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Abstract

We propose a New Keynesian DSGE model of the Eurozone and analyze an asymmetric recession in a vulnerable member state characterized by a trilemma of high public debt, weak banks, and deteriorating competitiveness. We compare macroeconomic adjustment under continued membership with two exit scenarios that introduce flexible exchange rates and autonomous monetary policy. An exit with stable investor expectations could significantly dampen the short-run impact. Stabilization is achieved by a targeted monetary expansion combined with depreciation. However, investor panic may lead to escalation, aggravate the recession and delay the recovery.

Keywords

Currency union, exchange rate flexibility, fiscal consolidation, sovereign debt, banks

JEL Classification

E42, E44, E60, F30, F36, F45, G15, G21

1 Introduction

The global financial crisis revealed large imbalances in the Eurozone. The banking sector in several Eurozone countries was highly leveraged and had a large share of non-performing loans. This impaired banks' ability to absorb large shocks, requiring government support in many cases. With rising public debt, doubts emerged about the fiscal stability of several member states, leading to higher risk premia and rising borrowing costs for those governments. In addition, some countries in the Eurozone periphery had gradually lost competitiveness in the pre-crisis boom during the early 2000s and experienced stagnant growth thereafter. High debt constrains the borrowing capacity and thereby impairs the role of the fiscal budget in stabilizing the economy during a recession. Instead of providing fiscal relief, governments may be forced to pursue consolidation.

One prominent example of this Eurozone trilemma of high public debt, weakened banks, and stagnant growth is Italy: First, public debt already accounted for 130 percent of GDP prior to the Covid-19 crisis. The chronically high debt level is mainly a result of the 1980s and early 1990s. While it had remained stable at around 100 percent of GDP between the late 1990s and 2008, the financial crisis led to a surge in the public debt ratio. Second, Italian banks suffered from many non-performing loans. Their share increased from six to 16 percent between 2006 and 2013 (Schivardi et al., 2017) but is declining since then. Another source of financial fragility is that banks hold large amounts of domestic sovereign bonds, more than 11 percent of bank assets in 2017, according to ECB data. Third, the Italian economy has long suffered from sluggish growth. In 2017, real GDP per capita was virtually the same as in 2000. An important reason for this pattern is stagnant or declining labor productivity since the 1990s, which contributed to rising unit labor costs.

The present paper analyzes the policy options of a country that suffers from the Eurozone trilemma and experiences a local recession. We proceed in two steps: First, we examine the consequences of financial and fiscal shocks like an increase in non-performing loans or fiscal consolidation, which mirror key aspects of the financial and Eurozone debt crises. Second, we consider the exit of a vulnerable member state from the currency union. An exit involves a shift from centralized to autonomous monetary policy and allows for exchange rate flexibility. The key question is whether a vulnerable member state could benefit from an autonomous monetary policy more targeted to domestic needs. Evidence by Terzi (2020) suggests that the lack of independent monetary policy explains 25 percent of the overly recessionary character of macroeconomic adjustment in the Eurozone periphery (2010-15).

To analyze these issues, this paper formulates a New Keynesian dynamic stochastic general equilibrium (DSGE) model with three regions: a Eurozone member state (domestic economy), the rest of the Eurozone, and the rest of the world. The focus is on the domestic economy; the other two regions are intentionally kept stylized but are connected with trade and capital flows. The model is empirically implemented to represent the situation of Italy.

The model of the domestic economy captures three reinforcing drivers of the Eurozone crisis. First of all, firms finance risky investments predominantly with bank loans. Firm bankruptcy shocks provide an explicit micro-foundation for non-performing loans that may create large bank losses. In addition, banks are exposed to fluctuations in sovereign bond prices as they hold large amounts of long-term government bonds. Such losses erode equity and thereby limit the lending capacity of banks. The model also includes fiscal consolidation rules in the spirit of the Maastricht criteria. The need to consolidate public debt may slow growth, for instance, due to increased tax distortions or reduced productive government spending. The key nominal rigidity is wage stickiness.

The restrictions of a currency union may exacerbate the domestic impact of a strong asymmetric recession in a vulnerable member state. We thus analyze a counterfactual exit from the monetary union and compare domestic economic performance in the two alternative regimes. Within the union, monetary policy is centralized, and the internal exchange rate is fixed. An exit, by contrast, allows exchange rates to adjust and monetary policy to be specifically targeted to domestic needs. Given the large uncertainties about how an exit might unfold in the short and medium run, we consider two polar scenarios: a 'benign' exit from the Eurozone with stable investor expectations, and an 'escalating' exit with a loss of confidence that causes a concurrent surge in borrowing costs of banks and the government as the country exits the monetary union.

Our results provide a number of novel insights. On the one hand, we use an impulse response analysis to quantify the power of the mutually contagious effects in the interaction between banks, governments, and the real economy. Specifically, higher bankruptcy rates in the real sector weaken banks, and a one-time shock to the non-performing loan (NPL) ratio by three percentage points reduces bank credit by roughly four percent and causes a drop in GDP of about 1.75% below trend, after 8 to 10 quarters. Likewise, the banking sector is strongly affected by the government's financial situation (sovereign-bank nexus). A sudden increase in the annual risk premium on sovereign bonds by four percentage points reduces bond valuations by about 10%. These losses erode bank equity and thereby restrict lending and investment. Ultimately, GDP falls by about one percentage point in our simulation. We also consider how a highly indebted government may damage the real sector. We consider how a substantial increase in public debt after a large spending shock triggers subsequent fiscal consolidation with tax increases and spending cuts to satisfy 'Maastricht-type' fiscal rules. Higher distortionary taxes and lower productive public spending tend to slow GDP growth over a long period until the government succeeds in bringing back the debt-to-GDP ratio to its long-run target. Finally, we quantify how much autonomous monetary policy, targeted to national rather than union-wide aggregates, can contribute to the stabilization of the local economy, although at the cost of higher inflation variance.

Could a vulnerable member state reduce the output losses from an asymmetric recession and accelerate the recovery by an exit from the currency union, and thereby moving to autonomous monetary policy and flexible exchange rates? As a reference, we consider the effects of a severe, local recession under continued membership and common monetary policy, leading domestic output to contract by about 9% below trend. The rest of the union is not directly affected. We then compare the effects of the same recession after a 'benign' exit with stable investor expectations. The more targeted response under autonomous monetary policy rule, that is, the domestic monetary expansion, is roughly five times larger than under continued membership, and the flexibility achieved through exchange rate devaluation indeed significantly lowers the output costs of such a recession. In the presence of nominal wage rigidity, more inflation reduces real wages and dampens the short-run contraction. Depreciation offsets the effects of rising domestic prices on international competitiveness and thereby protects export performance.

Whether forced or by accident, an exit of a vulnerable member state is likely to involve short-run disruptions due to high uncertainty. For instance, investors are concerned about the solvency of banks, the sovereign, and large parts of the real economy and charge higher risk premia. This scenario of an 'escalating exit' accompanied by investor panic eliminates the short-term gains from a benign exit and reinforces the output recession. The large increase in funding costs magnifies the increase in domestic prices coupled with a larger exchange rate devaluation. Inflation stabilizes employment only in the short run but at the cost of much larger real wage reductions of workers. Our model also indicates that an escalating exit leads to higher and longer-lasting income losses than a recession within the currency union.

The existing literature on the Eurozone is large and predominantly relates to specific aspects of the crisis. The present paper aims to capture vicious spirals and self-enforcing feedback loops in a DSGE model and quantitatively evaluate alternative policy scenarios. Specifically, it compares the recovery following a recession under continued membership in the monetary union with two exit scenarios. Closest to our endeavor is the research by Gourinchas et al. (2016) and Chodorow-Reich et al. (2019), who suggest an open economy New Keynesian DSGE model to explain the evolution of the Greek economy during the crisis. Martin and Philippon (2017) develop a stylized two-country model to analyze the contrasting behavior of the periphery and core countries and to investigate macroprudential policies. They also include amplifying feedback mechanisms in reduced form. Gilchrist et al. (2017) develop a DSGE model with two financially heterogeneous regions where financial frictions prevent price adjustments. Unlike these papers, we consider an exit scenario modeled as a complete regime shift, that is, moving from fixed to flexible exchange rates and from centralized to autonomous monetary policy.

Kriwoluzky et al. (2020), in turn, explicitly analyze a potential exit from a monetary union using a New Keynesian model. They focus on exit expectations during a sovereign debt crisis, which contribute to rising interest rates for public and private borrowers prior to an exit, thereby reinforcing the debt crisis and depressing economic activity. The importance of such expectations is one reason why we model shocks to risk premia in our 'escalating exit' scenario. Furthermore, an exit scenario resembles the break-up of currency pegs. Schmitt-Grohe and Uribe (2016), for example, show how downward wage rigidity combined with free capital mobility causes over-borrowing in booms and unemployment during recessions, resembling key aspects of the Eurozone crisis.

The present paper emphasizes a trilemma of high public debt, weak banks, and deteriorating competitiveness (Shambaugh, 2012). Empirical research documents the importance of these three reinforcing drivers of the Eurozone crisis: First, a systemic banking crisis entails severe macroeconomic costs. Laeven and Valencia (2012), for example, estimate a 32 percent median cumulative output loss in advanced economies. In addition, a banking crisis typically leads to a massive increase in public debt and thus can rapidly transform into a public debt crisis, as the Irish experience has shown (e.g., Acharya et al., 2014).

Second, a sovereign debt crisis undermines financial stability. European banks typically hold large amounts of domestic sovereign bonds (e.g., Acharya and Steffen, 2015; Altavilla et al., 2016; Ongena et al., 2019). Given this exposure, a public debt crisis causes a contraction of private credit, especially if banks' sovereign bond holdings are large and they are highly leveraged (Gennaioli et al., 2014). Bofondi et al. (2018) show that domestic Italian banks reduced credit significantly more during the sovereign debt crisis than foreign banks that operate in Italy.

Third, a lack of competitiveness can become an obstacle to economic growth and lead to persistent unemployment. This feeds back not only on the fiscal budget but also on banks because non-performing loans tend to rise as private defaults become more frequent. The empirical literature emphasizes the role of growth and unemployment (e.g., Louzis et al., 2012; Salas and Saurina, 2002) or the specific impact of recessions (Quagliariello, 2007). A large stock of such non-performing loans, in turn, weakens growth by constraining credit supply and new investment.

Our approach adds at least four novel extensions to existing research on the Eurozone: (i) We explain the emergence of non-performing loans by bankruptcy shocks in the business sector, thereby providing a rough 'micro-foundation' of the non-performing loans problem of banks that originates in the real sector. (ii) We introduce an effect of sovereign bond prices with long-lived government debt on banks' balance sheets and thereby introduce an important link reflecting the doom loop between banks and sovereigns. (iii) We introduce an equity channel of bank lending. Using the framework of Begenau (2020), we model inertia in bank dividends that slows down equity accumulation. This restricts bank credit supply after large losses in a crisis. (iv) We offer a detailed modeling of fiscal consolidation rules mimicking the Maastricht debt and deficit rules. This captures the difficulty of highly indebted countries in providing strong fiscal stabilization when monetary policy is centralized. All these extensions are central in our analysis of an asymmetric recession in a currency union and of the consequences of a potential exit.

The remainder of the paper is organized as follows. Section 2 sets out the model, and Section 3 provides the quantitative analysis. Section 4 concludes.

2 The Model

We propose a monetary DSGE model with three regions, a domestic economy (Italy), the rest of the Eurozone (RoE), and the rest of the world (RoW). Italy and RoE form a currency union with common monetary policy and a fixed exchange rate. The focus is on the domestic economy, which is subject to nominal wage rigidity and faces a 'trilemma' of high public debt, weak banks, and stagnant growth. The rest of the Eurozone and the rest of the world are more stylized. The model presentation is in nominal terms and highlights the key transmission channels. We refer to the Technical Appendix for a complete documentation (Keuschnigg, 2022).

2.1 Firms

Firms produce output with capital and specialized labor. Capital structure choice between debt (bank loans) and equity rationalizes loan demand. A stylized bankruptcy process explains the origins of non-performing loans which impose losses on banks.

Technology: Firms produce output using capital and a bundle of specialized labor services, subject to productivity shocks Z_t,

$$Y_t = Z_t K_{t-1}^{\alpha} L_t^{1-\alpha}, \quad L_t = \left[\int_0^1 L_{jt}^{(\sigma-1)/\sigma} dj \right]^{\sigma/(\sigma-1)}, \quad \sigma > 1. \tag{1}$$

Minimizing wage costs, $\min_{L_{jt}} \int_0^1 w_{jt} L_{jt} dj$, gives demand for specialized labor services,

$$L_{jt} = \left(w_t^L / w_{jt} \right)^{\sigma} L_t, \quad w_t^L = \left[\int_0^1 w_{jt}^{1-\sigma} dj \right]^{1/(1-\sigma)}, \tag{2}$$

where w_t^L denotes the nominal wage index. Total labor cost is $w_t^L L_t = \int_0^1 w_{jt} L_{jt} dj$.

Capital Structure: Each period, firms invest an amount $\bar{I}_t$ of new capital goods, which are a bundle of domestic goods and imports. Total investment cost is $\bar{P}_t(\bar{I}_t + J_t)$, where $\bar{P}_t$ is the price index and $J_t = \psi^k K_{t-1} \left(\bar{I}_t / K_{t-1} - \delta^k - s_t \right)^2 / 2$ are installation costs. Capital depreciates at a rate $\delta + s_t$ where s_t are capital losses due to bankruptcy,

$$K_t = \bar{I}_t + \left(1 - \delta^k - s_t \right) K_{t-1}, \quad B_t^l = N_t^l + \left(1 - \delta^k - s_t \right) B_{t-1}^l. \tag{3}$$

Firms finance assets K_t with bank loans and equity. Given N_t^l new loans, the stock of debt grows by (3.ii). When the underlying capital good depreciates, firms repay $\delta^k B_{t-1}^l$ of their debt. A share s_t of businesses faces bankruptcy and cannot repay. Banks can seize the underlying capital goods and sell them at a discount. Depending on the discount, *non-performing loans* can impose substantial losses on banks.

