Sovereign Debt Crises, Fiscal Austerity and Corporate Default

Sergio de Ferra* Gabriel Fritsch †

February 2025

Abstract

During the Eurozone debt crisis, Italy suffered from an increase in sovereign borrowing costs followed by a sharp fiscal tightening and a reduction in credit to firms. What is the link between sovereign default risk and firms' credit? We propose a transmission channel from sovereign debt crises to firm-level financial frictions through the action of fiscal policy. Using firm-level data for 10 European economies, we show that firm default risk, credit conditions, and performance deteriorate following fiscal consolidations, with a larger impact on firms in the non-tradable sector. We then address this question in a model of endogenous sovereign default in which lending to firms is risky. A fiscal contraction in the crisis country causes a reduction in firms' profits and an increase in their default risk. Firms are heterogeneous in the degree to which the crisis affects them: those in the non-tradable sector are more vulnerable, as the crisis causes demand for their output to fall. Finally, as observed in Italy, the sovereign crisis leads to a contraction in economic activity.

*University of Oxford and CEPR. Email: sergio.deferra@economics.ox.ac.uk
†University of Oxford. Email: gabriel.fritsch@economics.ox.ac.uk

1 Introduction

What is the impact of a sovereign debt crisis on credit to the private sector? What is the role of fiscal policy in transmitting the adverse effects of a crisis from the government to firms? Severe recessions accompanied the 2011-13 sovereign debt crisis in the euro area. In Italy, the rise in government borrowing costs was followed by a sharp tightening in the stance of fiscal policy and by an increase in the cost of funding for firms. Moreover, during the crisis, the performance of Italian firms was impaired to a heterogeneous degree, with very severe effects for domestically-oriented firms that exported only a small fraction of their output.

In this paper, we introduce a model to jointly analyze sovereign default risk, fiscal policy and corporate default risk. We propose a transmission channel from sovereign debt crises to firm-level financial frictions through the action of fiscal policy. An increase in sovereign default risk leads to a rise in the cost of government borrowing. Higher borrowing costs induce the fiscal authority to reduce its exposure to international financial markets and, instead, to raise revenues domestically via taxation. The contraction in fiscal policy causes firms' profits to deteriorate and the risk of corporate default to rise. Sovereign risk is, thus, transferred to domestic firms via the endogenous response of fiscal policy. Firms' borrowing costs rise along with default risk, leading to a tightening of financial frictions in the productive sector and a reduction in output in the domestic economy.

We motivate the model with empirical evidence that a fiscal contraction leads to a deterioration in firm performance and an increase in firm borrowing costs for a panel of 10 Euro area economies. Using Jordà (2005) local projections and firm-level data from Compustat Global, we show that a tax-led fiscal consolidation shock leads to a significant decline in firm real sales and investment as well as an increase in default probabilities and interest expenses. Furthermore, these effects are heterogeneous in the tradability share of firms, with firms producing non-tradable goods (i.e. a lower tradability share) experiencing a relatively larger negative impact from fiscal austerity than firms producing tradable goods.

Our model allows for a quantitative study of the three key elements of this mechanism. The fundamental structure of the framework is that of an endogenous sovereign default model à la Eaton and Gersovitz (1981) and Arellano (2008). Sovereign default emerges as the optimal choice of a benevolent planner weighing the benefits of integration in international financial markets against the cost of debt repayment. We augment the baseline model along three dimensions. First, we introduce the presence of a meaningful corporate sector, composed of firms that hire labor supplied by households to produce output. Second, we calibrate the model to replicate quantitative features of the Italian economy. Finally, the model features the presence of distortionary taxation, so that government choices have implications for endogenous

variables such as output.[1]

Importantly, we impose no direct linkage between borrowing costs faced by firms and those faced by the government. Contagion of risk emerges endogenously because of the taxation's detrimental effects on firms. Both firms and the government borrow from risk-neutral lenders on international financial markets. Default by both types of agents emerges in equilibrium, but default by the government does not necessarily trigger default by firms or cause their exclusion from international financial markets. As firms can borrow from foreign lenders, they are insulated from the effects of a sovereign crisis on holders of government debt. Thus, financial intermediation by domestic banks is not necessary for the transmission of risk from the sovereign to firms to arise in this model.

Finally, we consider two different types of firms that differ in terms of their exposure to the domestic economy. All firms rely equally on labor supplied by domestic households as their sole input to production. Firms producing non-tradable goods, however, are constrained in that they are not able to export their production. Firms in this sector are therefore more reliant on the domestic economy, which is the sole destination market for their output. On the other hand, firms that produce tradable goods are less exposed to domestic considerations, as they can export their production to foreign residents.

Interest rates on government and firms' debt display positive co-movement in the model economy. The interest rate is high for both the government and firms in bad times, when aggregate productivity is low and government debt is high. First, in times of low productivity, the government faces a strong incentive to default. Foreign lenders require compensation for the high default risk and charge a high interest rate on government debt. Low productivity is also detrimental to firms' profits. Low profits imply a high risk of default by firms, which, in turn, leads to a high interest rate on firms' debt. Second, a high level of government debt also strengthens the government's incentive to default, thus implying a high interest rate on government debt. At the same time, high borrowing costs induce the government to run a surplus when government debt is high. The government sets higher taxes to raise revenue domestically and to generate the surplus. In turn, higher taxes lead to a contraction in firms' profits. As firms' profits fall, their default probability rises. Firms' borrowing costs rise along with their default probability, as lenders are compensated for the higher default risk.

We consider in this framework the implications of a sovereign debt crisis that hits the model's small open economy. A sovereign debt crisis is a shock leading to a sharp increase in the cost of borrowing for the government of the small open economy. The sovereign debt crisis causes a fiscal contraction, a tightening in financial frictions faced by firms, a reduction

[1] Cuadra, Sanchez and Sapriza (2010) introduce a model of endogenous sovereign default in which the government raises revenue domestically via distortionary taxation and sets the level of government expenditure.

in output and a more severe deterioration in the performance of non-exporting firms. The effects of the crisis in the model are extremely similar to those observed in Italy during the recent recession. First, the higher cost of borrowing induces the government to reduce its stock of debt, leading to an increase in taxation. Second, higher taxes lead to a fall in output and to a reduction in firms' profits. Third, firms' lower profits lead to a rise in their default risk, and to a higher cost of their borrowing. Finally, the crisis leads to a contraction in demand, making its effects particularly severe for firms in the non-tradable sector.

Related Literature. This paper is related to several strands of the literature on sovereign debt. First, it contributes to the literature on endogenous sovereign default initiated by the seminal work of Eaton and Gersovitz (1981). The model in this paper builds on the quantitative framework developed by Arellano (2008) and Aguiar and Gopinath (2006). We depart from the baseline model by introducing endogenous production of heterogeneous goods by firms facing idiosyncratic default risk. As in Cuadra, Sanchez and Sapriza (2010), we allow for the presence of distortionary taxation, government expenditure and endogenous labor supply by households. In addition, unlike most papers in this literature, we calibrate the model economy to replicate quantitative features of an advanced economy like Italy, rather than those of emerging market economies.

Second, this paper contributes to the literature on the interaction between sovereign debt and credit to the private sector. Mendoza and Yue (2012) study the endogenous determination of the costs of sovereign default by assuming the presence of a direct link between government and firms in their borrowing costs and in their ability to access international financial markets. We abstract from assuming the presence of such direct linkages and study, instead, how the correlation of borrowing costs and market access between the two agents emerges endogenously, as sovereign risk is transmitted to the private sector through fiscal policy.[2] Arellano, Bai and Bocola (2024) also study the contractionary effects of sovereign debt crises that arise because of the interaction between the government and firms. Kaas, Mellert and Scholl (2020) develop a one-sector model of a small open economy calibrated to Argentina where this interaction also occurs via fiscal policy.

The literature has extensively analyzed the endogenous determinants of linkages between sovereign debt markets and credit to the private sector. Many authors have studied how the adverse effects of a sovereign crisis on the balance sheet of domestic lenders cause a contraction in credit to firms. Gennaioli, Martin and Rossi (2014) provide a notable example of an analysis of this transmission channel. Similarly, the adverse implications of sovereign

[2]In a New-Keynesian framework, Corsetti et al. (2014) also assume the presence of a direct linkage in the borrowing costs of government and firms, to study the effects of fiscal policy in a union of countries subject to sovereign debt crises.

debt for credit to the private sector stem from the exposure of domestic creditors to the government in Guerrieri, Iacoviello and Minetti (2013), Acharya, Drechsler and Schnabl (2014), Broner et al. (2014), Mallucci (2021), Perez (2018), Sosa-Padilla (2018) and Bocola (2016).[3] We contribute to this field of research by studying the transmission of shocks between sovereign and firms in a framework in which debt of government and firms is held outside of the domestic economy. In this paper, fiscal policy set by the government affects fundamentals of the economy and the severity of firms' default risk, independently of the identity of holders of government debt. Arellano and Kocherlakota (2014) introduce a model in which a crisis is transmitted from the private sector to the government, as tax revenues fall in times of financial distress.

A number of contributions to the literature have empirically documented the presence of linkages between credit conditions of government and firms. Ağca and Igan (2019) show how policies aimed at reducing the stock of government debt have significant adverse affects on credit to the private sector. In addition, they show that effects are heterogeneous across firms, depending, in particular, on their degree of exposure to the domestic economy. Arteta and Hale (2008) document that sovereign default crises are associated with contractions in credit to the private sector in emerging market economies. Bofondi, Carpinelli and Sette (2018) and Başkaya et al. (2023) empirically document the impact of sovereign risk on private-sector credit via the channel of domestic intermediaries. In this paper, we provide empirical evidence for the transmission channel from fiscal policy to firm output, investment, and financial frictions using firm-level data.

