \right)^{-\sigma} V_{t+1}^{*r} \right\} \tag{239}$$

$$\lambda_t^* = \bar{\lambda}^* \left(\frac{1}{\tilde{K}_t^*} H_t^* \right)^{\rho_\lambda} \tag{240}$$

$$\tilde{H}_t^{*T} = H_t^* \left(1 - \tilde{A}_t^* \right) \tag{241}$$

$$\Gamma_{t+1} \tilde{A}_{t+1}^* = \lambda_t^* \phi \left[1 - \tilde{A}_t^* \right] + \phi \tilde{A}_t^* \tag{242}$$

- Government

$$\frac{\tilde{G}_t^*}{f(\mathcal{S}_t)} = \tilde{B}_t^* - R_{Bt-1}^{r*} \left(1 - \mathbb{I}_{Dt}^* \gamma_t^* \right) \frac{\tilde{B}_{t-1}^*}{\Gamma_t} + \tau_t^{l*} \tilde{W}_t^{r*} L_t^* - \tilde{T}_t^{r*} + \tau_t^{c*} \tilde{C}_t^* + \tau_t^{k*} R_{kt}^{r*} \tilde{K}_t^* \tag{243}$$

$$\text{GDP}_t^{r*} = \frac{Y_{Ht}^*}{f(\mathcal{S}_t)} \tag{244}$$

$$\hat{G}_t^* = -\varphi_g \hat{Y}_{Ht}^{HW*} - \zeta_g \hat{b}_{t-1}^* + \hat{u}_t^{g*} \tag{245}$$

$$\hat{T}_t^* = -\varphi_T \hat{Y}_{Ht}^{HW*} - \zeta_T \hat{b}_{t-1}^* + \hat{u}_t^{T*} \tag{246}$$

$$\hat{\tau}_t^{k*} = \varphi_k \hat{Y}_{Ht}^{HW*} + \zeta_k \hat{b}_{t-1}^* + \varphi_{kl} \hat{u}_t^{l*} + \varphi_{kc} \hat{u}_t^{c*} + \hat{u}_t^{k*} \tag{247}$$

$$\hat{\tau}_t^{l*} = \varphi_l \hat{Y}_{Ht}^{HW*} + \zeta_l \hat{b}_{t-1}^* + \varphi_{lk} \hat{u}_t^{k*} + \varphi_{lc} \hat{u}_t^{c*} + \hat{u}_t^{l*} \tag{248}$$

$$\hat{\tau}_t^{c*} = \varphi_{ck} \hat{u}_t^{k*} + \varphi_{cl} \hat{u}_t^{l*} + \hat{u}_t^{c*} \tag{249}$$

- Resource constraint

$$\tilde{Y}_{Ht}^* = \tilde{C}_{Ht}^* + \tilde{C}_{Ft} + \tilde{H}_t^{T*} + \tilde{I}_t^* + \tilde{G}_t^* + \tilde{\vartheta}_{\mathbf{t}}^* \mathbb{I}_{\mathbf{Dt}}^* \tag{250}$$

$$\tilde{B}_t^* = \tilde{B}_{Ht}^* + \tilde{B}_{Ft} \tag{251}$$

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Parameter	Value	Parameter	Value	Parameter	Value
β	0.985	ζ	0.60	ρ_ξ	0.92
σ	1.00	ζ_l	2.80	ρ_g	0.93
υ	0.40	ζ_k	3.50	ρ_l	0.90
φ	3.00	ζ_c	1.70	L_1	1.00
α	0.60	ρ_λ	0.90	L_2	1.00
ϵ	3.50	$\bar{\chi}$	0.02	Γ	1.006
δ	0.02	ρ_χ	0.84	τ_c	0.20
η	2.00	$\bar{\lambda}_1$	0.63	τ_{HW}	0.90
ϕ	0.98	$\bar{\lambda}_2$	0.68	τ_l	0.30

Table 4: Parameter values of the model, calibrated at quarterly frequencies

Variable	Country One		Country Two	
A. Macro Variables	std	ac1	std	ac1
Consumption index growth	1.62%	0.54	1.54%	0.58
Investment growth	6.54%	0.69	6.07%	0.75
GDP growth	2.68%	0.31	2.49%	0.37
B. Financial Variables	mean	ac1	mean	ac1
Debt-to-GDP	42.5%	0.69	30.2%	0.74
Return on bonds	5.67%	0.72	3.41%	0.75
Return on capital	7.06%	0.59	6.82%	0.63

Table 5: Annualized macroeconomic and financial moments

Consumption correlation between the two countries: 0.35