The debt capacity of firms is constrained to a fraction b^k of total assets,

$$B_t^l \leq b^k \cdot \bar{P}_t K_t. \tag{4}$$

Profit Maximization: Firms earn profits equal to revenue $P_t Y_t$ net of wage cost $w_t^L L_t$, installation cost $\bar{P}_t J_t$, cost of debt $i_t^l B_{t-1}^l$ with i_t^l denoting the loan rate, and must pay a tax at rate τ_t^k. Investment spending $\bar{P}_t \bar{I}_t$ is financed with new debt N_t^l and retained earnings. After debt repayment $\delta^k B_{t-1}^l$, owners are left with net of tax dividends

$$\chi_t^k = \left(1-\tau_t^k\right)\left(P_t Y_t - \bar{P}_t J_t - w_t^L L_t - i_t^l B_{t-1}^l\right) - \bar{P}_t \bar{I}_t + N_t^l - \delta^k B_{t-1}^l. \tag{5}$$

Owners require a return on equity $i_t^k = i_t + \theta_t^k$ and discount future dividends accordingly (i_t is the safe deposit rate and θ_t^k an exogenous equity premium). Firms optimally choose employment, new debt and investment to maximize the present value of future dividends, $V_t = \max_{\bar{I}_t, N_t^l, L_t} \chi_t^k + V_{t+1}/\left(1+i_t^k\right)$, subject to the leverage constraint (4) and the laws of motion. We replicate the observed interest rate structure with appropriate assumptions on equity premia. Given $i_t^k > i_t^l$, the debt constraint is binding, $B_t^l = b^k \cdot \bar{P}_t K_t$. Capital accumulation thus determines loan demand. Demand for the composite labor input satisfies the standard optimality condition $P_t F_{L,t} = w_t^L$. Optimal investment is

$$\bar{I}_t = \left[\delta^k + s_t + \frac{Q_t^k - \left(1-b^k\right)}{\left(1-\tau_t^k\right)\psi^k}\right] \cdot K_{t-1}, \quad Q_t^k \equiv \frac{\lambda_{t+1}^f}{\left(1+i_t^k\right)\bar{P}_t}. \tag{6}$$

Investment must replace depreciated capital $\left(\delta^k + s_t\right) K_{t-1}$. Net investment becomes positive whenever the marginal value of equity capital, as measured by Q_t^k, exceeds marginal retained earings, $1-b^k$. The shadow price λ_{t+1}^f measures the expected value of equity, equal to the present value of marginal future dividends discounted with the required return on equity i_t^k. Investment is thus driven by Tobin's Q-theory with taxes.

2.2 Households

Households are extended families of size $\bar{N}$ and provide full insurance to household members. They earn income from different assets and provide specialized labor services. Given specialization, they enjoy local market power in wage setting.

Preferences: Households derive contemporaneous utility from consuming a bundle $\bar{C}_t$ of domestic and imported goods, holding real money balances $\bar{M}_t = M_t/\bar{P}_t$, and supplying labor of type $N_{j,t}$ by household member $j \in [0,1]$,

$$u_t\left(\bar{C}_t, \{N_{j,t}\}, \bar{M}_t\right) = \frac{\left[\bar{C}_t - \Phi\left(\{N_{j,t}\}\right)\right]^{1-1/\sigma^c}}{1-1/\sigma^c} + m_t^{1/\sigma^m} \frac{\bar{M}_t^{1-1/\sigma^m}}{1-1/\sigma^m}. \tag{7}$$

Total effort cost of labor supply is $\Phi_t \equiv \phi_t^{-1/\eta} \int_0^1 N_{jt}^{1+1/\eta} \bar{N} dj / (1+1/\eta)$, where η corresponds to the Frisch elasticity of labor supply, and ϕ_t is a preference shifter. Given family size $\bar{N}$, total labor supply of variety j is $N_{jt}\bar{N}$.

To model trade flows, we consider goods that are differentiated by geographic origin and use the same aggregator for consumption and investment demand. Composite consumption $\bar{C}_t = \left[\sum_j (s^j)^{1/\sigma^r} \left(C_t^{ij}\right)^{(\sigma^r-1)/\sigma^r}\right]^{\sigma^r/(\sigma^r-1)}$ is a basket of domestic goods $C_t = C_t^{ii}$ and imports from the rest of the Eurozone C_t^{ie} and the rest of the world $C_t = C_t^{io}$ where the second index $j = \{i, e, o\}$ refers to the source country. σ^r is the Armington trade (substitution) elasticity. The exchange rate e_t^{ij} is defined as domestic currency per unit of foreign currency (e.g., one Euro is e_t^{ij} of the domestic currency, which we refer to as 'Lire'). Within the currency union, the exchange rate is fixed at $e_t^{ie} = 1$. Accordingly, prices of domestic and import goods are P_t, $P_t^{ie} = e_t^{ie} \cdot P_t^e$, and $P_t^{io} = e_t^{io} \cdot P_t^o$ (with $P_t^o = 1$ being the numeraire). Goods demand is

$$C_t^{ij} = s^j \left(\bar{P}_t/P_t^{ij}\right)^{\sigma^r} \bar{C}_t, \quad \bar{P}_t = \left[\sum_j s^j \left(P_t^{ij}\right)^{1-\sigma^r}\right]^{1/(1-\sigma^r)}. \tag{8}$$

The *consumer price index* is $\bar{P}_t$, and spending equals $\bar{P}_t\bar{C}_t = \sum_j P_t^{ij} C_t^{ij}$.

Utility Maximization: Households earn wages w_{jt} for differentiated services $N_{j,t}$, pay income and consumption taxes at rates τ_t and τ_t^c, and receive social transfers E_t, seignorage T_t^M, and capital income χ_t^A from all sources other than residual savings A_t (international bonds). The nominal budget is

$$\begin{aligned} A_t &= (1+i_{t-1}) A_{t-1} + \int_0^1 (1-\tau_t) w_{jt} N_{jt} \bar{N} dj + E_t \\ &: \quad +\chi_t^A + T_t^M - (M_t - M_{t-1}) - (1+\tau_t^c) \bar{P}_t \bar{C}_t. \end{aligned} \tag{9}$$

Households choose consumption $\bar{C}_t$, real money balances $\bar{M}_t$, and set a wage w_t^* whenever a new wage setting opportunity emerges (see below). Maximizing life-time utility $V_t^h = \max_{\bar{C}_t, \bar{M}_t, w_t^*} u\left(\bar{C}_t, \{N_{j,t}\}, \bar{M}_t\right) + \beta_t V_{t+1}^h$ gives

$$u_{\bar{C},t} = \beta_t (1+r_t) \cdot u_{\bar{C},t+1}, \quad \frac{u_{\bar{M},t}}{u_{\bar{C},t}} = \frac{1}{1+\tau_t^c} \frac{i_t}{1+i_t}, \tag{10}$$

where $u_{\bar{C},t} \equiv du_t/d\bar{C}_t$ and $u_{\bar{M},t} \equiv du_t/d\bar{M}_t$ are marginal utilities. Using (7) relates demand for real money balances $\bar{M}_t = m_t \cdot \left[\frac{1+i_t}{i_t}(1+\tau_t^c) H_t^{1/\sigma^c}\right]^{\sigma^m}$ to consumption leisure utility $H_t \equiv \bar{C}_t - \Phi_t$, with σ^m governing the interest elasticity of money demand. The Euler equation determines intertemporal allocation depending on the real interest rate r_t,

$$1 + r_t = \frac{1+i_t}{1+\pi_t}, \quad 1+\pi_t = \frac{\left(1+\tau_{t+1}^c\right) \bar{P}_{t+1}}{(1+\tau_t^c) \bar{P}_t}. \tag{11}$$

Wage Setting: Individuals of type j are organized in a 'small union' and face demand $L_{j,t}$ for differentiated services as in (2), $L_{j,t} = N_{j,t}\bar{N}$. A monopolist of type j exploits local market power, taking the wage index w_t^L and aggregate demand L_t as given. A real wage after taxes equal to the marginal rate of substitution $MRS_{j,t} = -u_{N_{j,t}}/u_{\bar{C},t}$ would just compensate individuals for labor effort. Due to limited market power, unions can do better by restricting labor supply and insisting on a mark-up over the $MRS_{j,t}$. In a steady state where all marginal valuations and, in turn, old and new wages are the same, the real wage is

$$\frac{(1-\tau) w^*}{(1+\tau^c) \bar{P}} = \frac{\sigma}{\sigma - 1} \cdot MRS. \tag{12}$$

In the short term, however, nominal wages are rigid. Following Calvo (1983) and Gali (2015), we assume that only a *random fraction* $1-\omega$ of workers can optimally set wages in period t. We denote the wage paid in t but set in $t-i$ by $w_{t-i,t}$. The wage chosen in t is $w_{t,t} = w_t^*$ and remains constant thereafter, until a new wage setting opportunity arrives. In consequence, setting a new wage w_t^* is forward-looking since it determines not only current, but also expected future income. We thus replace the right-hand side of (12) by a present value of marginal valuations: The optimal wage w_t^* equates the current real wage with an average of present as well as expected and discounted future valuations $MRS_{t,t+i}$. Note that only a fraction $1-\omega$ of wages are re-optimized while the remaining part ω of contracts are stuck with previously set wages as reflected in last period's wage index w_{t-1}^L. In consequence, the wage index, which determines total labor demand and employment, changes only with some delay,

$$\left(w_t^L\right)^{1-\sigma} = (1-\omega)\cdot\left(w_t^*\right)^{1-\sigma} + \omega\cdot\left(w_{t-1}^L\right)^{1-\sigma}. \tag{13}$$

In a steady-state, the wage index is $w^L = w^*$. New and old wages are equal, as in (12).

2.3 Government

Spending and Taxes: Fiscal spending consists of productive services $P_t G_t$ and social transfers E_t. In the spirit of Barro (1990), the government accumulates infrastructure K_t^G, which boosts total factor productivity Z_t in (1),

$$K_t^G = G_t + (1-\delta^g)\,K_{t-1}^G, \quad Z_t = (1-\rho)\,\bar{Z}\left(1+\sigma^z\left(K_{t-1}^G - \bar{K}^G\right)/\bar{K}^G\right) + \rho Z_{t-1} + \varepsilon_t^Z. \tag{14}$$

Tax revenue T_t stems from taxing wage income, firm profits and consumption at rates τ_t, τ_t^k and τ_t^c, respectively.

Sovereign Bonds: The government issues long-term sovereign bonds sold to domestic banks and households. Each period, a bond is repaid at face value with probability μ and continues with probability $1-\mu$. Expected duration is $1/\mu$. Given new bond issues N_t^G, the stock of sovereign bonds accumulates by

$$B_t^G = N_t^G + (1-\mu)\,B_{t-1}^G, \quad (1+i_t^g)\,Q_t = \bar{\imath} + \mu + (1-\mu)\,Q_{t+1}. \tag{15}$$

Investors require a return $i_t^g = i_t + \theta_t^g$ accruing in $t+1$, which includes a sovereign risk-premium. Given a fixed coupon rate $\bar{\imath}$ and a repayment rate μ, the bond price Q_t must adjust to generate the required return. Since $\bar{\imath}$ and μ are symmetric, all bonds trade at the same price Q_t, independent of their issuance date.

Fiscal Policy: The value of new bond issues $Q_t N_t^G$ and the primary surplus S_t^G must finance interest expenses and repayment of outstanding bonds,

$$\bar{\imath} B_{t-1}^G + \mu B_{t-1}^G = Q_t N_t^G + S_t^G, \quad S_t^G \equiv T_t - P_t G_t - E_t. \tag{16}$$

To stabilize sovereign debt, the government adopts a consolidation policy. In the spirit of the Maastricht rules, we assume government to target a long-run debt-to-GDP ratio $\bar{b}^g$, which it aims to approach with a given adjustment speed. Since the Maastricht criteria allow for temporary deviations, we distinguish actual and structural surpluses, S_t^G and $\tilde{S}_t^G$, with the difference arising from temporary spending shocks and revenue fluctuations. We thus specify a fiscal consolidation rule that targets a structural surplus $\tilde{S}_t^G$,

$$\tilde{S}_t^G = [\bar{\imath} + \mu + (1-\mu) Q_t - \gamma^g Q_t]\, B_{t-1}^G - (1-\gamma^g)\, \bar{b}^g P_t Y_t, \quad 0 < \gamma^g < 1. \tag{17}$$

Absent fiscal shocks, structural and actual surpluses are identical, $S_t^G = \tilde{S}_t^G$. Using (16) and (15.i), the consolidation rule becomes $Q_t B_t^G = \gamma^g Q_t B_{t-1}^G + (1-\gamma^g)\, \bar{b}^g P_t Y_t$ in this case. The value of sovereign debt thus converges with speed γ^g to the debt to GDP target $\bar{b}^g$.

Targeting a structural surplus $\tilde{S}_t^G$ requires to adjust spending and tax policies by

$$\begin{aligned} P_t G_t &= \bar{g} \cdot P_t Y_t - \xi^g \cdot \tilde{S}_t^G + \varepsilon_t^G, \\ E_t &= \bar{e} \cdot w_t^L L_t - \xi^e \cdot \tilde{S}_t^G + \varepsilon_t^E, \\ T_t &= \bar{g} \cdot P_t Y_t + \bar{e} \cdot w_t^L L_t + (1 - \xi^g - \xi^e) \cdot \tilde{S}_t^G. \end{aligned} \tag{18}$$

Given spending shocks ε_t^G, productive spending fluctuates around a normal GDP ratio $\bar{g}$, but is subject to spending cuts to finance a share ξ^g of the required structural surplus $\tilde{S}_t^G$. The same applies to social transfers. The required tax revenue T_t covers the structural part of public spending, $\bar{g} P_t Y_t + \bar{e} w_t^L L_t$, plus tax increases of $(1 - \xi^g - \xi^e)\, \tilde{S}_t^G$, which are needed to reduce public debt. The government must adjust all tax rates on income, profit and consumption by a common factor t_t^s such that tax revenue matches this target level.