Finally, this paper is related to the growing area of research that has studied the recent euro area sovereign debt crisis. Lane (2012) and Shambaugh (2012) provide a detailed discussion of the economic and sovereign debt crisis. Ardagna and Caselli (2014) discuss the conditions attached to the Greek government bailouts of 2010 and 2011. De Santis (2012) studies the spillover from the Greek crisis to the rest of the euro area.

The rest of the paper is organized as follows. Section 2 presents the key facts about the recent crisis in Italy and the empirical evidence on the effect of austerity on firms that motivate our model. Section 3 introduces the model and its calibration to the Italian economy. Section 4 presents the key results, by describing the main quantitative properties of the model economy and presenting a sovereign debt crisis episode. Section 5 concludes.

[3] Chari, Dovis and Kehoe (2020) show that financial repression, in the form of incentives to domestic agents to hold domestic government debt, can be welfare-improving, by improving the ability of the government to repay debt.

2 Empirical Evidence

This section presents the empirical facts and analysis that motivate the quantitative model in our paper. First, we describe key facts about the sovereign debt crisis in Italy: (1) in response to a sharp increase in sovereign spreads, the government implemented a predominantly tax-based fiscal consolidation; (2) firms suffered significantly in the aftermath of the crisis across several indicators, with those in the non-tradable sector faring even worse; (3) borrowing costs for firms rose in tandem with sovereign spreads, and non-tradable firms faced deeper deleveraging and a larger share of reported financial constraints. We then present empirical evidence on the effects of a tax-led fiscal contraction on firm-level variables: real sales and investment (proxied by change in total assets) decline, while the implied probability of default and interest expenses increase, while the interest coverage ratio (debt servicing capacity given internal cash flows) falls. These effects are mostly heterogeneous in the tradability share of firms.

2.1 Motivation

Fiscal policy in the sovereign debt crisis. Concerns about the sustainability of public debt emerged in some European countries following large fiscal expansions in 2008-09 to mitigate the effects of the Global Financial Crisis (GFC). In 2010, investors began demanding higher interest rates on government bonds and yields spiked in countries like Greece, Italy, Spain, and Portugal. In Italy, 5y sovereign spreads rose to 574 basis points at its peak in November 2011.[4] A considerable increase in the borrowing cost for Italian firms also followed, as seen in Figure 1a. The increase in government borrowing costs was sharp but relatively short lived, remaining high and volatile until the second half of 2012 but quickly returning theraefter to a level close to its pre-crisis mean. Interest rates for firms, however, remained persistently higher for several years after the initial crisis shock.

Responding to investor anxiety about fiscal sustainability, the Italian government embarked in a multi-year fiscal consolidation plan starting in 2011.[5] The adjustment was mostly revenue-based, with the government raising property and value-added tax rates and excise duties, with implicit corporate and income tax rates also rising significantly. The overall consolidation in 2012, for example, amounted to 3.3% of GDP, with over two-thirds coming from revenue-based measures, according to data from Alesina et al. (2017) (see Figure 1b). As a result, Italy's cyclically-adjusted primary balance rose from 0.6% of GDP in 2010 to 4.0% of GDP in

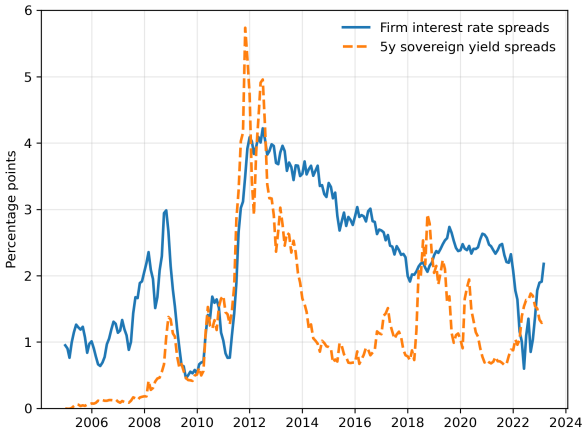
[4] We measure the sovereign spread as the difference between the yield on Italian 5-year treasury bonds (BTPs) and the yield on German 5-year *Bunds*.

[5] See Alesina et al. (2015), Alesina and Giavazzi (2011), and IMF (2012) for a detailed discussion about Italy's fiscal plans.

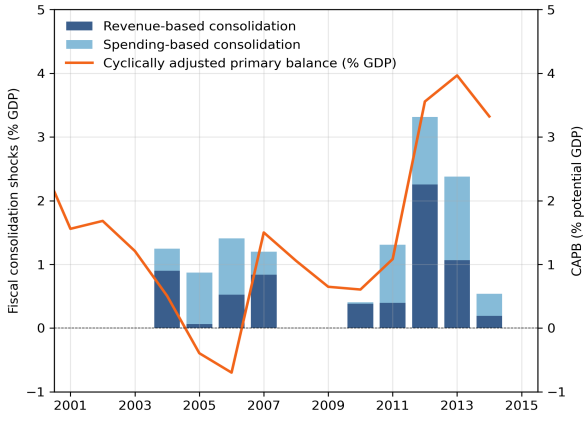
2013.

Figure 1: Sovereign debt crisis and the fiscal policy response in Italy

(a) Sovereign and firm spreads



(b) Fiscal adjustment in 2011-13



Left panel: Sovereign spread is the difference between 5-year Italian government bonds and German bunds. Firm spread is the average interest rate on new loans to non-financial corporations in Italy minus the 5-year Bund yield. Source: Bank of Italy, ECB, and Bloomberg. **Right panel:** Fiscal consolidation measures as a percentage of GDP for the 2011-2013 period based on narrative identification and cyclically-adjusted primary balance (% potential GDP). Source: OECD, Alesina et al. (2017).

Heterogeneous impact of the crisis on firms. Firm performance during the Euro sovereign debt crisis weakened substantially in Italy, with firms in non-tradable sectors faring even worse, as seen in Figure 2.[6] At the industry level, real gross value added for the non-tradable sector declined by a cumulative 5% between 2011 and 2015 and remained stagnant thereafter, while the tradable sector saw a 4% decline and quickly recovered after 2013 – a pattern of heterogeneous performance not observed during the GFC where the impact on tradables was larger. At the firm level, using aggregated firm data, we also see a much larger deterioration of fundamentals for firms in the non-tradable sector, with a larger and more persistent decline in real revenue.[7]

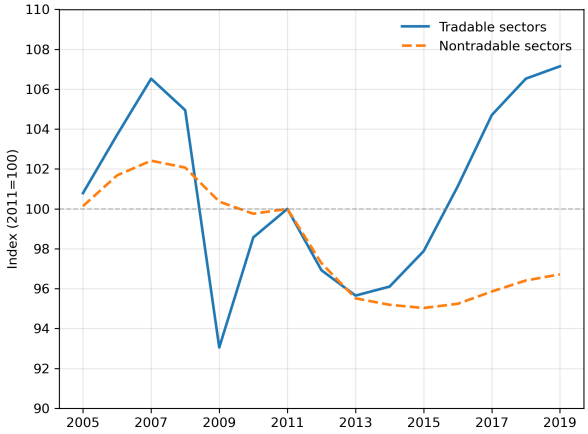
Credit conditions for firms. Firm credit conditions also deteriorated significantly during the 2011-13 sovereign debt crisis, which was also heterogeneous in the tradability level of firms. As seen in Figure 3, interest rates on bank loans increased by more than 2 percentage points across the board, with firms in the non-tradable facing higher borrowing costs relative

[6]We define sector tradability at the NACE 2-digit industry level following Lombardo and Ravenna (2012) and Broadbent et al. (2022). A tradability index (i.e. the ratio of exports plus imports to final demand) is constructed at basic prices from Eurostat Supply and Use tables. An industry is 'tradable' if more than 10% of its total demand is traded.

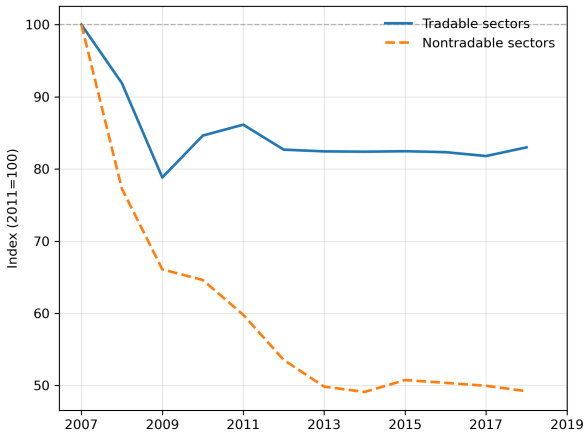
[7]Firm-level real revenue data is taken from the Competitiveness Research Network (CompNet) at the NACE 2-digit industry level and aggregated up based on sector tradability.

Figure 2: Heterogeneous firm performance in Italy

(a) Real gross value added by sector



(b) Real firm-level revenue by sector

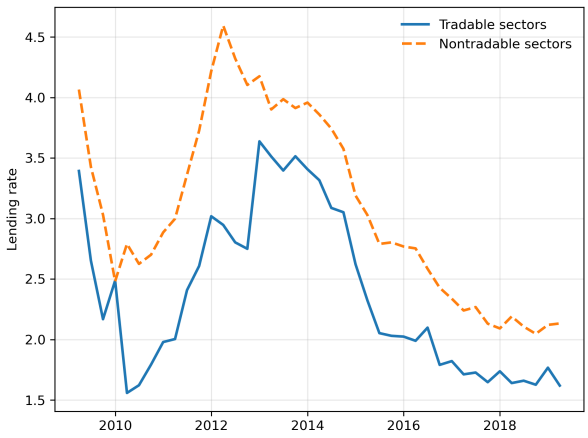


Left panel: Real gross value added at NACE 2-digit industry level aggregated up to tradable/nontradable sectors based on industry tradability following Lombardo and Ravenna (2012) and Broadbent et al. (2022). Source: Eurostat, author's calculations. **Right panel:** Mean real revenue at 2-digit industry level from Compnet aggregated using relative weights of each industry and tradability index. Source: CompNet, author's calculations.