The parameters ξ^e and ξ^g determine whether consolidation is tax or expenditure based; low values indicate that budget consolidation is mostly tax based. We thus connect to research on the effectiveness of tax- versus spending-based consolidation (e.g., Alesina et al., 2015). Higher tax rates discourage labor supply and investment and slow down growth. Productive spending cuts eventually impair total factor productivity, see (14).

2.4 Banks

We explicitly model two major sources of asset risk that contribute to bank equity losses, namely, non-performing loans and sovereign bond holdings. Given that equity mostly stems from retained earnings, losses are offset only gradually. Since capital regulation restricts leverage, the equity shortage constrains credit supply.

Balance Sheet: Non-performing loans (NPL) have been a key challenge for many European banks after the crisis. Italian banks recorded one of the highest NPL ratios in Europe after the financial crisis. We add a stochastic process of bankruptcy rates of firms (see 3) which determines the NPL ratio and is related to macroeconomic fundamentals,

$$s_t = (1-\rho^s)\left[\bar{s} + \sigma^s \cdot \left(\bar{Y}_t - Y_t\right)/\bar{Y}_t\right] + \rho^s s_{t-1} + \varepsilon^s_t. \tag{19}$$

Depending on σ^s, the share of non-performing loans rises in a recession when actual output falls short of potential output, $Y_t < \bar{Y}_t$.

Moreover, banks are major buyers of sovereign bonds, which exposes them to large price fluctuations during a public debt crisis. We assume that banks purchase a share $\tilde{s}^b$ of bonds issued by the government. Newly acquired and total bond holdings are $N^g_t = \tilde{s}^b N^G_t$ and $B^g_t = \tilde{s}^b B^G_t$, respectively. Trading results in bond turnover

$$B^g_t = N^g_t + (1-\mu-\delta)\, B^g_{t-1}, \quad V^g_t = Q_t N^g_t + (1-\mu-\delta)\, V^g_{t-1}. \tag{20}$$

In each period, a fraction μ of sovereign bonds is paid back. In addition, banks sell a fraction $\delta < 1-\mu$ of bonds each period at the market price Q_t. This forces them to realize gains or losses so that price fluctuations affect the balance sheet. The book value of bonds in terms of acquisition costs is $V_t^g = \sum_i Q_{t-i} B_{t-i,t}^g$. Since bonds purchased at date $s < t$ are sold off at rate $\mu + \delta$, stocks shrink by $B_{s,t}^g = (1 - \mu - \delta)\, B_{s,t-1}^g$. The book value of bond holdings thus changes by (20.ii). Two limiting cases are informative: For $\delta = 0$, banks hold bonds to maturity and turnover is very slow. For $\delta = 1 - \mu$, banks replace the entire stock of outstanding bonds by new ones each period such that $B_t^g = N_t^g$ and $V_t^g = Q_t B_t^g$. Market and book values coincide, and the bank immediately realizes gains and losses due to fluctuating bond prices.

At the end of period t, assets consist of loans B_t^l and sovereign bond holdings worth V_t^g, and are financed with equity E_t^b and deposits D_t. The balance sheet identity is $B_t^l + V_t^g = E_t^b + D_t$. Accordingly, the flow constraint implies that new loans N_t^l and sovereign bond purchases $Q_t N_t^g$ need to be financed with new deposits, $N_t^d = D_t - D_{t-1}$, and equity (retained earnings), $N_t^l + Q_t N_t^g = N_t^d + N_t^b$. Retained earnings N_t^b augment bank equity which evolves by $E_t^b = E_{t-1}^b + N_t^b - (\delta^k + s_t) B_{t-1}^l - (\delta + \mu) V_t^g$. Any reduction in assets due to repayment, depreciation, write-offs, or realization of gains or losses lead to a corresponding reduction in equity which may be offset by retained earnings.

Eventually, capital structure is largely determined by minimum capital requirements. Equity must be at least a fraction κ^B of loans and κ^G of the value of sovereign bonds,

$$E_t^b \geq \kappa^B B_t^l + \kappa^G V_t^g. \tag{21}$$

Dividends: Inflows consist of earnings on loans and bonds. Outstanding loans generate interest earnings $i_t^l B_{t-1}^l$. A part δ^k is repaid in full, while a share s_t defaults and fails to repay. By liquidating underlying assets, banks recover a share $1 - \ell_t$ of these loans and realize a loss ℓ_t per loan, giving revenues of $(1 - \ell_t)\, s_t B_{t-1}^l$. Sovereign bond holdings yield revenue $(\bar{\imath} + \mu)\, B_{t-1}^g$ from coupon plus repayment, and δB_{t-1}^g from selling a part δ at a price Q_t prior to maturity. Finally, sourcing new deposits adds N_t^d. Outflows are interest on deposits $i_{t-1}^d D_{t-1}$, new lending N_t^l, bond purchases $Q_t N_t^g$ and dividends χ_t,

$$\begin{aligned} & i_t^l B_{t-1}^l + \delta^k B_{t-1}^l + (1 - \ell_t)\, s_t B_{t-1}^l + (\bar{\imath} + \mu)\, B_{t-1}^g + \delta Q_t B_{t-1}^g + N_t^d \\ & \quad = i_{t-1}^d D_{t-1} + N_t^l + Q_t N_t^g + \chi_t^b. \end{aligned} \tag{22}$$

Banks accumulate equity with retained earnings. Noting the balance sheet identity and the flow constraints to replace D_{t-1} and N_t^l, retained earning are

$$\begin{aligned} N_t^b = \; & \left(i_t^l + (1-\ell_t)\, s_t + \delta^k - i_{t-1}^d\right) B_{t-1}^l + i_{t-1}^d E_{t-1}^b \\ & + (\bar{\imath} + \mu + \delta Q_t)\, B_{t-1}^g - i_{t-1}^d V_{t-1}^g - \chi_t^b. \end{aligned} \tag{23}$$

When banks need to accumulate equity by retaining more earnings, they could cut dividends χ_t^b. However, there are limits because shareholders value steady dividends close to a benchmark $\bar{\chi}^b$. Reducing dividends below this benchmark meets progressive resistance, whereas owners are concerned about an erosion of equity if banks pay out too much. To capture dividend inertia, we follow Begenau (2020) by introducing convex adjustment costs, $z\left(\chi_t^b\right) = \frac{1}{2}\psi^b\left(\chi_t^b - \bar{\chi}^b\right)^2$, measured in units of the investment good. Shareholders thus receive a net dividend of $\chi_t^b - z\left(\chi_t^b\right)\bar{P}_t$ only. Losses on loans and bonds are thus primarily absorbed by retained earnings N_t^b as in (23). Dividend inertia slows down internal equity accumulation. Together with the minimum capital requirements in (21), this tends to constrain credit supply whenever banks recover from large losses.

Optimization: Shareholders require a return on equity $i_t^b = i_t + \theta_t^b$ including a premium. Bank managers choose new loans and retained earnings to maximize shareholder value $V_t^b = \max_{N_t^l, N_t^b} \chi_t^b - z\left(\chi_t^b\right)\bar{P}_t + V_{t+1}^b / \left(1 + i_t^b\right)$, subject to the minimum capital requirements in (21). The Technical Appendix details the optimality and envelope conditions of the Bellman problem. Since equity is more expensive than deposits, $i_t^b > i_t^d$, the regulatory constraint binds. Banks set an optimal loan interest rate

$$i_t^l = \kappa^B \cdot \tilde{\imath}_t^b + \left(1 - \kappa^B\right) \cdot i_{t-1}^d + \ell_t s_t, \quad \tilde{\imath}_t^b \equiv \left(1 + i_t^b\right) \lambda_t^b / \lambda_{t+1}^b - 1. \tag{24}$$

Given dividend adjustment costs, the effective cost of equity $\tilde{\imath}_t^b$ may temporarily deviate from the required return i_t^b. The shadow price of equity, $\lambda_t^b \equiv dV_t^b / dE_{t-1}^b$, reflects the present value of marginal dividends created by an increase in retained earnings today (as in a 'Q-theory of bank equity'). A shortage of equity thus leads to a high valuation λ_t^b today relative to the future and thereby implies a high cost of equity $\tilde{\imath}_t^b$. Higher effective funding costs are passed on to borrowers via a higher loan rate, which is an average of the cost of equity and deposits plus a premium $\ell_t s_t$ to cover credit risk.

2.5 International Equilibrium

The domestic economy (Italy) trades with the rest of the Eurozone and the rest of the world (RoW). Given our focus on Italy, we abstract from fiscal policy, banks, firms, and labor in the other two regions. Furthermore, Italy borrows internationally by issuing (net) foreign debt purchased exclusively by Eurozone investors.

Current Account: The trade balance TB_t is equal to the value of exports minus imports. Households are invested in domestic equity, supply deposits to banks, hold part of government debt, and derive income χ_t^A from those investments.[1] Any residual savings (borrowing) in (9) is in foreign bonds held by Eurozone investors, $B_t^f = A_{t-1} < 0$. Net foreign debt, denominated in domestic currency, pays interest i_{t-1} and grows by

$$B_t^f = (1 + i_{t-1}) B_{t-1}^f + TB_t, \quad TB_t = P_t E_t^x - P_t^{ie} \left(C_t^{ie} + I_t^{ie}\right) - P_t^{io} \left(C_t^{io} + I_t^{io}\right). \tag{25}$$

As noted in (8), exchange rates convert prices in foreign into domestic currency. As long as the domestic economy is part of the Eurozone, the internal exchange rate is fixed, $e_t^{ie} = 1$, giving $P_t^{ie} = P_t^e$. With separate currencies and free capital flows, the Lire/Euro exchange rate must adjust to satisfy a modified interest rate parity condition,

$$(1 + i_t) e_t^{ie} / e_{t+1}^{ie} = (1 + i_t^e) \theta_t^f. \tag{26}$$

Following Schmitt-Grohé and Uribe (2003), we assume that the risk-premium θ_t^f on Italian bonds increases in the country's foreign debt-to-GDP ratio b_t^f. With net debt, the return on Italian bonds (in Euros) must exceed the return on a Eurozone bond i_t^e. The country premium thus adjusts by

$$\theta_t^f = \left(1 - \rho^f\right) \left[1 + \gamma \left(e^{b_t^f - \bar{b}^f} - 1\right)\right] + \rho^f \theta_{t-1}^f + \varepsilon_t^f, \quad b_t^f \equiv B_t^f / (P_t Y_t). \tag{27}$$

In a steady state, interest and exchange rates are constant and equal to $i = i^e = 1/\beta$ to support stationary consumption. The country premium must vanish, $\theta^f = 1$, giving $b^f = \bar{b}^f$. The debt to GDP ratio must return to its long-run natural value.

[1] In total, $\chi_t^A = \chi_t^k + \chi_t^b - z_t \bar{P}_t + \left(i_{t-1}^d D_{t-1} - N_t^d\right) + (\bar{\imath} + \mu) B_{t-1}^h - Q_t N_t^h$, see the Technical Appendix.

Rest of the Eurozone: Production is given by a process

$$Y_t^e = \left(1 - \rho^{Y,e}\right) Y_0^e + \rho^{Y,e} Y_{t-1}^e + \varepsilon_t^{Y,e}. \tag{28}$$

Given income $P_t^e Y_t^e$, households choose intertemporal consumption and money demand. Preferences are similar to (7), except that labor supply is fixed. As in (10), consumption growth rises with higher real interest, and the demand for real money balances $\bar{M}_t^e$ falls with higher nominal interest i_t^e. With current consumption $\bar{C}_t^e$ determined by intertemporal optimization, households allocate spending on home goods and imports,

$$\bar{P}_t^e \bar{C}_t^e = P_t^e C_t^e + P_t^{ei} C_t^{ei} + P_t^{eo} C_t^{eo}, \tag{29}$$

where $P_t^{ei} = P_t^i / e_t^{ie}$ and $P_t^{eo} = P^o e_t^{eo}$ are Euro prices of imports from Italy and RoW. Goods demand is parallel to (8). The trade balance $TB_t^e = P_t^e E_t^{x,e} - P_t^{ei} C_t^{ei} - P_t^{eo} C_t^{eo}$ and the current account are the mirror image of (25). Net foreign debt of Italy corresponds to net foreign assets of the Eurozone.

Rest of the World: All other countries (indexed by o) are modeled even simpler. The fixed endowment of the final good serves as the *numeraire*, $P^o = 1$. We thus abstract from monetary policy in RoW. Similarly, we abstract from savings and capital flows as consumers simply allocate their endowment to different goods. Demand for Italian and Eurozone exports mirrors (8), except that demand levels are given by s^{oi} and s^{oe},

$$C_t^{oi} = s^{oi} \cdot \left(e_t^{io} / P_t\right)^{\sigma_r}, \quad C_t^{oe} = s^{oe} \cdot \left(e_t^{eo} / P_t^e\right)^{\sigma_r}. \tag{30}$$

Without capital flows, trade is balanced in RoW, $TB_t^o = P^o E_t^{x,o} - P_t^{oe} C_t^{oe} - P_t^{oi} C_t^{oi} = 0$.

2.6 Currency Union and Monetary Policy

We distinguish between (i) monetary policy in a currency union consisting of Italy and the rest of the Eurozone and (ii) an autonomous monetary policy in either region. The exchange rate e_t^{ie} is fixed in a currency union and flexible otherwise. We analyze fluctuations around a steady state with constant money supply and zero inflation. Money demand follows Gali (2020), among others, who combines this with alternative money supply rules. We relate money supply to the output gap and inflation, as in Ascari and Ropele (2013) and Sargent and Surico (2011).

In a *currency union*, monetary policy is centralized, and money supply must accommodate total demand for real balances in both regions, $M_t^{s,u} = \bar{P}_t \bar{M}_t + \bar{P}_t^e \bar{M}_t^e$. Money supply is based on the state of the whole union. Specifically, common monetary policy targets inflation and the output gap,

$$M_t^{s,u} = (1-\rho^m)\,\phi^{m,u}\bar{Y}_{t-1}^u \cdot \frac{\left(\bar{Y}_t^u / Y_t^u\right)^{\psi_y}}{\left(1+\pi_t^u\right)^{\psi_\pi}} + \rho^m M_{t-1}^{s,u} + \varepsilon_t^{m,u}. \tag{31}$$

Actual and potential output in the Eurozone is $Y_t^u = Y_t + Y_t^e$ and $\bar{Y}_t^u = \bar{Y}_t + \bar{Y}_t^e$.[2] Inflation is the growth rate of the average price level $\bar{P}_t^u = s^Y \bar{P}_t + \left(1-s^Y\right) \bar{P}_t^e$ where s^Y is the nominal output weight $s^Y = PY/\left(PY + P^e Y^e\right)$. Since monetary policy aims at dampening fluctuations around trend, money supply consists of a trend and a cyclical component: The trend component $\phi^m \bar{Y}_{nt-1}$ accounts for a permanent increase in output. The cyclical part dampens short-run fluctuations, depending on parameters ψ_y and ψ_π. If current output is below trend, $Y_t^u < \bar{Y}_{t-1}^u$, money supply scales up by a factor $\left(\bar{Y}_t^u / Y_t^u\right)^{\psi_y} > 1$. If actual inflation exceeds the trend rate ($\pi_t^u > 0$), it is scaled down by $1/\left(1+\pi_t^u\right)^{\psi_\pi} < 0$. However, the smaller the domestic economy relative to the currency union, the weaker is the common monetary policy response to fluctuations in the domestic economy.

In an *autonomous regime*, money markets are separate, $M_t^s = \bar{P}_t \bar{M}_t$ and $M_t^{s,e} = \bar{P}_t^e \bar{M}_t^e$. Monetary policy is decentralized and tailored to local conditions (e.g., local output gap and inflation). Money supply exclusively depends on the state of the domestic economy,

$$M_t^s = (1-\rho^m)\,\phi^m \bar{Y}_{t-1} \cdot \frac{\left(\bar{Y}_t / Y_t\right)^{\psi^{yi}}}{\left(1+\pi_t\right)^{\psi^{\pi i}}} + \rho^m M_{t-1}^s + \varepsilon_t^m. \tag{32}$$

Monetary policy in the rest of the Eurozone is modeled in parallel. Exit from the Eurozone reflects a regime change from common to separate monetary policy.

[2]Potential output is a slow moving average $\bar{Y}_t = (1-\rho^y)\,Y_{ss} + \rho^y \bar{Y}_{t-1}$ of past realizations, and similarly $\bar{Y}_t^e$. Potential output eventually converges to the steady state value Y_{ss}.

3 Quantitative Analysis

3.1 Calibration and Estimation

Parameters and Structural Data: We calibrate a stationary state and estimate selected parameters and shock processes to track past economic performance. We use detrended quarterly data. After detrending, growth and inflation rates are zero. Model solutions thus reflect deviations from long-run rates. We normalize Italian GDP to 100 so that all macro data are interpreted in percent of GDP. We infer relative country size from Eurostat and Worldbank data. Italy produced 18% of Eurozone GDP which, in turn, accounted for 17% of world GDP.

Table 1 lists key parameters and data that are calibrated. Appendix Table A.1 reports selected estimated parameters. By OECD data, Eurozone sovereign bonds paid an annual rate of roughly 4%, largely the same in all member states. The prototype safe asset are long-term US treasuries, which paid on average 2% per annum. We assume that all assets other than deposits yield the same risk-adjusted return of 3% annually, corresponding to 0.75% quarterly. Eurostat data yield a typical return on equity of 2.5% (10% p.a.). The interest rate on private credit is 1.25%, or 5% p.a. We calibrate the discount factor β and the risk premia θ to support these interest rates and returns in stationary equilibrium.

Preferences are calibrated in line with prior research: We use a Frisch labor supply elasticity of 0.4 (Keane and Rogerson, 2012; Chetty et al., 2011). The intertemporal substitution elasticity is $\sigma_c = 0.5$, a typical value as in Smets and Wouters (2003, 2005), for example. The price sensitivity of trade flows depends on the Armington elasticity of substitution between goods of different country origin. Evidence in Adolfson et al. (2007) and Obstfeld and Rogoff (2000) gives $\sigma^r = 5$. Taking this as a pior, we estimate a value of 3.93 in Table A.1. Finally, we follow Gali (2015, p.177) and set the substitution elasticity for labor varieties to $\sigma = 4.5$ and the degree of wage stickiness to $\omega = 0.8$. This is broadly consistent with Schmitt-Grohe and Uribe (2005) who rely on wage stickiness between 0.64 and 0.87 and with Erceg et al. (2000) who use a value of 0.75.

In production, we set the capital share in value added to $\alpha = 0.3$, which is close to OECD data on the income share of capital. The depreciation rate is $\delta^k = 0.03$, or 12% annually. Demand for bank credit follows from firms' debt-to-asset ratio $b^k = 0.6$, which corresponds to Eurostat data for Eurozone non-financial firms.

Table 1: Key Parameters and Data

Quarterly interest rates:		
i	0.5%	safe, benchmark interest rate
i^g	0.75%	sovereign interest rate
i^k, i^b	2.5%	required return on equity
i^l	1.25%	loan interest rate
Households:		
η	0.4	Frisch labor supply elasticity
σ	4.5	elasticity of labor substitution
σ_c	0.5	intertemporal elasticity of substitution
σ^m	0.035	interest elasticity of money demand
ω	0.8	rate of wage adjustment
Firms and banks:		
α	0.3	capital income share
b^k	0.6	debt/asset ratio firms
δ^k	0.03	capital depreciation rate
s	0.015	non performing loans (NPL) ratio
ℓ	0.3	loss share of NPL
κ^B	0.15	equity/asset ratio banks
Dynamics:		
b^f	0.88	net foreign debt/GDP ratio (quarterly)
γ	0.0124	interest sensitivity w.r.t. foreign debt

Table A.1 of the Appendix reports estimated values of autocorrelation coefficients and selected structural parameters.

Turning to the banking sector, the equity ratio of Italian banks has recently fluctuated around 15% of total assets ($\kappa^B = 0.15$) well above the minimum capital requirements of 8% for corporate credit. In the early 2000's, their non-performing loans (NPL) ratio amounted to 6.6%, substantially exceeding the 2.5% NPL ratio in the Eurozone. In the aftermath of the Eurozone crisis, this share reached a maximum of almost 18% in 2015, and declined considerably since then. We view these (large) deviations to be temporary in nature and calibrate a stationary ratio of 6% p.a., or a quarterly flow rate of 1.5%. The loss ratio on non-performing loans amounts to 30% ($\ell = 0.3$), reflecting estimates for total recovery rates between 50 and 85%.[3] The NPL ratio is sensitive to output fluctuations, and we estimate a sensitivity of $\sigma^s = 0.025$ as detailed in the Appendix.

Moreover, net foreign debt amounts to 22% of annual GDP, or 88% of quarterly GDP. An increase in net foreign indebtedness translates into a higher country premium and raises domestic interest rates. We normalize the country premium to zero in the steady state, so that $\theta = 1$ in (27). We then calibrate γ such that an increase in the debt-to-GDP ratio by 20 percentage points raises the interest rate by 25 basis points (1 percentage point annually).[4] Turning to trade flows, Italy imported 23% of GDP and exported 21%, according to Eurostat data. Of all imports, 47% were sourced from the EA and 53% from RoW. On the export side, 47% of all exports went to the EA and 53% to RoW. Using export data from RoW to all individual EA countries (except Italy), we can determine EA's import share as 19% of GDP, of which 12% stemmed from Italy and 88% from RoW.

By OECD data, the Italian public debt was 105% of annual GDP in 2006 and has grown since then to about 130% of annual GDP pre Covid, which is much higher than in the Eurozone excluding Italy. We take the pre-Covid level to be the stationary debt ratio equal to 520% of quarterly GDP, and set $\bar{b}^g = 5.2$. Banks (and other financial institutions) hold around 35% of national public debt in Italy, giving $\tilde{s}^b = 0.35$. The parameter γ^g determines the speed of fiscal consolidation. We estimate this value to be $\gamma^g = 0.98$ (see Appendix), which implies a half-life of debt adjustment of 30 quarters, or about 7.5 years. We estimate in the Appendix that 70% of consolidation results from tax increases and 30% from spending cuts. One third of spending cuts relate to social spending ($\xi^e = 0.1$),

[3] Acharya et al. (2007) report a mean loan recovery rate of 81% from a sample of non-financial US corporations over 1982-1999. Grunert and Weber (2009) find a 73% retrieval rate for German firms while Caselli et al. (2008) estimate a rate of only 48% for Italian SMEs.

[4] Specifically, we define $(1 + i_t)\, e^e_t / e^e_{t+1} \equiv 1 + \tilde{\imath}_t$ to calculate the slope $d\tilde{\imath}_t / db^f_t = (1 + i^e)\, \gamma$ where $e^{b^f - \bar{b}^f} = 1$ in a steady state. Replicating this response requires $d\tilde{\imath}_t / db^f_t = (1 + i^e)\, \gamma = .0025/.2$. Noting $i^e = i = .0075$, we find the parameter $\gamma = .0124$.

and two thirds to productive spending ($\xi^g = 0.2$).

Social spending absorbs 18.5% of GDP which is 30% of gross wage income ($\bar{e} = 0.295$). Public consumption in Italy amounts to 14.6% of GDP ($\bar{g} = .15$). Adding debt service gives a total expenditure share of 44.3% of GDP. Following Barro (1990), we allow for a positive productivity effect of productive public spending. Our estimate of $\sigma^z = 0.04$ in the Appendix is consistent with typical estimates of the output effect.[5]

Turning to money demand, Gali (2020, p.7) reports an average, quarterly income velocity of 2.7 in the Euro Area for 1999-2015. Accordingly, we set money balances to be $M^s = \bar{P}\bar{M} = \phi^m \cdot Y$ with $\phi^m = 2.7$. Taking money demand as in (10), we compute a semi-elasticity of $\frac{d\bar{M}/\bar{M}}{di} = -\frac{\sigma^m}{(1+i)i}$. Following Gali (2020) and Ireland (2009), we take empirical estimates of the (quarterly) semi-elasticity of money demand to be $\varepsilon^{md} = 7$ and accordingly calibrate $\sigma^m = (1+i)i \cdot \varepsilon^{md}$. The money supply rule (32) allows for rule based stabilization. Ascari and Ropele (2013) have estimated the sensitivities of money supply to changes in the price level and the output gap and report values between 1 and 3 for ψ_π and a range of 0 to 1 for ψ_y. We use $\psi_y = 1$ and $\psi_\pi = 2$.

Transitional dynamics depend on adjustment costs and auto-regressive shock processes: First, we assume quadratic capital installation costs in line with a large empirical literature, and allow for dividend inertia in banking as in Begenau (2020). We estimate the cost parameters at $\psi^k = 1.15$ for capital adjustment and $\psi^b = 0.25$ for dividend inertia (see Appendix). Second, short-run dynamics depend on the persistence of shock processes. We set the priors of the auto-regressive coefficients of business cycle shocks

[5]Colombier (2009) finds that an increase in spending on transport, water systems and education by one percentage point raises the per capita growth rate of real GDP by 0.5 percentage points. The estimate of Bleaney et al. (2001) is lower at 0.3 percentage points. In (14), the long-run productivity effect is $\hat{Z} = \sigma^z \hat{G}$, where $Z = \bar{Z}$ and $G = \delta^g K^G$. Assuming constant user cost and employment, technology $Y = ZK^\alpha L^{1-\alpha}$ implies $\hat{Y} = \hat{Z} + \alpha\hat{K}$ while Y_K constant yields $\hat{Y}_K = \hat{Z} - (1-\alpha)\hat{K} = 0$. Combining, the long-run output effect is $\hat{Y} = \frac{1}{1-\alpha}\hat{Z} = \frac{\sigma^z}{1-\alpha}\hat{G}$. In levels (percentage points, $dY = Y \cdot \hat{Y}$), we obtain $\frac{dY}{dG} = \frac{\sigma^z}{1-\alpha}\frac{Y}{G}$. With $\alpha = .3$ and our estimate $\sigma^z = .04$, the output effect of productive spending is $\frac{.04}{.7}\frac{100}{15} = 0.39$, well within the range of typical estimates.

(ρ-coefficients) equal to 0.95. Estimated values range from 0.94 to 0.97 (see Appendix) which results in slightly more persistent shocks compared the estimates of 0.85 and 0.95 by Smets and Wouters (2003) and Gerali et al. (2010).

3.2 Impulse Responses

Economists such as Shambaugh (2012) have argued that the combination of weak competitiveness and slow growth, high sovereign debt and banking sector risks can cause an escalating crisis. This vulnerability could threaten the stability of the Eurozone and create exit pressure in the presence of strong asymmetric shocks and a sudden loss of market confidence. To illustrate the key transmission channels of the model, we discuss the model's impulse responses to three shocks that could initiate a doom loop between the real sector, the government and banks.

3.2.1 Non-Performing Loans Shock

The first scenario is a sudden increase in the non-performing loans (NPL) ratio. Some researchers have considered shocks to the quality of capital (e.g., van der Kwaak and van Wijnbergen, 2014). We extend this idea by distinguishing between debt and equity of firms and introducing firm bankruptcy shocks. Since banks can only sell the underlying assets at a discount, the shock causes losses of the banking sector. The contagion is from the real sector to banks. When observing a larger NPL ratio, banks raise the loan rate, leading to higher borrowing costs for the real sector. In addition, increased credit losses shrink bank equity and, due to regulatory constraints, limit credit supply, which further holds back investment and growth. In the stationary equilibrium, the NPL ratio s is 1.5% per quarter or 6% per annum. To highlight this reinforcing mechanism, we impose a shock that unexpectedly increases the NPL ratio by 50%, up from 6% to 9% annually, and vanishes thereafter. An auto-regressive coefficient of $\rho^s = .95$ implies a half-life of 13 quarters. The output sensitivity $\sigma^s = .025$ induces pro-cyclical behavior so that the subsequent contraction magnifies the NPL shock.