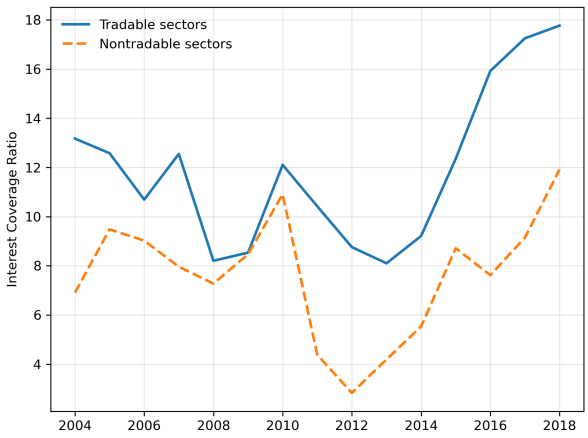
to those in the tradable sector. At the firm level, interest coverage ratios – that is, income relative to interest expenses – also fell, with a steeper deterioration for nontradable firms.[8]

Figure 3: Heterogeneous credit conditions in Italy

(a) Interest rates on firm credit by sector



(b) Interest coverage ratio by sector



Left panel: Annual interest rate on bank loans (new business in the quarter) by non-financial firms aggregated to tradable/nontradable sectors weighted by total outstanding loans in each sector. Source: Bank of Italy, author's calculations. **Right panel:** Firm-level interest coverage ratio, defined as the ratio of EBITDA to interest expenses. Source: Compustat, author's calculations.

[8]Interest coverage ratios are defined as the ratio of EBITDA to interest expenses. It is a measure of debt servicing capacity/ability to make interest payments using internal cash flows.

2.2 Analysis

Motivated by the empirical facts about the fiscal response and sectoral heterogeneity in firm performance and credit conditions in Italy following the sovereign debt crisis described in Section 2.1, we now provide empirical evidence for the transmission channel explored in our quantitative model – namely, that contagion of risk to firms happens via the endogenous reaction of fiscal policy to sovereign risk.

We estimate the effect of fiscal consolidation on firm performance and financial frictions by compiling an annual panel dataset for 10 European economies from 1990 to 2018 that combines (i) firm-level data from Compustat Global for publicly-listed European firms; (ii) narrative fiscal consolidation shocks from Alesina et al. (2017) which extends the dataset of narrative-identified fiscal stabilizations in Guajardo, Leigh and Pescatori (2014), (iii) the tradability of each firm's 2-digit NACE code from Supply and Use tables from Eurostat as in Broadbent et al. (2022); and (iv) macroeconomic data from the Jordà, Schularick and Taylor (2015) Macrohistory Database for country-level control variables.[9]

We use Jordà (2005) local projections to estimate the dynamic causal impact of the identified fiscal consolidation shocks on firm-level variables, and test for the heterogeneous effect across sectors by interacting the effect of the shock with the tradability of each firm. The consolidation shocks in Guajardo, Leigh and Pescatori (2014) and Alesina et al. (2017) are identified using policy documents discussing revenue and expenditure-related fiscal consolidations. The identifying assumption is that these policy changes were not implemented with the objective of cyclical stabilization. We test for the effect of fiscal consolidation shocks on five firm-level variables: (i) implied probability of default derived from a firm's distance-to-default, as in Gilchrist and Zakrajšek (2012) and Ottonello and Winberry (2020), (ii) interest coverage ratio, (iii) interest expense ratio (relative to total debt), (iv) (log) real sales as a measure of firm output, and (v) (log) total assets as a measure of firm investment. See Appendix

Two specifications are estimated. Firstly, we consider the average effect of a fiscal shock on firms across all sectors. For firm i in country j at time t,

$$\Delta y_{i,j,t+h} = \alpha_i^h + \beta_1^h \varepsilon_{j,t} + \Gamma_1 X_{i,t-1} + \Gamma_2 Z_{j,t-1} + e_{i,j,t}, \tag{1}$$

where $\Delta y_{i,j,t+h}$ is the cumulative change in the outcome variable at $t+h$ relative to $t-1$, $\varepsilon_{j,t}$ are the identified fiscal shocks for country j, and β_1^h is the coefficient of interest measuring the effect of the shock at time t on the firm-level outcome at $t+h$. Furthermore, α_i^h are firm fixed effects, $X_{i,t-1}$ is a vector of lagged firm-level controls which includes (i) real sales growth, (ii) current assets as a share of total assets, and (iii) size (i.e. log total real assets) (as in **?**),

[9] The 10 countries in the dataset are Italy, Spain, Portugal, Belgium, France, Germany, Denmark, Finland, Sweden, and the United Kingdom. See Appendix A.1 for more details on data construction.

and $Z_{j,t-1}$ is a vector of lagged country-level controls.

Second, we then allow for heterogeneous effects due to sector tradability. The specification becomes

$$\Delta y_{i,s,j,t+h} = \alpha_i^h + \beta_1^h \varepsilon_{j,t} + \beta_2^h (\varepsilon_{j,t} \times a_{s,t-1}) + \Gamma_1 X_{i,t-1} + \Gamma_2 Z_{j,t-1} + e_{i,j,t}, \tag{2}$$

where $a_{s,t-1}$ is the tradability share of each firm-country pair's NACE Rev. 2 code and β_2^h measures the heterogeneity in response of firm-level outcomes to the firm's sector tradability.

Figure 4 plots the impulse responses for the average effects obtained from the first specification. For financial variables, a tax-led fiscal consolidation equivalent to 1% of GDP leads to statistically significant deterioration of financial frictions across all three variables. The implied probability of default increases on impact and remains elevated over the subsequent 4 years, at a permanent level 0.5pp above. The interest coverage ratio declines particularly 1 and 2 years after the shock, pointing to a temporary deterioration in the average firm's debt servicing capacity. Finally, the interest expense ratio relative to total debt also increases both at impact and at subsequent periods, pointing to an average increase in borrowing costs. For real variables, we also see that output (measured by real sales) declines significantly on impact and in subsequent periods, peaking at -2% 2 years after the shock. Investment (measured by the change in log total assets) also declines significantly on impact and in the following two years, mean reverting four years after the shock.

We now examine whether these average effects are heterogeneous in firm tradability. Figure 5 shows the impulse responses for the second specification. For most of the variables, the results suggest that effects are indeed heterogeneous in firm tradability. The interaction coefficient for the implied probability of default is negative on impact, suggesting that firm default risk is decreasing in tradability. That is, firms that are more exposed to domestic demand (i.e. nontradable) face a larger increase in default probabilities following austerity. This is also true for the interest coverage ratio, suggesting that the negative change in the debt servicing capacity of firms following a tax shock is significantly muted for higher tradable firms. For interest expenses, while the average effect is significantly positive, we don't see any evidence of heterogeneity across this dimension. Finally, for real variables, the interaction coefficient is significantly positive for both sales and investment. While austerity is contractionary for the average firm (as seen by the IRFs for β_1), this effect is much deeper for firms that cannot export their production.

Taken together, these results are consistent with the theoretical mechanism presented in the model. Tax-based fiscal consolidations as a result of fiscal sustainability concerns (including increases in sovereign risk) generates a negative effect on firm output and investment and worsens financial frictions that firms face, increasing borrowing costs and default risk.

Therefore, contagion of risk from the sovereign to firms emerges endogenously via the reaction of fiscal policy. Furthermore, these effects vary conditional on the level of tradability of firms, with those in non-tradable industries experiencing stronger effects.