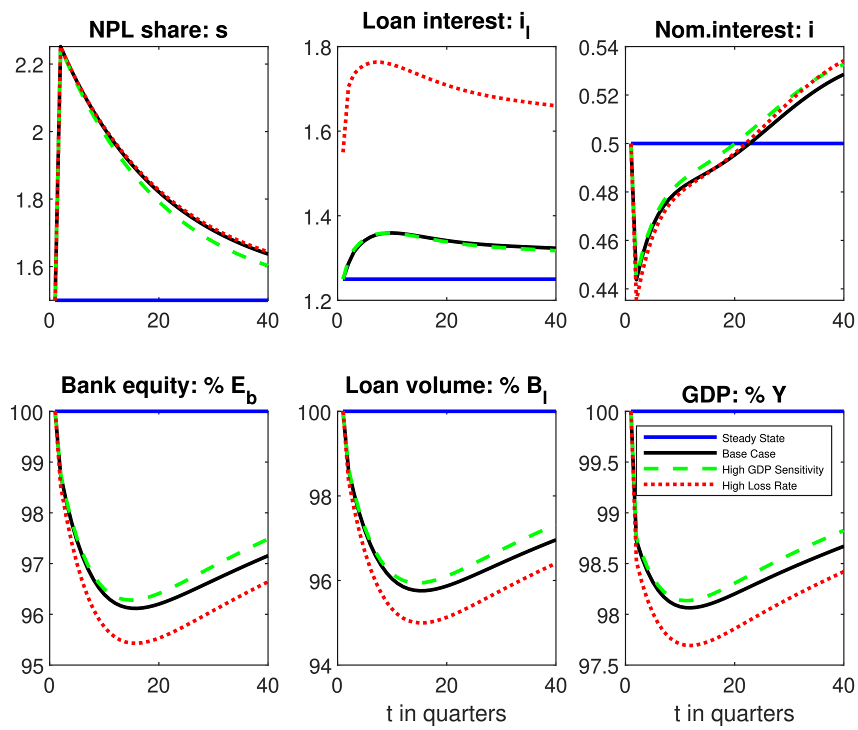

Figure 1: A Non-Performing Loan Shock

Figure 1 illustrates the short-run consequences. The black solid line gives the baseline response, the other two lines report sensitivity analyses. The first panel plots the shocked NPL ratio. Loan pricing reflects funding costs of banks plus a credit risk premium. Since the deposit rate is predetermined, the NPL shock forces banks to raise the loan rate on impact. The other direct effect is a loss in equity, which restricts lending. Hence, the loan volume, investment and GDP decline. On the firm side, the reduction in investment results from the credit crunch accompanied by a higher loan rate.

One period later, the deposit rate in line with other interest rates significantly declines, reflecting smaller funding needs. The loan rate falls in parallel. A key mechanism is dividend inertia as banks try to avoid large dividend cuts and do not instantaneously retain more earnings. Therefore, equity further declines and banks charge higher loan rates to cover credit losses as long as the loss rate is above average. Effects get weaker as the shock fades away. After about ten quarters, bank equity is lowest, almost 4% below the stationary state. The loan volume, the capital stock and GDP are at their turning point, with GDP about 1.75% below trend. As the shock eventually disappears, recovery sets in. The economy reverts back to the steady state. The recovery boosts investment demand and funding needs, which makes the interest rate overshoot.

Since bankruptcy tends to be low in booms and high in recessions, we have introduced a procyclical component of the NPL ratio (19), which magnifies macroeconomic fluctuations. To illustrate the effects of procyclicality, we shut off the output sensitivity by setting $\sigma^s = 0$. The green dashed lines show how the impulse response reactions change relative to the base case. The output losses after a shock lead to a further increase in non-performing loans and thereby make them more persistent. When the output sensitivity is shut off, the NPL ratio declines faster as the first panel shows. In consequence, the erosion of bank equity is more limited and ends earlier. For this reason, the same NPL shock produces a more moderate credit crunch and smaller output losses.

Finally, the transmission of NPL shocks to the banking sector should importantly depend on the loan recovery rate that results from frictions in liquidating capital goods after a bankruptcy. In the base case, the loan loss rate is $\ell = 0.3$, implying a recovery rate of 70%. The red dotted lines in Figure 1 illustrate the impact of the NPL shock when the loss rate is 50% and fluctuates around this higher value. Calibration with a higher loss rate shifts the path of loan interest rates to a permanently higher value, see the second panel. Starting at this higher level, the shock further increases the loan rate, which is subsequently reduced somewhat due to lower deposit interest and then follows the pattern discussed before. The key consequence of a higher loss rate is that the same shock produces larger credit losses, destroys more bank equity and magnifies the credit crunch and output losses. Since the output sensitivity of the NPL shock introduces some inertia, the recovery also gets delayed to a minor extent.

3.2.2 Sovereign Risk Premium Shock

Highly indebted countries are more prone to a loss of market confidence. We capture this by a shock to the sovereign risk premium. The sudden increase in required returns could start a sovereign-bank doom loop. Since banks typically hold a large share of domestic government bonds, a falling market value inflicts losses on them and impairs equity. Given that accumulating new equity is a slow process, the shock forces banks to deleverage and restrict credit supply. Reduced economic activity negatively feeds back on the government. We highlight this mechanism by simulating a shock that raises the required sovereign bond return by 1 percentage point quarterly (4 points annually). Thereafter, investor confidence rebounds and the premium returns to normal levels.

Base Case: The black solid lines in Figure 2 illustrate the base case. In general, effects are quite small. Even though the debt-to-GDP ratio is large (130% of annual GDP pre-Covid), the low interest rate environment (0.75% per quarter, or 3% annually) limits the fiscal burden of debt. For this reason, an isolated and temporary shock translates into a rather minor quantitative impact, with some exceptions. Our model assumes long-term bonds with an average duration of 32 quarters and a fixed coupon rate. The first panel plots the required market return on sovereign bonds. The immediate consequence of the confidence shock is a drop in the market value of about 10%, see panel 2. A large part of these bonds is held by local banks. Depending on trading behavior and bond turnover, banks experience substantial losses when selling off bonds at a lower market price. These losses impair the volume of bank equity by about one percent in this scenario (panel 3). With a binding regulatory constraint, the lower equity leads to reduced lending, which lowers investment and GDP over several quarters. As the shock fades away, sovereign bond prices recover again and reverse the adjustment. The strong recovery even leads to a slight overshooting in loan volume, which peaks after roughly 20 quarters. The maximum loss in output is about one percentage point and already occurs in the second quarter. The recovery in employment after the initial drop shifts the recovery in GDP forward. Although the government's consolidation policy allows for some temporary deficits, it has to raise tax rates and cut some spending to prevent a larger deterioration of the fiscal surplus. The effect is rather small, though.

Bond Trading: How a loss of investor confidence in sovereign bonds affects banks

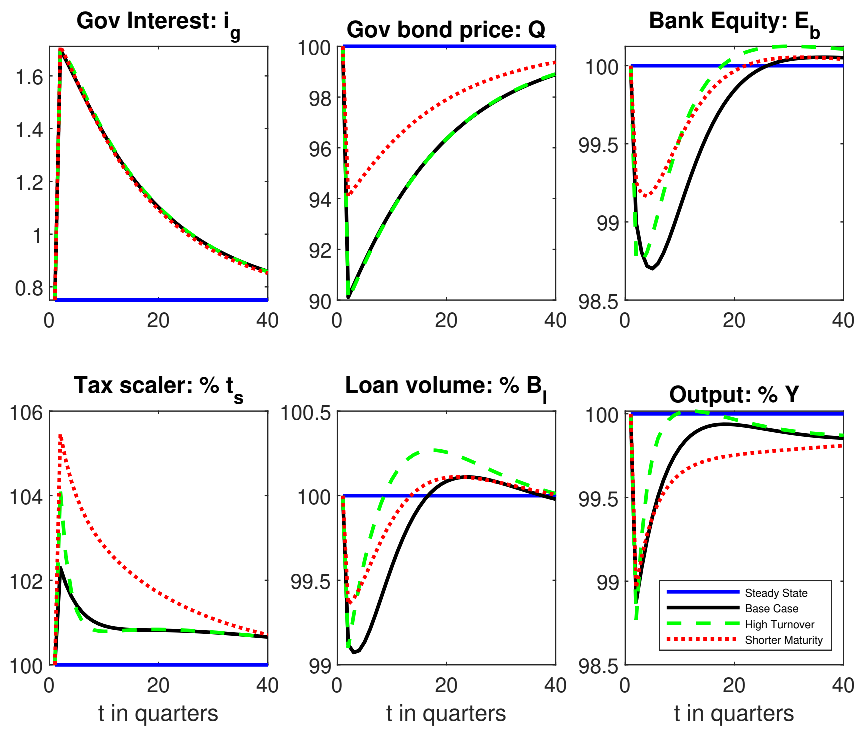

Figure 2: A Sovereign Risk Premium Shock

partly depends on the frequency of bond turnover. In the base case, banks sell off 20% of their bonds each quarter ($\delta = 0.2$) and replace them with new bonds, depending on supply. To check sensitivity, we increase the turnover rate of bond holdings to 40%. The green dashed lines highlight the consequences relative to the base case. Initially, the reduction in market valuation of bonds is largest. With more frequent trading, banks realize a larger part of losses in bond values in the first two quarters, leading to larger losses in bank equity. However, they also benefit earlier from the recovery of bond prices when trading more frequently. The reduction of bank equity due to losses on bond holdings are shifted forward in time. As a result, the credit squeeze is worse in the first two quarters but relaxes faster thereafter. This pattern transmits to the real economy and results in a sharper recession in the first quarter of the shock and a stronger recovery thereafter.

Debt Maturity: How interest rate shocks affect the government budget depends very much on the maturity structure of sovereign debt. The parameter μ is the fraction of debt to be refinanced each period, and $1/\mu$ is bond duration. With one period bonds

($\mu \to 1$), the government must fully repay and refinance the entire stock of debt. Changing interest rates would apply to the entire stock and may have quite dramatic budgetary consequences. With long-term bonds, interest rate shocks are reflected in changing bond prices, while the coupon rate remains fixed. The longer maturity $1/\mu$ is, the smaller is the share of debt to be refinanced each period. Changes in interest rates apply only to newly issued rather than old debt and affect the fiscal budget with much delay. Basically, interest rate risk is shifted from the government to private investors and banks.

In the base case, bond duration is 32 quarters (8 years), so that about 3% of debt is rolled over each quarter. We now reduce it to 10 quarters (2.5 years) so that 10% of the stock must be refinanced. Comparing the red dotted lines in Figure 2 to the black solid lines representing the base case illustrates the reasoning above. The instantaneous decline in the bond price is much lower and persists over a longer time period. The government must refinance a much larger share of debt with initially high interest rates, implying a substantial increase in the interest burden. Given fiscal consolidation rules, it must raise tax rates substantially and over a prolonged time period of about 20 quarters, with unfavorable consequences for employment and investment. This negative effect is alleviated by the banking sector since a weaker drop in bond prices inflicts smaller losses on banks and thus restricts credit supply by less. On net, the tax increases lead to higher output losses initially and over a longer period.

3.2.3 Fiscal Spending Shock

The 'Maastricht-type' consolidation rule in (17-18) is a key feature of the model. Together with high public debt, it severely restricts fiscal policy, which may be needed to stabilize the domestic economy during a recession. To illustrate the keys mechanisms of fiscal consolidation, we consider a large increase in public transfers. As a temporary spending shock, it is not part of the structural deficit but raises public debt, which activates the consolidation rule. Specifically, we add 5% of GDP to social spending (18.5% of GDP initially) over a three-year period, accumulating to 15% of initial annual GDP.[6]

The consolidation rule kicks in after the first quarter, when the debt-to-GDP ratio starts deviating from the long-run target.[7] For that reason, the total increase in public debt falls short of the cumulative spending increase, about 13% of initial annual GDP. The consolidation rule requires a mix of tax hikes and spending cuts over a prolonged period to bring the debt ratio back to its initial level. In the base case scenario, the consolidation speed corresponds to a half-life of 30 quarters (7.5 years, parameter $\gamma^g = 0.98$, roughly corresponding to the Maastricht rules).[8] In line with recent experience, consolidation is mostly tax based, with cuts in productive and social spending contributing only 20 and 10% to consolidation.

Base Case: The black solid lines in Figure 3 show the effects of the spending shock which lasts for 12 quarters. At the end of the deficit period, the face value of public debt is almost 10% higher, raising the debt-to-GDP ratio by 13 ($= 130 \times 0.1$) percentage points of initial GDP. The consolidation rule requires tax hikes and spending cuts right from the beginning, and ever more so as the debt ratio increasingly deviates from the long-run target. After 12 quarters, the spending shock ends. Debt is highest in quarter 13 and then falls with a fiscal consolidation speed that roughly corresponds to Maastricht criteria. At the end of the shock period, consolidation needs are largest and *all* tax rates must be scaled up by a factor of 1.03. For instance, the wage tax rate rises from 30 to 31%. Higher taxes discourage economic activity. To a minor extent, the consolidation

[6] A recent example would be the Covid crisis which has greatly increased government spending to replace private incomes and has led to a discrete jump in sovereign debt.

[7] In our model, this long-run target is 130% of annual GDP, equal to the calibrated level reflecting recent history. Our analysis is not concerned with eliminating historic debt to comply with the Maastricht debt target but considers fluctuations around a 'vulnerable' steady state with high debt.

[8] The consolidation rule is formulated in terms of a target path for the structural primary surplus which is largely equivalent to a target path for the debt-to-GDP ratio $d_t^g = \gamma^g d_{t-1}^g + (1-\gamma^g)\bar{d}^g$ where $\bar{d}^g$ is the long-run target and the root γ^g controls for the adjustment speed. The solution path is given by $d_t^g = (\gamma^g)^t d_0^g + \left(1-(\gamma^g)^t\right)\bar{d}^g$. Half of debt reduction is complete when $d_t^g - \bar{d}^g = 0.5\left(d_0^g - \bar{d}^g\right)$. Substituting for d_t^g, the half-life is given by $(\gamma^g)^t = 0.5$, giving $t^{0.5} = \log(0.5)/\log(\gamma^g)$.

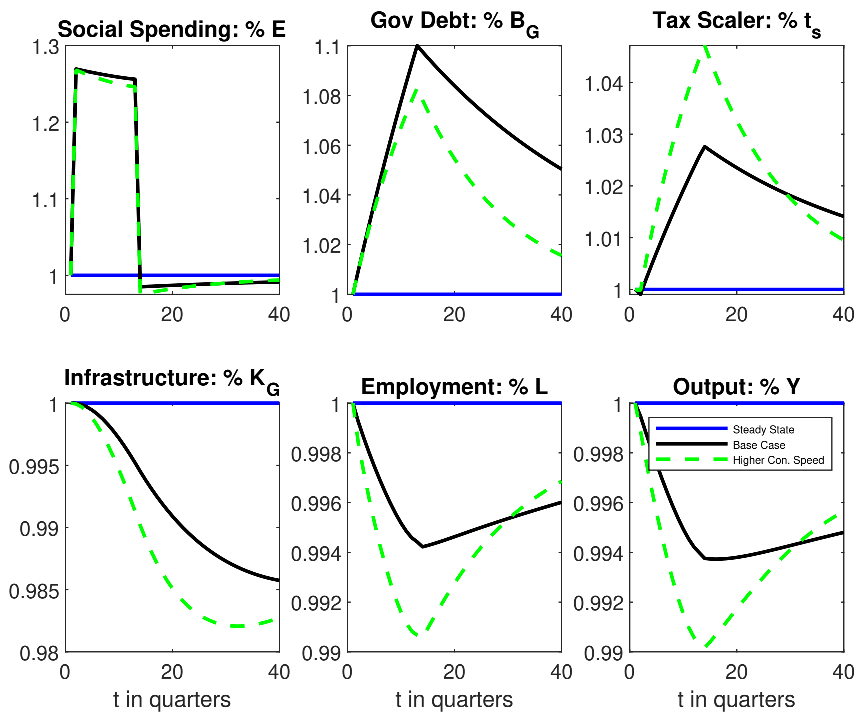

Figure 3: A Fiscal Spending Shock

policy also cuts productive spending, which impairs factor productivity.

The impact on economic performance is quite moderate, however. The reason is that low interest rates imply a relatively small burden of public debt. When debt is largest, output is somewhat less than 1% below trend, reflecting lower employment and reduced capital formation. If interest rates were higher, consolidation needs and the required tax increases would be substantially larger.

Higher Consolidation Speed: Arguably, high-debt countries must be more ambitious in reducing debt and pursue more aggressive fiscal consolidation. One reason could be a deterioration in bond market access. We can approximate this argument by reducing the parameter γ^g from 0.98 to 0.95. With this change, the half-life of debt reduction falls by about 50% from 30 quarters (7.5 years) to 13.5 quarters (3.4 years). Comparing the green dashed lines with the base case illustrates how debt reduction is shifted forward. By assumption, the policy rule responds to the growing gap between the debt ratio and its long-run target right from the start. The cumulative increase in the debt-to-GDP ratio in the shock period is smaller. The government is forced to pursue more aggressive consolidation, raising tax rates faster and by more. Spending similarly is reduced by more, leading to minor reductions in social spending and public services (infrastructure), see the first, third and fourth panels of Figure 3. The reduction in employment, capital formation and output is faster and deeper. After the shock period ends, however, recovery is faster as well, overtaking base case employment and GDP after about thirty quarters. More aggressive consolidation early on means that fiscal policy can relax earlier thereafter. Costs are shifted forward in time.

3.2.4 Monetary Stabilization

In a currency union, monetary policy is centralized and the internal exchange rate is fixed by sharing the same currency. Common monetary policy aims at lowering output and inflation gaps in the entire union, but is ineffective in stabilizing output and inflation in specific member states when asymmetric shocks would require a targeted intervention. In contrast, autonomous monetary policy would target the specific situation separately in each region. For illustration, we assume that both regions are subject to productivity shocks (corresponding to output shocks in the rest of the Eurozone) with a standard error of 1% of the stationary productivity/output values. We then compute the variance of output and inflation in Italy when it is part of the union (scenario 'EMU'). Figure 4 shows that local output fluctuations are relatively high while the variance of the inflation rate is low. Membership in the currency union comes with improved price stability but higher output fluctuations. In our model, the weight of Italy in union-wide output is about 18%. Therefore, monetary stabilization of output is weak. Indeed, economists typically argue (e.g., Colciago et al., 2008) that national policies should compensate for the loss of monetary autonomy by strengthening fiscal stabilizers and implementing structural reforms for higher resilience of the local economy.

The scenario 'No EMU' considers autonomous monetary policy in the absence of a currency union. With separate currencies, the internal exchange rate is flexible. We as-

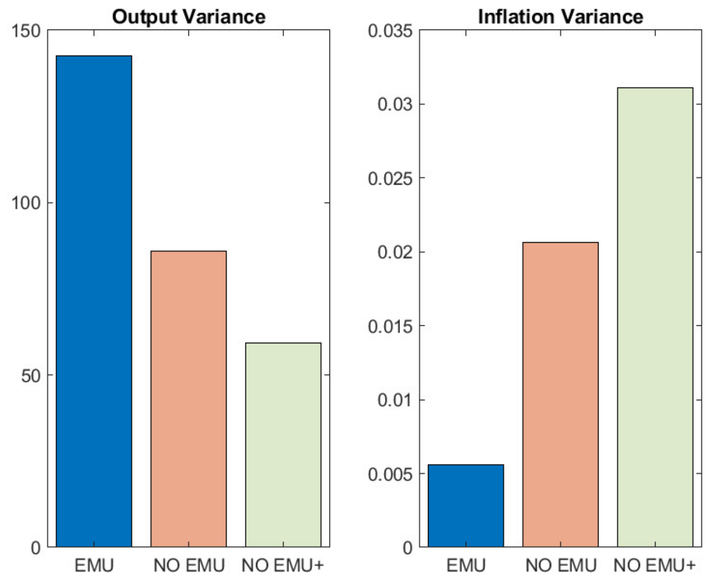

Figure 4: Monetary Stabilization

sume that both regions adopt exactly the same monetary policy rule, except that it is now conditional on output and inflation within each own region separately. Rather than being attributed a weight of only 18%, domestic output fluctuations now fully enter into the central bank's decision problem. The targeted reaction of monetary policy substantially reduces local output variance, by almost a half, whereas inflation variance more than doubles. More stable output is at the expense of weaker price stability. Suppose now that the national central bank pursues a more aggressive policy of dampening output fluctuations (scenario 'No EMU+'), i.e., the sensitivity of local money supply with respect to output gaps is doubled. Again, output variance is further reduced at the cost of even higher inflation variance.

3.3 Recession and Exit

How can a country cope with a severe asymmetric recession if exchange rate adjustment is not possible and monetary policy cannot directly target its specific situation? Whether intentional or forced, an exit from the currency union and the introduction of a national currency (Lira) might become a possibility. Given the vulnerability to shocks, a natural question is whether a member state could reduce the output costs of an asymmetric recession, and by how much, when moving to autonomous monetary policy and flexible exchange rates. Given the complexity of the problem, our analysis can be no more than a crude approximation of possible developments.

We focus on three scenarios in response to a severe, asymmetric recession. The latter is a combination of adverse shocks to total factor productivity, which falls by 3% of the base case value, and to the NPL ratio, which increases by 50% as described in Section 3.2.1. These shocks are temporary and last for four quarters.

- Currency Union: The domestic economy experiences an asymmetric recession, while other regions are unaffected. Apart from these exogenous shocks, the emerging output gap endogenously magnifies the share of non-performing loans, and the consolidation rule applies (see 3.2.3) and restricts productive fiscal spending, which feeds back on factor productivity.

- Benign exit: The country experiences the very same recession, which instantaneously triggers exit from the currency union. The Euro/Lira exchange rate is flexible, and monetary policy is autonomously chosen. The exit is benign in the sense that it does not involve investor panic and speculative capital flight.

- Escalating exit: To mimic investor panic, we add two additional shocks by simultaneously raising the risk premia on government bonds and bank deposits relative to the safe reference asset (international bonds). All else equal, the deposit rate (sovereign bond return) rises from 2 to 6% (3 to 7%) annually. In addition, we include a temporary preference shock in favor of current consumption. Households thus require higher interest rates to keep up savings and to supply the required funding. The preference shock further raises interest rates across the board, which deepens the current recession. Technically, we reduce the subjective discount factor β by 2 points (from 0.995 to 0.975). All shocks last four quarters.

We emphasize two implications of the model to prepare intuition for the results. First, we treat the recession as a purely temporary event. After the recession ends, the shock variables revert back to initial values in line with the estimated auto-regressive processes. In the same vein, monetary policy may have substantial effects in the short but is neutral in the long-run. Since we abstract from permanent changes in structural parameters, the economy gradually reverts to the same stationary equilibrium.[9] Second, whenever the economy is in a steady state and no shock occurs, autonomous monetary policy fully replicates centralized policy making and investor expectations are stable, an unanticipated exit is completely neutral. Any effect on the exchange rate can only result from asymmetric shocks and from differences in monetary policy in the two regions. We thus expect in our scenarios rather modest changes in exchange rates even after an exit. Figures 5 and 6 decompose the cumulative effects of the three scenarios and illustrate transitional dynamics for key economic indicators. Tables A.2 to A.4 in the Appendix report more detailed information of the effects in all three scenarios.

Recession Within the Currency Union: The dashed, black lines in Figures 5 and 6 refer to the impact of a deep asymmetric recession in Italy. The internal exchange rate remains fixed and cannot adjust, and monetary policy is conditional on the average economic performance in the entire currency union. Therefore, it cannot directly address the recession in one member state and responds only insofar as the recession affects union-wide output and inflation. Given large negative shocks to productivity and loan quality, the recession is bound to be very severe and involves an instantaneous output loss of about nine percent. This loss persists over eight quarters. After that, shocks start to fade out, and economic recovery sets in.

The recession feeds on several sources. Most importantly, the negative productivity shock reduces investment and labor demand. The effect on investment is reinforced by a rising NPL ratio, which is endogenously magnified by the large output gap. Banks raise

[9] An exit likely entails additional long-run consequences (e.g., exchange rate risks, transaction costs). Consistent with our focus on recession and recovery in the short-run, we abstract from such effects.

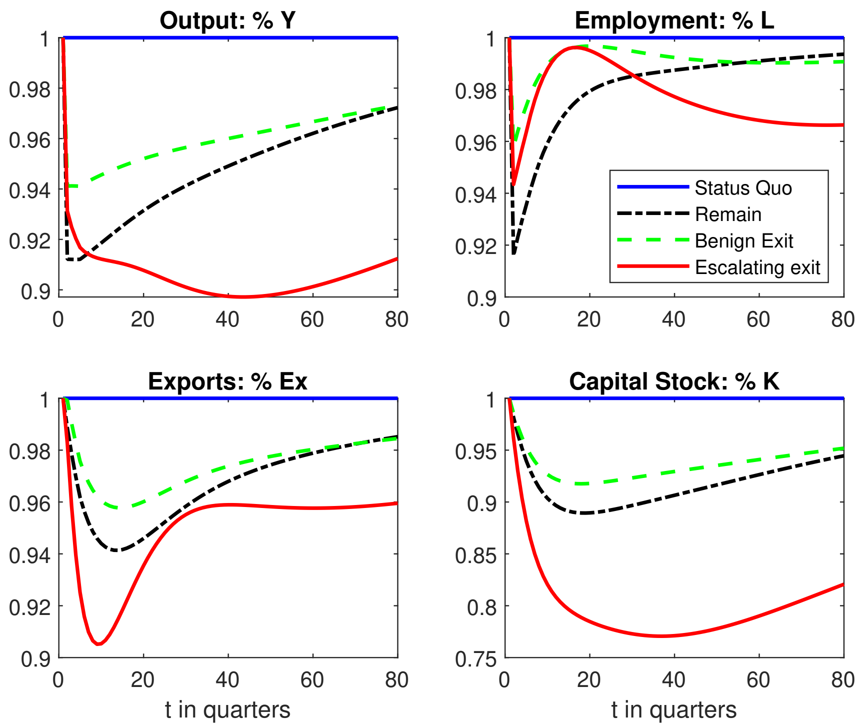

Figure 5: Recession and Exit

the loan rate both because credit risk is higher and equity losses restrict their lending capacity. Despite a decline in the deposit rate due to the reduced demand of banks, the loan rate rises on net. Both lower productivity and higher costs of capital discourage firm investment. Roughly 20 quarters after the start of the crisis, the capital stock is thus almost 11% lower than in the initial stationary equilibrium.

The negative productivity shock also reduces employment. Nominal wage stickiness prevents an immediate reduction in wages. Wage inertia and the loss in productivity cause an increase in producer prices. The latter lead to a decline in the real wage, which is beneficial for employment. It falls by much less than the capital stock. However, given a constant exchange rate with the most important trading partners, the rising producer prices weaken international competitiveness and substantially erode exports as well.