Figure 4: Fiscal consolidation effect across all firms

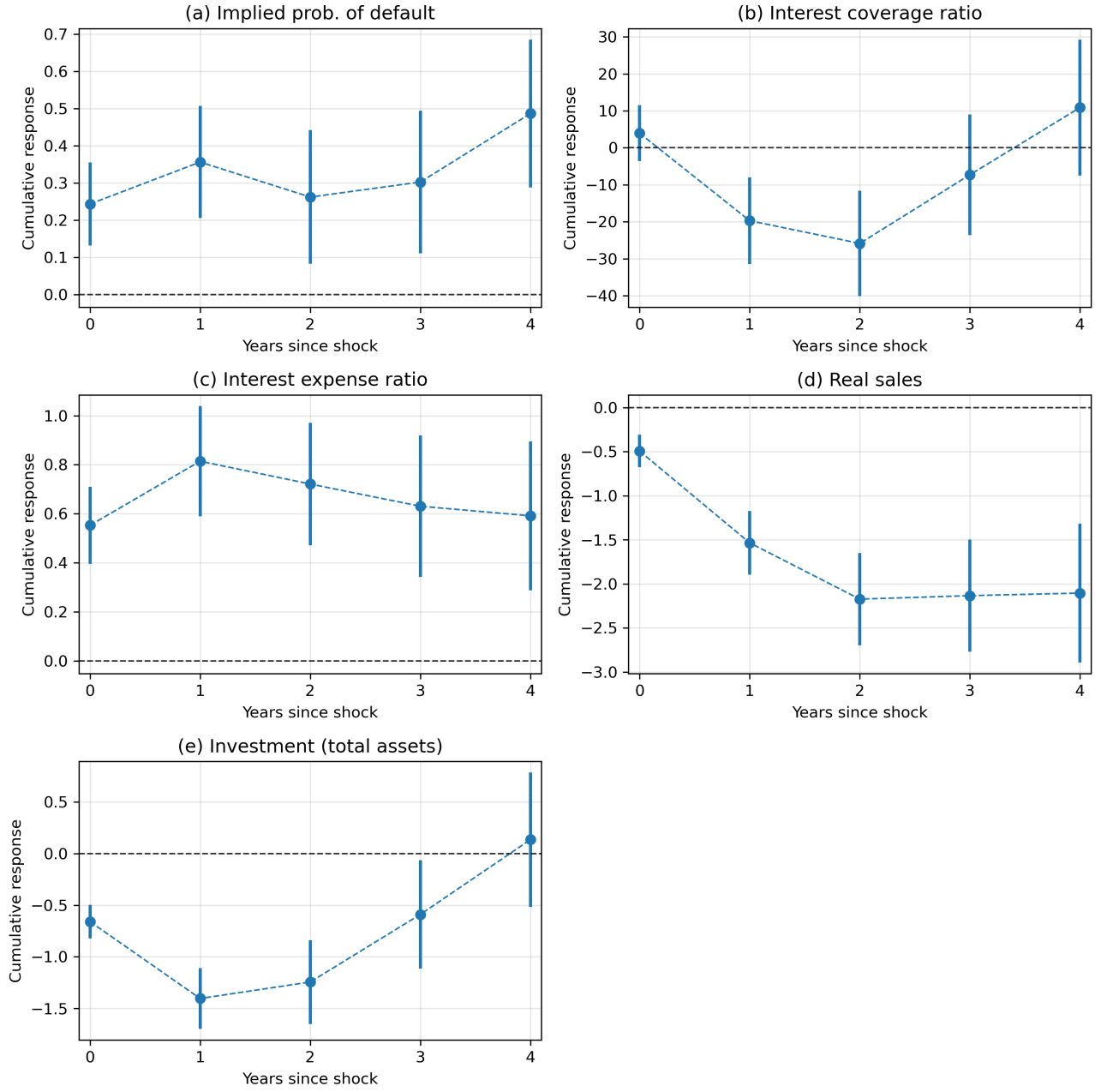
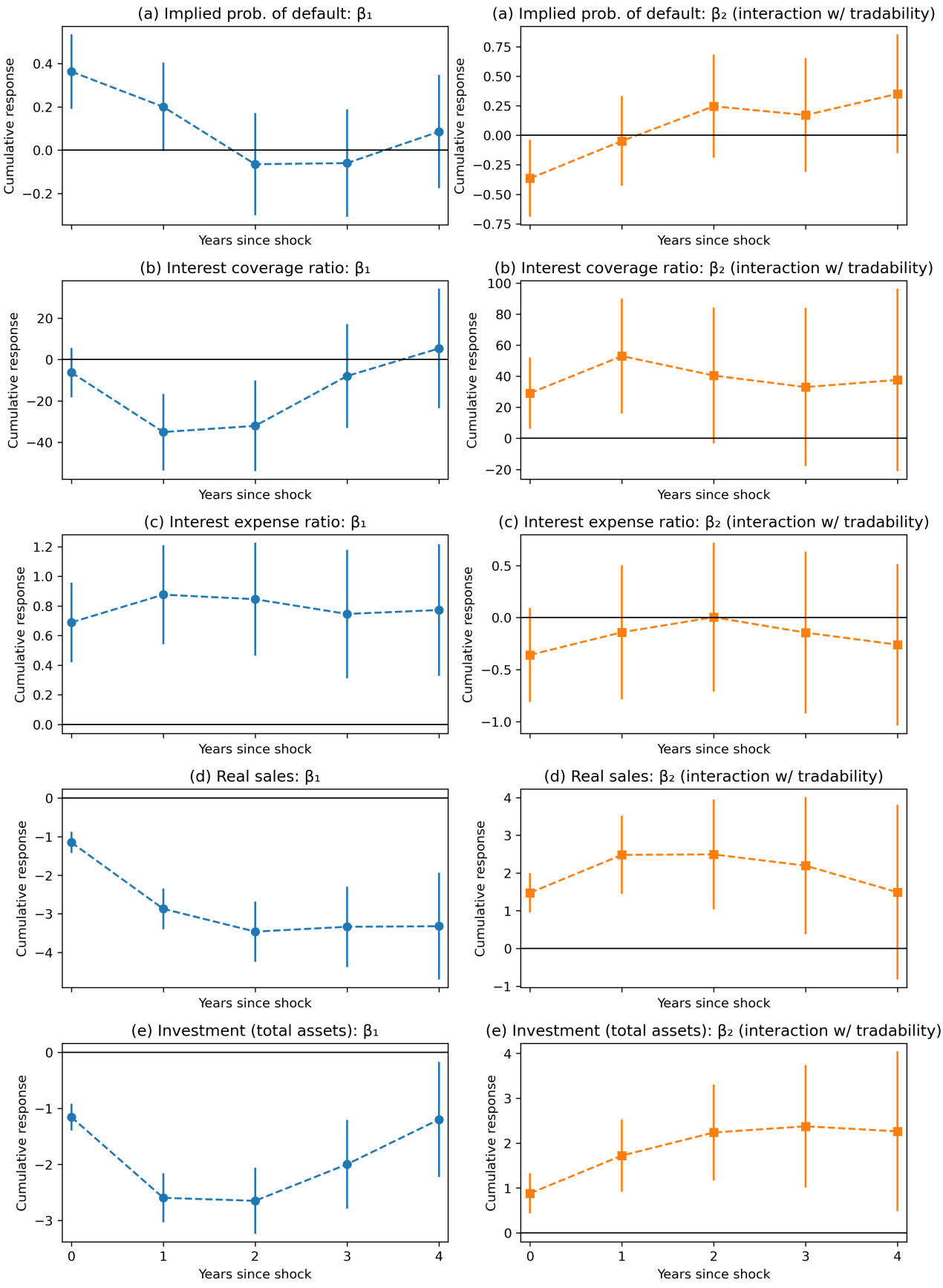


Figure 5: Heterogeneous effect of fiscal consolidation across sectors



3 Model

We consider an infinite-horizon, small open economy trading in goods and assets with the rest of the world. Time is discrete and is indexed by t. The small open economy is populated by three types of agents: a representative household, firms and a government. The household derives utility from leisure and from consumption of two different goods, tradable and non-tradable. The representative household owns the firms that operate in the economy. Firms hire labor to produce output of tradable or non-tradable goods. In each period, the government purchases an exogenous amount of goods. To fund this expenditure, the government can raise taxes on domestic households, and it can borrow from foreign lenders. The government borrows by issuing one-period, non-contingent but defaultable debt. The government internalizes the welfare of the representative households, and its objective is to maximize its utility.

3.1 Households

Preferences of the representative household are summarized by its expected lifetime utility, which is given by:

$$\mathbb{E}_0 \left[\sum_{t=1}^{\infty} \beta^t \frac{1}{1-\gamma} \left(c_t - \chi \frac{l_t^{1+\psi}}{1+\psi} \right)^{1-\gamma} \right], \tag{3}$$

where c_t is a composite consumption good and l_t denotes hours of labor supplied by the household. $\mathbb{E}_0$ is the expectation operator conditional on information available at time 0. The subjective discount factor is denoted by $\beta < 1$ and the coefficient of relative risk aversion by $\gamma > 0$; $\psi > 0$ denotes the inverse of the elasticity of labor supply; and χ is a scaling parameter that determines the relative marginal utility of consumption and leisure. Consumption c_t is defined as a CES aggregator of tradable and non-tradable consumption goods, $c_{T,t}$ and $c_{N,t}$:

$$c_t = \left[a^{\frac{1}{\theta}} c_{T,t}^{\frac{\theta-1}{\theta}} + (1-a)^{\frac{1}{\theta}} c_{N,t}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{4}$$

where θ represents the elasticity of substitution across the two goods, and a denotes the utility weight assigned in the aggregator to the tradable good.

In each period, the household faces a flow budget constraint given by:

$$c_{T,t} + p_{N,t} c_{N,t} = w_t (1-\tau_t) l_t + d_t - h_t. \tag{5}$$

The budget constraint is expressed in units of tradable good—the numéraire in this economy. The relative price of the non-tradable good in units of numéraire is given by $p_{N,t}$. The

left-hand side of this expression describes the household's expenditure for purchases of consumption goods. The right-hand side of the budget constraint describes the representative household's income. w_t denotes the wage rate per unit of labor supplied by the household. The household pays taxes on its labor income to the government, and τ_t is the proportional labor income tax rate. The household receives dividends from the firms that it owns, and d_t is the aggregate amount of such dividends. h_t is a lump-sum social security contribution that the household pays.[10] The household's total consumption expenditure can be expressed as $p_t c_t$, where p_t is the price index of the CES aggregator c_t:

$$p_t = \left[a + (1-a)\, p_{N,t}^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{6}$$

The household cannot directly interact with foreign residents. However, it indirectly borrows from or lends to international financial markets through the actions of the domestic government.

Each period, the household chooses $c_{T,t}$, $c_{N,t}$ and l_t to maximize its utility (3) subject to the flow budget constraint in period t, (5). The first-order conditions of this problem are given by:

$$a^{\frac{1}{\theta}} \left(c_t - \chi \frac{l_t^{1+\psi}}{1+\psi}\right)^{-\gamma} \left(\frac{c_t}{c_{T,t}}\right)^{\frac{1}{\theta}} = \lambda_t, \tag{7}$$

$$(1-a)^{\frac{1}{\theta}} \left(c_t - \chi \frac{l_t^{1+\psi}}{1+\psi}\right)^{-\gamma} \left(\frac{c_t}{c_{N,t}}\right)^{\frac{1}{\theta}} = \lambda_t p_{N,t}, \tag{8}$$

$$\chi l_t^{\psi} = \frac{w_t\,(1-\tau_t)}{p_t}, \tag{9}$$

where λ_t is the marginal utility of wealth, or the Lagrange multiplier on the budget constraint. Household preferences imply that the marginal utility of leisure is proportional to that of consumption, so that consumption does not appear in the first-order condition for hours, (9).[11] Finally, (7) and (8) can be combined to obtain the intra-temporal equilibrium condition linking the relative consumption of tradable and non-tradable goods to their relative price:

$$p_{N,t} = \left(\frac{1-a}{a}\right)^{\frac{1}{\theta}} \left(\frac{c_{T,t}}{c_{N,t}}\right)^{\frac{1}{\theta}}. \tag{10}$$

[10] In equilibrium, social security contributions serve to insure workers against losses due to default by firms on wage payments they are owed.