By construction, centralized monetary policy cannot target the specific situation in Italy and remains rather passive. Fiscal policy is constrained by a high level of debt and cannot run into a substantial deficit, thereby preventing automatic fiscal stabilization to a large degree. Given the consolidation rule as described in Section 2.4, the government must even tighten the fiscal stance to prevent a large further increase in public debt. For example, income tax rates increase by almost 1 percentage point. Our model simulation thus emphasizes that a Eurozone member state with excessive public debt, little competitiveness and a vulnerable banking sector is bound to experience more severe recessions than other member states if they were subject to the same shocks.

Benign Exit: A 'benign exit' is defined as one that occurs without panic-driven investor reactions (green, dashed lines in Figures 5-6). We consider the same asymmetric shocks as before but now the internal exchange rate is flexible, and monetary policy is autonomous and can help cushion the recession. We assume that the national central bank is a mere replica of the common central bank, with the same sensitivity of money supply to output and inflation gaps. However, the weight of the national economy in local monetary policy decisions is now 100%, rather than 18% in the currency union. The expansion of domestic money supply in response to the recession is thus roughly five times larger than under continued membership in the monetary union.

The key difference is that domestic producer prices rise by more than double, coupled with a depreciation of the new currency (Lira). Nominal interest rates including the nominal loan rate now substantially increase. However, high domestic inflation reduces real rates and leads to roughly the same pattern of real interest rates compared to the first scenario. The targeted monetary response and the exchange rate flexibility lead to a considerable stabilization relative to the first scenario. A depreciation of the exchange rate benefits the domestic economy by reducing imports and strengthening exports. The external devaluation fully compensates the loss in competitiveness so that exports shrink much less than in the base case scenario. The substantial increase in inflation and the resulting increase in producer prices bring the reduction in real wages forward in time and thereby prevent some unemployment. A benign exit could significantly reduce the output and employment losses in the early adjustment period, see Figure 5. In line with this, investment and exports are much stronger compared to the base case.

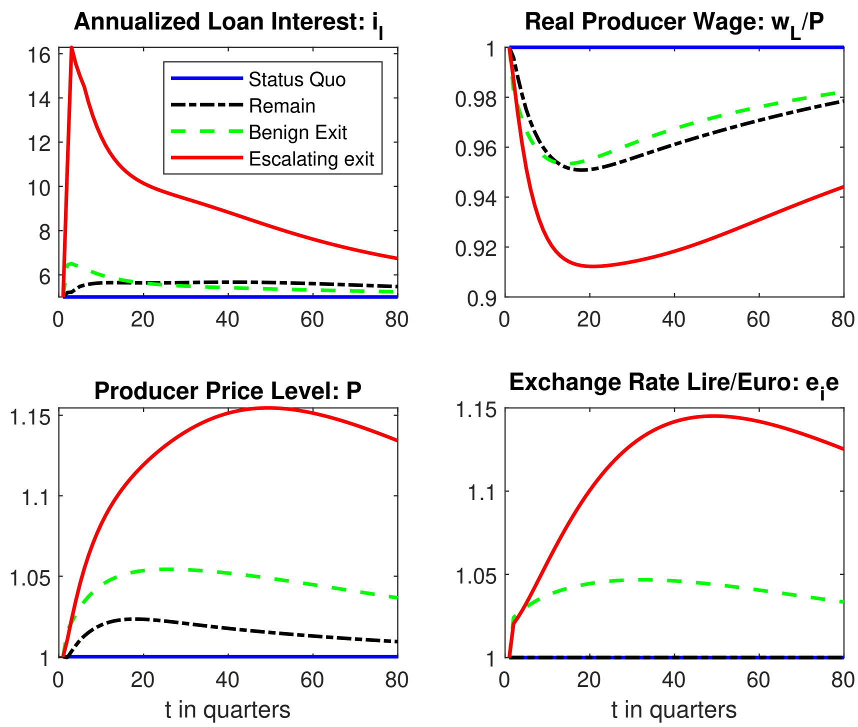

Figure 6: Recession and Exit

One might argue that national monetary policy could intervene much stronger to the emerging output gap in a large asymmetric recession and accept even more inflation compared to centralized policy making. Such a policy change could also devalue the real value of debt. Surely, short-run stabilization would be significantly enhanced, although at the cost of higher inflation. Since we do not want to mix the effects of an exit scenario with the effects of a change in monetary policy, we abstract from such possibility.

Escalating Exit: Since the economy starts from a vulnerable position, an exit can trigger a general loss of confidence and even panic-driven capital flight. An unanticipated inflation shock and a corresponding devaluation of the Lira implies a one-time reduction of wealth. We picture the loss of confidence by a sudden increase in risk premia on government bonds and bank deposits, in response to growing concerns over the solvency of the government and local banks. Interest rates on deposits and sovereign bonds roughly triple during the four quarter recession before they revert back to normal levels with some delay. In addition, we capture household pessimism regarding future developments by a preference shock that implies higher discounting. Although such a shock favors current consumption demand, it also pushes up interest rates to keep up funding of the real economy. The red solid lines in Figures 5-6 illustrate the dynamic adjustment, and Table A.4 in the Appendix provide more detailed results.

The loss of confidence transforms into a funding stop, with households supplying funds only at exceptionally high interest. These shocks much magnify the recession induced by the negative shocks to productivity and loan quality. Banks pass the higher funding costs onto borrowers via higher loan rates. In addition, larger losses on loans and sovereign bonds erode equity and, given dividend inertia, banks reduce credit supply. Much higher costs of capital sharply restrict investment and result in capital decumulation: Eight quarters after the onset of crisis, the capital stock is 17% lower, see Table A.4.

The other direct consequence of investor panic is a burst of inflation that raises domestic prices. Given nominal wage stickiness and rising capital costs, firms raise prices to digest increasing factor costs. Domestic inflation initiates a reduction in real wages and real interest rate. Real rates decline sharply at the onset of crises and then quickly increase and remain at higher levels over a prolonged time period, see Table A.4. The real wage reduction leads to a more favorable response of employment in the early adjustment period, but then remains subdued over a long time period thereafter, compared to the other scenarios. The long-lasting impairment of labor market performance is a legacy cost of the early crisis period which leads to a large reduction of productive capital.

The sudden increase in inflation after an exit has two important consequences. First, higher domestic prices erode export competitiveness. Even the larger devaluation of the domestic currency does not fully compensate for the loss in international price competitiveness. In fact, devaluation is also partly contributing to domestic inflation by increasing import prices. Despite the higher exchange rate (a depreciation of the domestic currency), exports substantially fall, which further deepens the recession. Second, the real value of outstanding government debt falls because of both higher inflation and bond prices, which decrease by 23% after four quarters mainly due to a higher risk premium. Lower bond prices inflict large losses on banks and households.

The large public debt prevents a decisive fiscal intervention to fight the crisis. Although the consolidation rule does allow for temporary deficits and requires only a slow reduction of structural deficits, consolidation must start early on to keep the debt ratio from growing even larger than currently high levels. After all, the high indebtedness with insolvency concerns might in the first place be a key reason for the escalating scenario. Except for the first quarter, tax rates must even increase during the crisis, to a small extent, as Table A.4 shows. Productive government spending is similarly held back by consolidation needs so that the stock of public infrastructure remains below trend over a long time period, with negative consequences for factor productivity and economic recovery after the crisis.

4 Conclusion

This paper considers an economy that is part of a monetary union and is exposed to the 'trilemma' of high public debt, weak banks, and a lack of competitiveness. It is thus especially vulnerable to adverse economic shocks, and a recession can set off a vicious cycle driven by mutual contagion between the government, banks, and firms.

Important adjustment mechanisms are missing in a monetary union: The internal exchange rate is fixed, and monetary policy is conducted conditional on the union-wide state of the economy. To compensate for the lack of monetary autonomy, the country would ideally rely on other economic stabilizers. However, the latter are significantly constrained: Fiscal stabilization requires low public debt, and banks that could, in principle, help absorb shocks suffer from low equity and many non-performing loans.

Using a New Keynesian DSGE model calibrated to Italy, we quantitatively analyze the macroeconomic adjustment of a vulnerable economy under continued membership in the monetary union and in the case of an exit and the introduction of its own currency. We simulate an asymmetric recession, which is a combination of adverse productivity and financial shocks, and compare three scenarios: First, under continued membership in the monetary union, the recession is severe, given the lack of monetary autonomy and tight constraints on fiscal policy. Second, a 'benign exit' from the Eurozone with stable investor expectations could dampen the negative short-run output and employment losses. Stabilization is achieved by an aggressive monetary expansion that causes higher inflation, however. Real wages decline due to nominal wage rigidity, which, together with exchange rate depreciation, helps restore international competitiveness. However, stable investor expectations after an exit might be unrealistic, given the large uncertainty. We thus consider a third scenario of an 'escalating exit', in which investor panic causes a surge in risk premia upon exit. This magnifies private and public borrowing costs, further depressing investment and constraining fiscal policy. Unfavorable capital market reactions offset the advantages of monetary autonomy. Such an exit scenario makes the recession deeper than under continued membership and considerably delays the full recovery.

A Appendix

A.1 Estimation

Following standard procedures in DSGE research, we add shocks to the model and apply Bayesian estimation techniques. The calibration results in a steady state reflecting the conditions at the start of the monetary union in the early 2000s. Using Bayesian estimation procedures we estimate several structural parameters. In the process, we let the model determine the shock processes to replicate key time series from 2000 to 2019.[10] Specifically, we estimate shocks to total factor productivity Z_t, to the non-performing loan share s_t, risk premia on sovereign bonds θ_t^g, deposits θ_t^d, and firms θ_t^k, as well as worker's preferences ϕ_t in Italy. Furthermore, we include a shock process to the Eurozone GDP Y_t^e and to monetary policy in the union M_t^u into our estimation.

With eight endogenously determined shocks, the model replicates exactly, without error, eight selected time series as part of the stochastic general equilibrium solution. Motivated by the earlier discussion of past economic performance in Italy, we track the wage index w_t, the GDP share of fiscal debt $B_t^G/(P_tY_t)$ and government expenditures $E_t/(P_tY_t)$, the non-performing loan share s_t, interest rates i_t^d and i_t^g on deposits and fiscal debt in Italy, as well as output and interest rates in the Eurozone $(Y_t^e,\, i_t^e)$. The estimation provides us with values for twelve parameters, which determine the government's spending behavior $(\gamma_g,\, \xi_g,\, \xi_e)$, the elasticities $(\sigma_z,\, \sigma_s,\, \sigma_r)$, the adjustment costs $(\psi_k,\, \psi_b)$, as well as the speeds of adjustment $(\rho_\theta,\, \rho_s,\, \rho_T,\, \rho)$. Table A.1 provides an overview of estimated shocks together with selected structural parameters and reports our prior assumptions together with the resulting posterior distributions.

Since standard deviations of shocks should be non-negative, we assume an inverse-gamma distribution (e.g. Gerali et al., 2010) with size-appropriate priors. Moreover, the persistence of the AR(1) processes should fall within the 0-1 range. The parameters are

[10] Since the model requires stationary data, we detrend the data by output growth. We also remove seasonal trends in wages.

thus assumed to be beta distributed with mean 0.95 and standard deviation 0.01.

Table A.1: Prior and Posterior Distributions

Parameter		Prior distribution			Posterior distribution		
		Density	Mean	St.dev	10%	Mean	90%
Autocor. risk premia	ρ^{th}	Beta	0.95	0.01	0.9302	0.9431	0.9555
Autocor. NPL shock	ρ^{s}	Beta	0.95	0.01	0.9362	0.9490	0.9610
Autocor. revenue losses	ρ^{T}	Beta	0.95	0.01	0.9367	0.9500	0.9626
Autocor. business cycle	ρ	Beta	0.95	0.01	0.9696	0.9755	0.9811
Consolidation speed	γ_g	Beta	0.97	0.001	0.9700	0.9771	0.9839
Sensitivity NPL rate	σ^{s}	Inv.Gamma	0.05	0.1	0.0195	0.0250	0.0353
Sensitivity Productivity	σ^{z}	Inv.Gamma	0.05	0.1	0.0195	0.0413	0.0717
Armington trade elasticity	σ^{r}	Normal	5	1	3.9346	5.1346	6.3537
Dividend adj. costs	ψ_b	Normal	0.25	0.01	0.2373	0.2505	0.2634
Investment adj. costs	ψ_k	Normal	1	0.1	1.0378	1.1586	1.2801
Consolidation share G	ξ_g	Normal	0.2	0.001	0.1865	0.1992	0.2120
Consolidation share E	ξ_e	Normal	0.1	0.001	0.0885	0.1011	0.1140
SD productivity shock IT	$\tilde{\sigma}^{z}$	Inv.Gamma	0.1	2	0.0112	0.0125	0.0139
SD income shock EZ	$\tilde{\sigma}^{ye}$	Inv.Gamma	10	4	3.6412	4.0659	4.5224
SD deposit shock	$\tilde{\sigma}^{d}$	Inv.Gamma	0.1	2	0.0087	0.0096	0.0107
SD gov. interest shock	$\tilde{\sigma}^{g}$	Inv.Gamma	0.1	2	0.0087	0.0097	0.0108
SD monetary policy shock	$\tilde{\sigma}^{Mu}$	Inv.Gamma	10	4	18.3378	20.4664	22.7203
SD labor supply	$\tilde{\sigma}^{\phi}$	Inv.Gamma	0.1	2	0.0788	0.0883	0.0983
SD NPL shock	$\tilde{\sigma}^{s}$	Inv.Gamma	0.1	2	0.0087	0.0098	0.0109
SD firm funding shock	$\tilde{\sigma}^{k}$	Inv.Gamma	0.1	2	0.0105	0.0118	0.0132

The last three columns of Table A1 show the means and confidence intervals of the posterior distributions as obtained by the Metropolis Hastings algorithm. We used five chains, each with 25,000 draws which ensures convergence of the sampling algorithm. Shock persistence is estimated to be quite high. Autocorrelation coefficients range from 0.92 (for the business cycle) to 0.96 for the risk premia. All other parameters are estimated to a value close to our prior assumptions. Section 3.1 provides a more detailed discussion of the economic interpretation of these estimated values.

Figure A.2 plots prior and posterior distributions of the estimated standard deviations. Moreover, Figure A.1 shows prior (gray curves) and posterior distributions (black

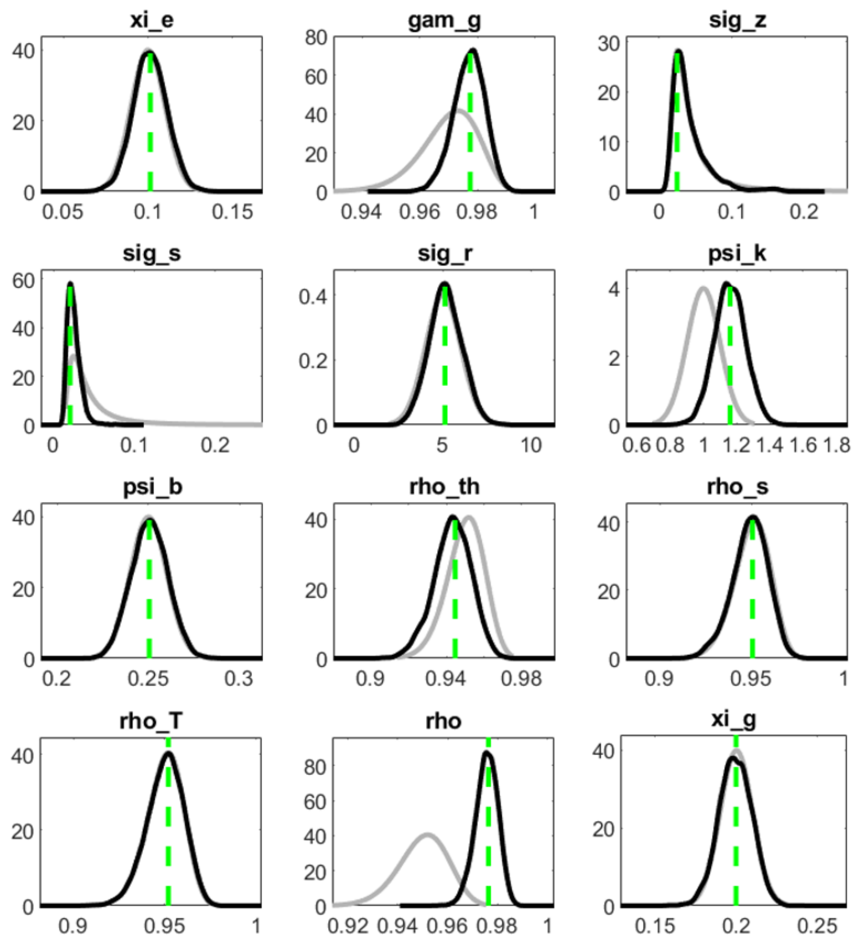

Figure A.1: Prior and Posterior Distribution of Parameters

curves) of the estimated parameters. The vertical dashed lines indicate the estimated posterior mode.[11] The smaller variance of the posterior indicates that the data appear to be informative of the persistence of shock processes.

[11]The mode is the most frequently computed value. It does not coincide with the mean for non-normal (non-symmetric) distributions and not necessarily with the peak of the posterior distribution.

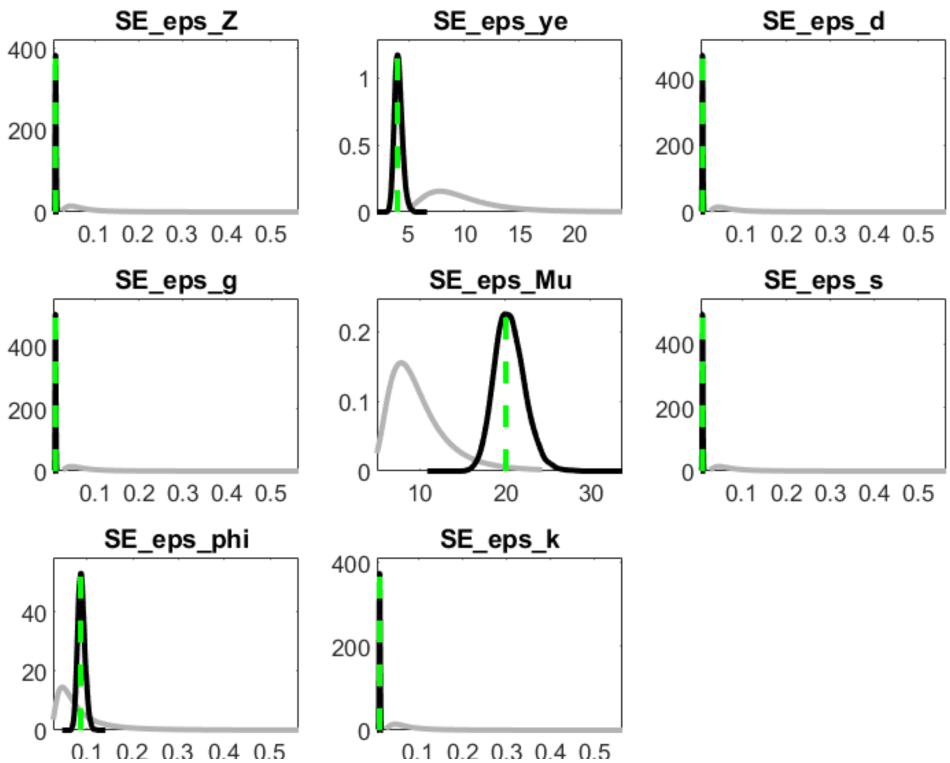

Figure A.2: Prior and Posterior Distribution of Shock SDs

A.2 Details on Exit Scenarios

Table A.2: Detailed Results of 'Remain' Scenario

Symbols	Names	SS	Q1	Q4	Q8	Q20	Q40
Q*B_G/PY	Fiscal Debt/GDP *)	5.2000	5.6469	5.5470	5.4358	5.2588	5.1692
Q	Sovereign Bond Price	1.0000	0.9918	0.9896	0.9876	0.9824	0.9779
s	Non-performing Loan Share Banks	0.0150	0.0226	0.0229	0.0218	0.0195	0.0175
Y	Real GDP	0%	-9%	-9%	-8%	-7%	-5%
Z	Factor Productivity	0%	-3%	-3%	-3%	-2%	-1%
K	Capital Stock	0%	-2%	-6%	-9%	-11%	-9%
L	Employment	0%	-8%	-6%	-4%	-2%	-1%
Cbar	Private Consumption	0%	-5%	-6%	-6%	-6%	-5%
Ex_e	Exports to Rest of EZ	0%	-1%	-4%	-6%	-5%	-3%
Ex_o	Exports to RoW	0%	-1%	-4%	-5%	-5%	-3%
K_G	Public Capital Stock	0%	0%	-1%	-2%	-4%	-5%
w_L/P	Producer Real Wage	0%	0%	-2%	-4%	-5%	-4%
MRS	Consumer Real Wage	0%	-2%	-4%	-5%	-5%	-4%
tau	Income Tax Rate	0.3000	0.3070	0.3057	0.3044	0.3029	0.3026
P	Producer Prices	1.0000	0.9995	1.0103	1.0184	1.0231	1.0173
Pbar	Consumer Price Index	1.0000	0.9985	1.0077	1.0147	1.0195	1.0152
i	Ann.Domestic Interest	0.0200	0.0178	0.0195	0.0203	0.0211	0.0235
i_d	Ann.Deposit Interest	0.0200	0.0178	0.0195	0.0203	0.0211	0.0235
i_g	Ann.Gov.Debt Interest	0.0300	0.0278	0.0295	0.0303	0.0311	0.0335
i_l	Ann.Loan Interest	0.0500	0.0520	0.0548	0.0562	0.0564	0.0567
gi	Ann.Inflation Rate	0.0000	0.0118	0.0078	0.0039	-0.0005	-0.0009
r	Ann.Real Interest	0.0200	0.0060	0.0117	0.0163	0.0216	0.0245
e_ie	Lire/Euro Exch.Rate	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
e_eo	Euro/Dollar Exch.Rate	1.0000	0.9969	1.0027	1.0078	1.0127	1.0112
B_f/PY	Net For. Debt/GDP *)	-0.8800	-0.9367	-0.8753	-0.8517	-0.9122	-0.9696

Remarks: * Quarterly GDP ratios. SS refers to the steady state.

Table A.3: Detailed Results of 'Benign Exit' Scenario

Symbols	Names	SS	Q1	Q4	Q8	Q20	Q40
Q*B_G/PY	Fiscal Debt/GDP *)	5.2000	5.3575	5.2856	5.2148	5.1358	5.1351
Q	Sovereign Bond Price	1.0000	0.9859	0.9881	0.9904	0.9921	0.9916
s	Non-performing Loan Share Banks	0.0150	0.0226	0.0228	0.0216	0.0191	0.0171
Y	Real GDP	0%	-6%	-6%	-6%	-5%	-4%
Z	Factor Productivity	0%	-3%	-3%	-3%	-2%	-1%
K	Capital Stock	0%	-1%	-5%	-7%	-8%	-7%
L	Employment	0%	-4%	-3%	-1%	0%	-1%
Cbar	Private Consumption	0%	-4%	-4%	-4%	-4%	-4%
Ex_e	Exports to Rest of EZ	0%	0%	-2%	-4%	-4%	-3%
Ex_o	Exports to RoW	0%	0%	-2%	-4%	-4%	-3%
K_G	Public Capital Stock	0%	0%	-1%	-1%	-3%	-3%
w_L/P	Producer Real Wage	0%	-2%	-3%	-4%	-4%	-3%
MRS	Consumer Real Wage	0%	-4%	-5%	-5%	-5%	-3%
tau	Income Tax Rate	0.3000	0.3045	0.3029	0.3013	0.2999	0.3003
P	Producer Prices	1.0000	1.0161	1.0307	1.0424	1.0538	1.0516
Pbar	Consumer Price Index	1.0000	1.0159	1.0290	1.0397	1.0511	1.0498
i	Ann.Domestic Interest	0.0200	0.0251	0.0245	0.0231	0.0211	0.0214
i_d	Ann.Deposit Interest	0.0200	0.0251	0.0245	0.0231	0.0211	0.0214
i_g	Ann.Gov.Debt Interest	0.0300	0.0351	0.0345	0.0331	0.0311	0.0314
i_l	Ann.Loan Interest	0.0500	0.0646	0.0638	0.0605	0.0561	0.0541
gi	Ann.Inflation Rate	0.0000	0.0177	0.0115	0.0066	0.0010	-0.0010
r	Ann.Real Interest	0.0200	0.0074	0.0130	0.0164	0.0201	0.0224
e_ie	Lire/Euro Exch.Rate	1.0000	1.0240	1.0303	1.0363	1.0448	1.0459
e_eo	Euro/Dollar Exch.Rate	1.0000	1.0156	1.0258	1.0348	1.0459	1.0465
B_f/PY	Net For. Debt/GDP *)	-0.8800	-0.8971	-0.8486	-0.8321	-0.8850	-0.9357

Remarks: * Quarterly GDP ratios. SS refers to the steady state.

Table A.4: Detailed Results of 'Escalating Exit' Scenario

Symbols	Names	SS	Q1	Q4	Q8	Q20	Q40
Q*B_G/PY	Fiscal Debt/GDP *)	5.2000	4.2838	4.2918	4.3324	4.5675	4.9716
Q	Sovereign Bond Price	1.0000	0.7714	0.7754	0.7871	0.8196	0.8701
s	Non-performing Share Banks	0.0150	0.0226	0.0229	0.0218	0.0197	0.0183
Y	Real GDP	0%	-7%	-8%	-9%	-9%	-10%
Z	Factor Productivity	0%	-3%	-3%	-3%	-2%	-1%
K	Capital Stock	0%	-4%	-12%	-17%	-22%	-23%
L	Employment	0%	-6%	-4%	-2%	-1%	-2%
Cbar	Private Consumption	0%	12%	7%	3%	-5%	-9%
Ex_e	Exports to Rest of EZ	0%	-2%	-8%	-10%	-6%	-4%
Ex_o	Exports to RoW	0%	-2%	-7%	-9%	-6%	-4%
K_G	Public Capital Stock	0%	0%	-1%	-2%	-5%	-8%
w_L/P	Producer Real Wage	0%	-1%	-5%	-7%	-9%	-8%
MRS	Consumer Real Wage	0%	-4%	-8%	-9%	-11%	-11%
tau	Income Tax Rate	0.3000	0.2994	0.3048	0.3046	0.3091	0.3131
P	Producer Prices	1.0000	1.0106	1.0454	1.0766	1.1218	1.1520
Pbar	Consumer Price Index	1.0000	1.0093	1.0402	1.0697	1.1171	1.1487
i	Ann.Domestic Interest	0.0200	0.0288	0.0388	0.0450	0.0502	0.0493
i_d	Ann.Deposit Interest	0.0200	0.0688	0.0788	0.0767	0.0659	0.0542
i_g	Ann.Gov.Debt Interest	0.0300	0.0788	0.0888	0.0867	0.0759	0.0642
i_l	Ann.Loan Interest	0.0500	0.1084	0.1498	0.1268	0.1005	0.0877
gi	Ann.Inflation Rate	0.0000	0.0573	0.0327	0.0220	0.0102	0.0021
r	Ann.Real Interest	0.0200	-0.0281	0.0061	0.0229	0.0400	0.0472
e_ie	Lire/Euro Exch.Rate	1.0000	1.0203	1.0326	1.0523	1.1040	1.1425
e_eo	Euro/Dollar Exch.Rate	1.0000	1.0070	1.0304	1.0569	1.1084	1.1426
B_f/PY	Net For. Debt/GDP *)	-0.8800	-0.9195	-0.9328	-1.0346	-1.3045	-1.3193

Remarks: * Quarterly GDP ratios. SS refers to the steady state.

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