[11] Specifically, the results follows from $\lambda_t = \frac{1}{p_t}\left(c_t - \chi \frac{l_t^{1+\psi}}{1+\psi}\right)^{-\gamma}$. These preferences are also known as GHH, following Greenwood, Hercowitz and Huffman (1988). Note that in models with non-tradable goods, wealth can affect the choice of labor supply in general equilibrium, through its impact on the price level, p_t (see Benigno et al. (2013)).

3.2 Firms

The small open economy is inhabited by a continuum of unit mass of firms. Firms are indexed by $i \in (0, 1)$. A subset of firms with mass m_T has access to a technology to produce tradable goods. The complementary set of firms, with mass $1 - m_T$, has access to a similar technology to produce non-tradable goods. In both sectors, the only input required to produce output is labor supplied by the representative household. The amount of goods produced by a generic firm i in each period t, $y_{i,t}$, is given by

$$y_{i,t} = z_t s_{i,t} l_{i,t}^{1-\alpha} - \varphi, \tag{11}$$

where $l_{i,t}$ is the amount of labor used in production by firm i; $s_{i,t}$ is an idiosyncratic productivity shock affecting the output of firm i; and z_t denotes an aggregate productivity shock. The output of all firms is net of a fixed cost, φ, which is denominated in units of the type of good produced by either firm. The elasticity of output, gross of fixed costs, to labor input is given by $1 - \alpha$.

Aggregate variables are known to all firms at the beginning of each period, before their production is realized. Such variables include aggregate productivity z_t and variables related to fiscal policy—namely, the tax rate τ_t and assets held by the government $b_{G,t}$. Idiosyncratic productivity $s_{i,t}$ is not revealed to firms until after their choices are made and production is realized, at the end of each period. The stochastic process driving idiosyncratic productivity is i.i.d. across periods and firms.[12]

Firms are subject to a working capital constraint. Due to the constraint, each firm must pay a fraction of its wage bill before production is realized. Firms can neither obtain equity from their shareholders nor retain earnings to store resources internally. However, in order to obtain resources to pay workers, firms can borrow by issuing intra-period, non-contingent and defaultable debt to foreign lenders. The working capital constraint is given by:

$$\zeta w_t l_{i,t} \leq q_{F,i,t} b_{F,i,t}, \tag{12}$$

where ζ denotes the fraction of the wage bill that the firm has to pay in advance; $b_{F,i,t}$ is the amount of debt issued by the firm; and $q_{F,i,t}$ is the unit price of such debt. The amount of resources that each firm raises on international financial markets at the beginning of each period is given by $q_{F,i,t} b_{F,i,t}$. Firm-specific variables affect the price of debt that each firm issues. In particular, this price is a function of the amount of debt issued and of labor hired by the firm itself, as well as of the relative price of the good that the firm produces. These variables determine in equilibrium the expected return to lenders on debt issued by the firm;

[12] Aggregate and idiosyncratic productivity both take values in the support $[0, \infty)$.

hence, they are necessary to determine the price at which such debt is traded.

At the end of each period, after idiosyncratic shocks are realized, all firms pay out output net of payments due to workers and lenders as dividends to the domestic household.[13] The dividend paid by each firm is given by

$$d_{i,t} = \max\left\{p_{i,t}y_{i,t} - (1-\zeta)\, w_t l_{i,t} - b_{F,i,t}, 0\right\}, \tag{13}$$

where $p_{i,t}$ is the relative price of output produced by each firm, given by $p_{N,t}$ if the firm produces non-tradable goods, and by unity otherwise. If the value of output is not sufficient to repay workers and lenders, $p_{i,t}y_{i,t} < (1-\zeta)\, w l_{i,t} + b_{F,i,t}$, the firm defaults on external lenders and it does not pay any dividend.[14] Upon default, a firm exits and is replaced in the following period by a new and identical one.

In each period, all firms hire labor and issue debt to maximize the expected value of dividends realized at the end of the period, subject to the working capital constraint (12) and taking into account how choices for labor and debt affect the price of debt. Dropping time subscripts, the problem of an individual firm is given by:[15]

$$\begin{aligned} \max_{l_i, b_i} \mathbb{E}_s\left(d_i\right) = \int_0^\infty \max\left\{p_i\left(z s l_i^{1-\alpha} - \varphi\right) - (1-\zeta)\, w l_i - b_{F,i}, 0\right\} f_s\left(s\right) ds \\ \text{s.t. } \zeta w l_i \leq q_{F,i} b_{F,i}, \end{aligned} \tag{14}$$

where $\mathbb{E}_s$ denotes the mathematical expectation operator over the distribution of firm-level idiosyncratic productivity shocks, which is denoted by $f_s\left(s\right)$. All firms have access to identical information sets, and all enter each period with no resources inherited from the past. Hence, all firms in a given sector optimally make identical choices. In equilibrium, the working capital constraint is binding with equality. Each firm optimally equates the expected marginal product of an additional unit of labor with its marginal cost. Formally, the first-order condition associated with the firm's problem is given by:

$$(1-\alpha)\, \mathbb{E}_s\left[s \middle| s \geq \hat{s}_i\right] p_i z l_i^{-\alpha} = w\left(1 - \zeta + \frac{\zeta}{q_{F_b,i} b_{F,i} + q_{F,i}}\right) - \frac{q_{F_l,i} b_{F,i}}{q_{F_b,i} b_{F,i} + q_{F,i}}, \tag{15}$$

where $q_{F_b,i}$ and $q_{F_l,i}$ denote the partial derivatives of the price of debt issued by the firm,

[13] As firms do not have access to a storage technology, resources would be wasted if not transferred as dividends to the household.

[14] Workers' claims on firm resources are senior with respect to those of lenders. However, if output were insufficient to fully compensate workers, $p_{i,t}y_{i,t} < (1-\zeta)\, w l_{i,t}$, the firm would also default on its obligations to workers.

[15] Note that the choices of the firm concern only current-period variables—namely $l_{i,t}$, $b_{i,t}$, $d_{i,t}$, $q_{F,i,t}$. It is possible, then, to ignore time subscripts to simplify notation.

$q_{F,i}$, with respect to debt issued and labor hired, respectively.[16] $\hat{s}_i$ denotes the threshold for idiosyncratic productivity below which a firm defaults on external lenders, which follows from the definition of firm dividends in (13). Given choices l_i and $b_{F,i}$ and aggregate variables z, w, and p_i, this threshold is given by:

$$\hat{s}_i = \frac{(1-\zeta)\, w l_i + b_{F,i} + p_i \varphi}{p_i z l_i^{1-\alpha}}. \tag{16}$$

The policy function for default of individual firms is given by $D_{F,i}$, which is defined as the indicator variable for idiosyncratic productivity falling below the default threshold

$$D_{F,i} = 1\left(\hat{s}_i < s_i\right). \tag{17}$$

A firm defaults on wage payments due to workers if output is insufficient to fully cover them, even after defaulting on external lenders. Default on workers occurs when idiosyncratic productivity falls below the threshold given by

$$\hat{\hat{s}}_i = \frac{(1-\zeta)\, w l_i + p_i \varphi}{p_i z l_i^{1-\alpha}}. \tag{18}$$

3.3 Government

The government is a benevolent agent that trades bonds in international financial markets and sets taxes in the domestic economy, in order to maximize utility of the representative household. The only type of asset that the government can trade in is a one-period, non-contingent and defaultable bond. The government can raise revenue domestically by charging a proportional labor income tax on the household. Revenues from taxation and external borrowing are used to finance a constant and exogenous stream of government expenditure. Government expenditure takes the form of a composite good, g, which is defined analogously to consumption:

$$g = \left[a^{\frac{1}{\theta}} g_{T,t}^{\frac{\theta-1}{\theta}} + (1-a)^{\frac{1}{\theta}} g_{N,t}^{\frac{\theta-1}{\theta}} \right]. \tag{19}$$

Government purchases of tradable and non-tradable goods are denoted by $g_{T,t}$ and $g_{N,t}$, respectively. The price index associated with g is the same one associated with private consumption, p_t.[17]

[16] Differentiability of the debt price function is established, in equilibrium, by (16), (17), (28) and by the assumption that the cumulative distribution function of the stochastic process driving s is also differentiable.

[17] Note that while aggregate government expenditure, g, is constant, the government can choose $g_{T,t}$ and $g_{N,t}$ in each period to minimize expenditure, $g_{T,t} + p_{N,t} g_{N,t}$, subject to (19).

If the government has access to international financial markets, its budget constraint is given by:

$$p_t g = \tau_t w_t l_t + b_{G,t} - q_G\left(z_t, b_{G,t+1}\right) b_{G,t+1}, \tag{20}$$

where $b_{G,t}$ denotes the amount of foreign assets held by the government, and $b_{G,t+1}$ is the amount of bonds purchased by the government in the current period. Both are denominated in units of tradable goods. A negative value for $b_{G,t+1}$ implies that the government is issuing debt in the current period, promising to repay one unit of consumption goods in the following period for each unit of bond issued. The price at which bonds are issued or bought by the government is given by $q_G\left(z_t, b_{G,t+1}\right)$, which is a function of current aggregate productivity and of the amount of bonds traded.

If the government does not have access to international financial markets, it cannot issue bonds and its expenditures are financed entirely by tax revenue. The government budget constraint is then given by:

$$p_{G,t} g = \tau_t w_t l_t. \tag{21}$$

Each period, if it has access to international financial markets, the government can choose whether to repay or to default on the debt it owes to foreign lenders. The government makes this decision by comparing the benefits of default with the costs it entails, in terms of welfare of the domestic representative household. The benefit of default lies in the fact that debt is not repaid, so a lower tax rate needs to be set to balance the government budget. On the other hand, default implies two different costs that are imposed on the domestic economy. First, upon default, the government temporarily loses access to international financial markets, so debt can no longer be used as a buffer against domestic shocks. Second, the representative household suffers from a direct cost of default in the periods during which the government is excluded from international financial markets. Such a default cost is meant to capture disruptions that befall the economy in the aftermath of a default episode.[18]

When the government chooses to repay the debt it owes to foreign lenders, it retains access to international financial markets. Hence, it chooses how much debt to issue and it sets the labor income tax rate in order to satisfy the government budget constraint (20). The government's intertemporal choice problem can be expressed recursively. The state variables for the government choice problem are aggregate productivity, z, and the amount of foreign assets held by the government, b_G. I removed time subscripts, making use of recursive notation.

$V\left(z, b_G\right)$ denotes the government value function, conditional on having access to international

[18] Cole and Kehoe (2000) and Arellano (2008) both introduce direct output costs of default in their models. A strand of the literature has more recently analyzed the endogenous determinants of sovereign default costs. Mendoza and Yue (2012) is a notable example.

financial markets. The government chooses to repay or to default on debt by comparing the value function associated with default, $V_D(z)$, with the one associated with repaying debt and maintaining access to international financial markets, $V_R(z, b_G)$. The discrete choice default problem is given by:

$$V(z, b_G) = \max_{D \in \{0,1\}} DV_D(z) + (1 - D) V_R(z, b_G), \tag{22}$$

where D denotes an indicator taking the value of unity in the event of default. The problem above defines the discrete policy function for sovereign default:

$$D(z, b_G) = 1(V_R(z, b_G) > V_D(z)). \tag{23}$$

If the government chooses to default, it sets the tax rate in order to satisfy the autarky budget constraint (21). While default causes the government to be excluded from financial markets, readmission occurs in the following period with exogenous probability λ. In the event of readmission, the value function of the government is given by $V(z, 0)$, as the government regains access to markets with zero assets. If the government is not readmitted, it remains in financial autarky and may be readmitted in the following period with probability λ. During periods of exclusion from financial markets, the default cost suffered by the representative household takes the form of a direct reduction in welfare. The function $\delta(z)$, which is increasing in aggregate productivity, describes the welfare cost of default for the household. [19]

The value function in the event of exclusion is given by:

$$\begin{aligned} V_D(z) = &\max_{\tau} \{u(c^*, l^*) - \delta(z) + \beta \mathbb{E}[\lambda V(z', 0) + (1 - \lambda) V_D(z') | z]\} \\ &\text{s.t. } p^* g = \tau w^* l^*, \end{aligned} \tag{24}$$

where $u(c, l)$ denotes the period utility function defined in (3), and c^* and l^* denote the equilibrium values of consumption and hours, respectively, that are consistent with the government choice for τ and with aggregate productivity z.[20] Similarly, w^* and p^* denote equilibrium values of the wage rate and of the price index. Prime superscripts denote next-period variable values. $\mathbb{E}[\cdot | z]$ denotes the expectation operator on next-period variables, conditional on information summarized by current-period productivity.

When the government retains access to international financial markets, it chooses both the amount of foreign assets to carry into the following period and the labor income tax

[19] A more common assumption in the literature is for default costs to detract from output or aggregate productivity. The present formulation of default costs as a direct reduction of welfare has the key advantage that sovereign default does not have implications for the relative abundance of the two goods or for variables that affect firms' problems, except through fiscal policy.

[20] A complete description of the competitive equilibrium of this economy is presented in Section 3.6.

rate to charge domestic households. When issuing debt to foreign lenders, the government internalizes how changes in the amount of debt affect its price, through the function $q_G\left(z, b'_G\right)$. The maximization problem is given by:

$$\begin{aligned} V_R\left(z, b_G\right) = \max_{\tau, b'_G} & \left\{u\left(c^*, l^*\right) + \beta \mathbb{E}\left[V\left(z', b'_G\right) \middle| z\right]\right\} \\ \text{s.t. } & p^* g = \tau^* w^* l^* + b_G - q_G\left(z, b'_G\right) b'_G. \end{aligned} \tag{25}$$

The problem above defines policy functions for the tax rate and for the amount of assets traded by the government, as a function of the aggregate state variables. Note that while star superscripts still denote equilibrium values of variables, such values differ, in general, from the ones in (24). This follows from the fact that the policy function for τ when the government has access to international financial markets differs from the one that applies under financial autarky.

3.4 Foreign Lenders

The rest of the world is inhabited by a continuum of infinitely-lived, identical and risk-neutral foreign lenders. Foreign lenders trade one-period debt with the government of the small open economy and buy intra-period bonds issued by firms. Foreign lenders are profit maximizers who behave competitively.

The price of a unit of government debt that compensates lenders for sovereign default risk is given by:

$$q_G\left(z, b'_G\right) = \beta_{ROW} \mathbb{E}\left[1 - D\left(z', b'_G\right) \middle| z\right], \tag{26}$$

where β_{ROW} denotes the subjective discount factor of foreign lenders. Lenders understand how the policy function for default depends on the state variables z and b_G, and they correctly evaluate the risk of sovereign default by forming expectations over this policy function. Given the binary nature of the policy function D, (26) can be rewritten as

$$q_G\left(z, b'_G\right) = \beta_{ROW}\left[1 - \Pr\left(D\left(z', b'_G\right) = 1 \middle| z\right)\right],$$

showing how the price of sovereign debt is decreasing in the probability of next-period default.

The price at which lenders buy firm-issued debt also compensates them for firms' default risk. However, when purchasing intra-period debt issued by firms, foreign lenders do not need compensation for their rate of time preference, as all transactions take place within each period. In the event of default, all output left in the firm, net of wage payments to workers and liquidation costs, is shared among lenders, proportionally to the amount of debt that

each holds. The amount of resources shared by lenders is given by:

$$\max\left\{\xi\left(p_i y_i - (1-\zeta)\, w l_i\right), 0\right\}, \tag{27}$$

where ξ is a parameter capturing the fraction of output left in the firm after losses due to liquidation costs. The price of debt issued by firm i that is consistent with optimization by foreign lenders is, then, given by:

$$q_{F,i} = \mathbb{E}_s\left[(1 - D_{F,i}) + D_{F,i}\frac{\xi \max\left\{\left(p_i y_i - (1-\zeta)\, w l_i\right), 0\right\}}{b_{F,i}}\right]. \tag{28}$$

3.5 Market Clearing

Market clearing for labor requires that the amount of labor demanded by firms equals labor supply by the representative household

$$l = \int_{i\in(0,1)} l_i di. \tag{29}$$

For the non-tradable goods market to clear, the amount produced must equal the amount consumed by the representative household and by the government,

$$c_N + g_N = y_N\left(1 - m_T\right), \tag{30}$$

where y_N is the amount of goods produced by an average firm in the non-tradable sector, and it is defined in Appendix B.1.

By combining the household budget constraint (5), the government budget constraint (20), the definition of firm dividends (13), and the market-clearing condition for non-tradable goods (30), we obtain the market clearing condition for tradable goods:[21]

$$c_T + g_T = m_T y_T + b_G - q_G b'_G. \tag{31}$$

Finally, social security contributions paid by the representative household must cover losses on wage payments suffered by workers due to firms' default. This is established by (35) in Appendix B.1.

[21] Note that this condition is satisfied by Walras' law.

3.6 Equilibrium

In equilibrium, firms choose the optimal amount of labor to hire and debt to issue. Households choose labor supply and consumption of tradable and non-tradable goods. Both household and firms make their choices taking as given government policy for taxation, debt issuance and default. In turn, the government sets policy, taking into account the optimal behavior of domestic households and firms and of foreign lenders. I define below the competitive equilibrium in the small open economy.

Definition 1 *A recursive equilibrium in the small open economy is characterized by:*

- *a set of value functions for the government V, V_R, and V_D;*
- *household policy functions for consumption c, c_T, and c_N, and labor supply l;*
- *policy functions for firms in the tradable and non-tradable sector for labor, l_T, l_N and debt issued $b_{F,T}$, $b_{F,N}$;*
- *government policy for taxation τ, asset holdings b'_G, default D and allocation of government expenditure g_N, g_T;*
- *government debt price function q_G;*
- *equilibrium good prices p_N, p, wage w, firm debt prices $q_{F,T}$, $q_{F,N}$, dividends d_T, d_N, default thresholds $\hat{s}_T$, $\hat{s}_N$, $\hat{\hat{s}}_T$, $\hat{\hat{s}}_N$, and social security contribution h,*

such that:

- *given government policy, the policy functions of household and firms solve their maximization problems and they are consistent with the first-order conditions (7) - (9) and (15);*
- *given the debt price function q_G and the policy functions of households and firms, the government value and policy functions solve its maximization problem (22), (24), (25);*
- *government and firms' debt prices are consistent with optimization by foreign lenders, (26) and (28),*
- *markets for labor and non-tradable goods clear domestically; (29) and (30), and firm dividends and default thresholds are consistent with firm choices and are given by (13), (16) and (18).*

3.7 Calibration

The aim of this paper is to study the Italian experience of a sovereign debt crisis followed by a fiscal policy tightening and a contraction in credit to the private sector, motivated by the empirical evidence presented in Section 2. To this purpose, we calibrate the model economy with empirical targets that we draw largely from Italian data. We then analyze quantitative properties of the equilibrium, focusing, in particular, on the nature of government policy and its implications for firm-level variables. We solve the model numerically, by means of an algorithm that expands on the one developed by Arellano (2008), and we set the parameters of the model economy to match means of variables in the ergodic distribution of the model-generated data with their empirical counterparts.[22] Table 1 summarizes the calibrated parameter values and corresponding empirical targets.

We set parameters governing the technology of firms in the model to target some key data on the Italian economy. The elasticity of gross output to labor input, $1-\alpha$, is consistent with the average share of labor income in GDP, which is equal to 62.5% in Italy.[23] Bartelsman, Haltiwanger and Scarpetta (2013) show that the standard deviation of labor productivity is consistently higher than that of total factor productivity, across industries and countries. In the model, a positive value for the fixed cost of production, φ, delivers this result. We set φ to target a standard deviation of log labor productivity that is 50% higher than that of log total factor productivity, as observed in the United States.[24] The recovery rate on payments received by lenders after default by firms, ξ, determines the price at which firms are able to issue debt, the standard deviation of idiosyncratic productivity and other technology parameters. We set this parameter to match an average yearly interest rate of 1.3% on firms' debt, in line with evidence on the interest rate that Italian banks charge firms.[25] The implied quarterly probability of default by a firm is equal to 0.5%.

We set the parameter governing the tightness of the working capital constraint, ζ, to unity, implying that firms have to finance the entire wage bill, similarly to Neumeyer and Perri (2005). This assumption is consistent with the observation that the stock of credit to non-financial corporations in Italy is of the same order of magnitude as the share of GDP accruing to labor income.[26]

The stochastic process driving aggregate productivity z is log-normal with autocorrelation

[22] Appendix B.2 describes the algorithm in more detail.

[23] European Commission (2007) reports this figure for the period 1960-2006.

[24] To our knowledge, firm-level data for these variables are not available for Italy. Bartelsman, Haltiwanger and Scarpetta (2013) report that the ratio of the two standard deviations in the United Kingdom is similar to that in the United States, while it is higher in France and the Netherlands.

[25] We make use of the same series for interest rates on loans to non-financial corporations used in Section 2, net of the nominal risk-free rate.

[26] Clearly, the model overstates the fraction of credit to firms that is used to finance wages, which is below unity in the data.

of 0.98 and standard deviation of the innovations equal to 0.6%. These values are standard in the real business cycles literature. We set the mean of this process to normalize to unity the average output of firms. We discretize the process with the method of Tauchen (1986) on a very fine grid. On average, each grid point spans 0.036 unconditional standard deviations of the process. The very fine grid ensures that the function $q_G\left(z, b'_G\right)$ is sufficiently smooth. The presence of jumps in this function would cause the government to choose values of borrowing that correspond to the jumps, leading to an underestimation of the amount of sovereign debt issued and of the interest rate paid on such debt.

Idiosyncratic productivity of firms follows a log-normal process that is i.i.d. across periods and firms. The standard deviation of the process is set to 9%. This value is low in comparison to those reported by Bartelsman, Haltiwanger and Scarpetta (2013). In this model, however, transitory shocks account for the entirety of firm-level dispersion in productivity. As persistent shocks are likely to capture a sizable fraction of such dispersion, it appears conservative to use a lower value for this standard deviation. The mean of the log-normal process is set to normalize average idiosyncratic productivity to unity.

Parameters related to preferences of the domestic household are standard in the literature on international macroeconomics. One period corresponds to one quarter, for comparison with data from national accounts. We set both the intratemporal elasticity of substitution between tradable and non-tradable consumption θ and the relative share of tradable goods in consumption a to 0.5, following Stockman and Tesar (1995). The subjective discount factor of the representative household, β, is set to 0.97, implying a standard deviation of the current account of 0.6%. The subjective discount factor of foreign lenders, β_{ROW}, is set to target an average world risk-free real interest rate of 2.5%.

Government expenditure is equal to the average ratio of government consumption to GDP in Italy between 1999 to 2007, 18.5%.

The function that determines the welfare cost of default is akin to the one introduced by Arellano (2008). Differently than in that paper, the default cost is specified here as a lump-sum loss in welfare for the representative household. Given this specification, the default cost has no implication for any of the variables determined in the competitive equilibrium. As in Arellano (2008), we set default costs to imply that, in the event of exclusion from international financial markets, the period utility of the representative household is increasing in aggregate productivity only for low values of aggregate productivity itself, and it is flat otherwise. This implies that the welfare cost of default is weakly increasing in aggregate productivity. Formally, we define default costs as follows:

Table 1: Parameter values

Calibrated Parameter		Value	Target / Source
Discount factor	β	0.97	Standard deviation of current account, 0.6%
Foreign lenders' discount factor	β_{ROW}	0.994	World risk-free rate, 2.5%
Relative risk aversion	γ	2	Standard
Frisch elasticity	$\frac{1}{\psi}$	2	Standard
Labor disutility	χ	2.49	Normalize $l = 1/3$
Share of tradable goods	a	0.5	Stockman and Tesar (1995)
Intra-temporal elasticity of substitution	θ	0.5	Stockman and Tesar (1995)
Elasticity to labor input of gross output	α	0.46	Labor income share, 62.5%
Fixed cost in production	φ	0.5	Relative volatility of labor productivity
Recovery rate	ξ	0.24	Average real interest rate on firm debt
Working capital constraint	ζ	1	Ratio of total credit to labor income
Aggregate TFP standard deviation	σ_z	0.006	Standard
Aggregate TFP autocorrelation	ρ_z	0.98	Standard
Idiosyncratic TFP standard deviation	σ_s	0.09	Bartelsman, Haltiwanger and Scarpetta (2013)
Government expenditure	g	0.185	Government consumption to GDP ratio
Welfare cost of sovereign default	δ	0.9	External sovereign debt to GDP ratio, 36%
Readmission probability	λ	0.1	Average length of exclusion period

$$\delta(z) = \begin{cases} 0 & \text{if } z < \delta \mathbb{E}(z), \\ u_{aut}(z) - u_{aut}(\delta \mathbb{E}(z)) & \text{otherwise,} \end{cases} \tag{32}$$

where $u_{aut}(z)$ denotes the period utility of the representative household in autarky, when the tax rate is set so that tax revenue alone covers government expenditure, for a given value of aggregate productivity. We set the parameter δ to deliver a ratio of sovereign debt to yearly GDP of 36%. This value is close to those observed in Italy prior to the sovereign debt crisis, when considering that only foreign lenders that reside outside of the small open economy hold sovereign debt in this model. Hence, empirical targets close to 100% of GDP must be corrected by subtracting the fraction of sovereign debt that is held domestically. This fraction is equal to one half in the period preceding the global financial crisis, according to Brutti and Sauré (2016). We set the parameter λ, governing the probability of readmission into international financial markets, to 0.1, a standard value in the endogenous sovereign default literature (e.g., Cuadra, Sanchez and Sapriza (2010)).

4 Quantitative Analysis

This section presents the main quantitative results. First, we discuss the salient properties of the model economy. In particular, we analyze the interaction between government and firms through the lens of the optimal fiscal policy chosen by the government, equilibrium interest rates, prices, and the heterogeneous choices made by firms in the two sectors.

Second, we study the effects of a sovereign debt crisis on fiscal policy and on firm-level variables. The sovereign debt crisis is a shock that causes a contraction in external lending to the government but that has no direct implications for firms. We show that the crisis causes a rise in interest rates on both government and firms, as well as a contraction in domestic demand that is particularly detrimental to non-tradable goods firms.

4.1 Sovereign Default Risk, Fiscal Policy and Firms

We illustrate here the nature of the interaction between government and firms by presenting key aspects of the equilibrium of the calibrated model economy.

First, we analyze the optimal fiscal policy chosen by the planner, in terms of government net lending and taxes. Second, we discuss the implications of government policy for private-sector variables. In particular, we show that interest rates on sovereign and corporate debt are positively correlated in the model economy. As will become clear, the positive correlation emerges in general equilibrium because the government and firms jointly rely on domestic resources for their activity. In turn, we show that fiscal policy more severely affects the performance of firms in the non-tradable sector, because of its adverse implications for domestic demand.[27]

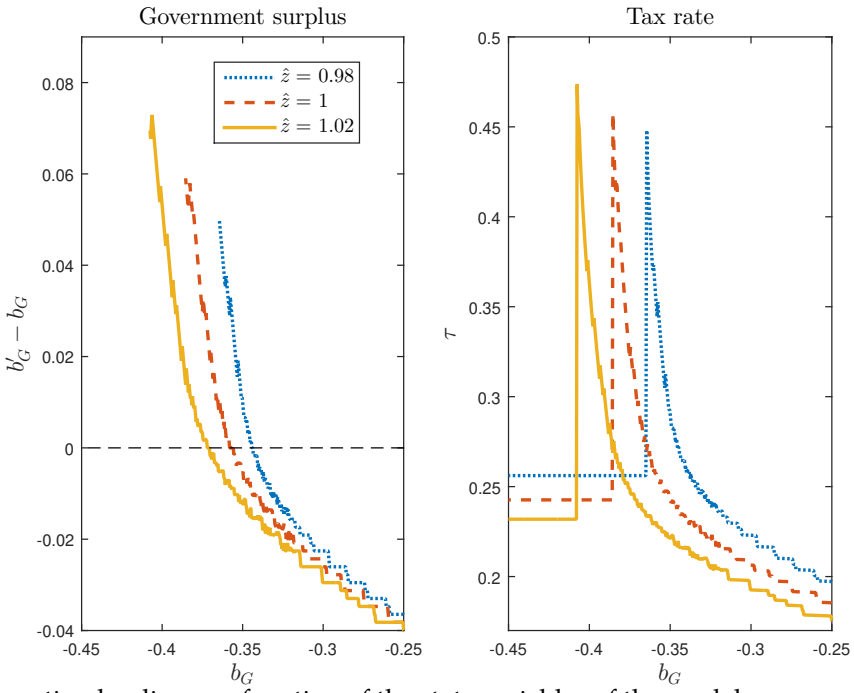
Optimal fiscal policy. The planner's choice of fiscal policy variables in terms of taxes and government borrowing is crucial in determining quantities and prices in the equilibrium of the model economy. Figure 6 displays the policy functions for government net saving and for the labor income tax rate, resulting from the solution to (25).

The government is the only agent in the economy that engages in intertemporal trade with foreign lenders, so net saving by the government corresponds to net saving of the economy as a whole. Government surplus is defined as the policy function for the change in government-held assets. Government surplus decreases in government assets, or it increases in government debt, and it decreases in aggregate productivity, as the left panel in Figure 6 shows.[28] The high cost of borrowing associated with issuing large amounts of debt induces

[27] Appendix B.3 discusses the planner's optimal default decision, and the implied function describing the price of sovereign debt.

[28] Note that while assets are divided by four, to be expressed as the ratio of a stock variable to a yearly flow,

Figure 6: Policy functions for government surplus and labor income tax rate.



The figure displays optimal policy as a function of the state variables of the model, government-held assets b_G and aggregate productivity, $\hat{z}$.

the government to run a positive surplus when it owes a relatively large amount of debt.[29] On the other hand, the relative impatience of the domestic household versus foreign lenders induces the government to run a deficit, allowing the household to front-load consumption when both government debt and government borrowing costs are low. By causing a shift in the sovereign debt price function, a positive productivity shock relaxes the constraint on external borrowing faced by the government. Hence, an improvement in aggregate productivity allows the government to choose a lower surplus, since it lowers its borrowing costs.

Taxes on labor income allow the government to raise resources from the private sector, which, in turn, it uses to finance expenditure and payments to foreign lenders. The right panel of Figure 6 displays the planner's optimal choice for the tax rate, again as a function of government-held assets and for three different values of aggregate productivity. Three main facts regarding the policy function for the labor income tax rate are worth noting. First, the planner's chosen tax rate is relatively high, as the government needs to finance high levels of government expenditure and debt. The tax rate set by the planner equals, on average, 28%, in the ergodic distribution of simulated series from the model solution. By comparison, the average implicit tax rate on labor income was equal to 42% in Italy between 2001 and

this is not necessary for the government surplus, which is a flow variable already. This fact needs to be taken into account when comparing the policy function for government surplus with the level of government debt.

[29] Appendix B.3 describes the price of debt associated with alternative choices for debt issued.

2007.[30,31]

Second, the policy function for the tax rate largely inherits the properties of the policy for government surplus: the tax rate policy function decreases in government-held assets, as well as in aggregate productivity. Intuitively, the government needs to set a higher tax rate to generate high savings, especially given the fact that the planner has no control over the level of expenditure.

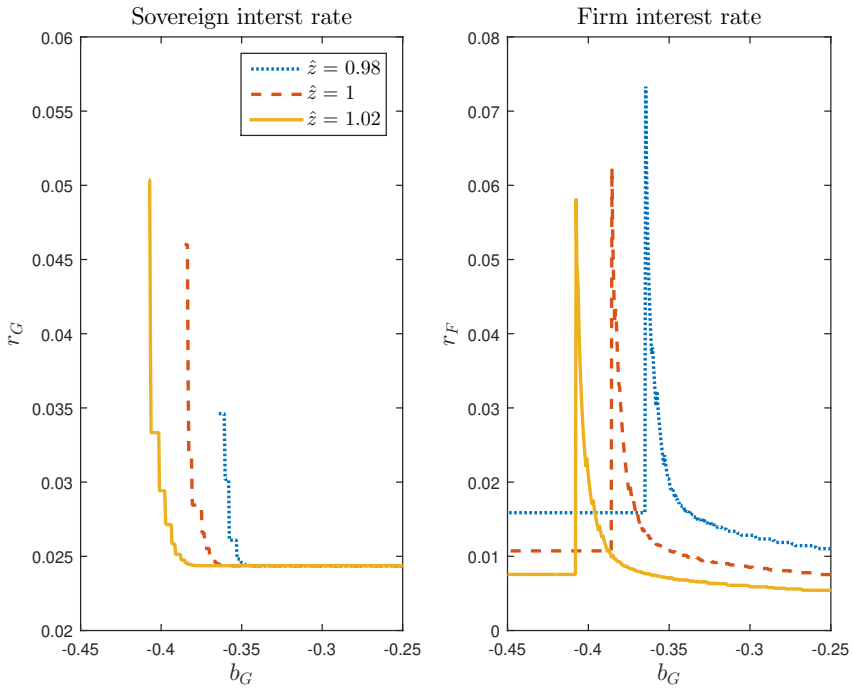
Finally, the distortionary nature of taxation implies that the tax rate increases non-linearly with government surplus. Due to the presence of a concave "Laffer curve" in tax revenue, a higher increase in the tax rate is necessary to generate the same increase in tax revenue, when starting from a higher tax rate. In particular, for two reasons, the tax rate increases when productivity falls. First, a higher government surplus is chosen given higher borrowing costs, as discussed above. Second, it is harder to generate tax revenues when productivity is lower. Indeed, a higher tax rate would have to be set, even when choosing to maintain a constant tax revenue. Importantly, the presence of financial frictions in the firms' problem affects the shape of the Laffer curve, as it influences the amount of resources that the planner can raise via taxes. In turn, as the planner's ability to raise tax revenues determines its incentive to default and the price of sovereign debt, the severity of financial frictions faced by firms affects the severity of the constraint faced by the government.

Sovereign and firms' interest rates. Borrowing costs of government and firms positively comove in this model economy. Several papers in this literature have studied the interaction between government default and the financial frictions faced by firms. In this paper, instead, the positive comovement emerges due to the endogenous, positive correlation in the default risk of government and firms. The key driver of the positive correlation in borrowing costs is the fact that a high risk of government default implies a high default risk for firms, and vice-versa. First, suppose that the risk of sovereign default is high due to, say, a large stock of government debt. Government borrowing costs are high, and the fiscal authority responds by charging high taxes, to generate a large government surplus, and to reduce the exposure of the fiscal authority to international financial markets. In turn, however, high taxes cause firms' default risk and borrowing costs to rise. Intuitively, distortionary taxes increase production costs, thereby reducing firms' profits and making their default more likely. Thus, distortionary taxation causes sovereign risk to be transmitted to the private sector.

[30] Data source: Eurostat database, Implicit tax rate on labour, table `tec00119`.

[31] Note that it may be possible to generate a higher average tax rate in the model by calibrating default costs for average sovereign debt to match a higher level of sovereign debt, closer to the entire stock of general government debt owed by Italy, rather than to the fraction held by foreign residents. This choice would, however, be counterfactual in other important dimensions—e.g., by overstating the impact of sovereign debt on aggregate demand.

Figure 7: Policy functions for the interest rate paid by government and firms on their debt



The policy functions are displayed as a function of the state variables of the model, government-held assets b_G and aggregate productivity, $\hat{z}$. The annual interest rate on government debt is the inverse of the fourth power of the debt price, minus one: $r_G = \frac{1}{q_G^4} - 1$. The firms' interest rate displayed is a weighted average of the interest rate paid by firms in the tradable and non-tradable sectors.

Second, low aggregate productivity causes a high risk of corporate default and, therefore, high interest rates on firms' debt. Low productivity is also detrimental to the government's tax revenues, thus strengthening the incentive to default on sovereign debt. Hence, a fall in productivity causes an increase in default risk for both government and firms, further leading to the positive correlation between borrowing costs for the two agents.

The mechanism in this paper differs from the one of transmission via domestic financial intermediaries, which the literature has studied extensively.[32] According to that channel, a fall in the value of sovereign debt held by domestic banks reduces the value of assets on their balance sheets. In the presence of financial frictions, a fall in asset values constrains the ability of financial intermediaries to lend to the productive sector. Hence, credit to firms contracts when borrowing costs for the government rise. This paper abstracts from this financial intermediation channel, since firms in the model borrow from foreign lenders who are well diversified and whose ability to lend is unaffected by fiscal variables in the small open economy.

Interest rates paid by both government and firms reflect, in the model, equilibrium default probabilities. Figure 7 displays policy functions for the interest rates on government's and

[32]See the literature review in Section **??** for a more extensive discussion of this strand of research.

firms' debt.[33] Both are increasing in the amount of government debt $|b_G|$ and decreasing in aggregate productivity z. First, the increase in interest rates paid by firms as government debt rises is due solely to the increase in taxes through which sovereign risk is transmitted to the private sector. An increase in government debt from 34% to 38% of GDP causes an increase in firms' interest rate by 300 basis points, when aggregate productivity is equal to its mean. As discussed earlier, a higher level of debt causes the government to set a higher labor income tax rate to generate higher government surplus. Firms' production costs rise along with the increase in the tax rate. In turn, their profits fall and their probability of default rises, leading to a higher interest rate on their debt. For the government, a higher level of initial debt $|b_G|$ induces a corresponding increase in the level of debt issued in the current period $\left|b'_G\right|$. Thus, the choice for debt issuance moves along the sovereign debt price function q_G, and debt is issued at a lower price, corresponding to a higher interest rate on government debt. The same increase in government debt from 34% to 38% of GDP causes the interest rate on government debt to rise by 40 basis points. The ability of the government to shift the cost of repayment to firms, by increasing taxes to run a larger surplus as debt rises, contributes to the relatively moderate increase in government borrowing costs.

Second, a fall in aggregate productivity also leads to a rise in the interest rate paid by firms. This result would already occur in the absence of fluctuations in fiscal variables, as lower productivity reduces firms' profits and it leads to an increase in their default probability. The increase in the tax rate associated with a decrease in productivity, however, magnifies the fall in profits, interacting with the direct effect of lower productivity and generating a rise in firms' interest rates. For the government, lower productivity leads to an increase in the probability of next-period default and to a shift in the sovereign default price function, causing the cost of sovereign borrowing to be higher for any given choice of debt issued. Hence, in equilibrium, the government pays a higher interest rate on its debt, given its choice for optimal fiscal policy.[34] A 2% fall in aggregate productivity from its unconditional mean value causes the interest rate on firms' and government debt to rise by 250 and 10 basis points, respectively, when government debt equals 36% of GDP.

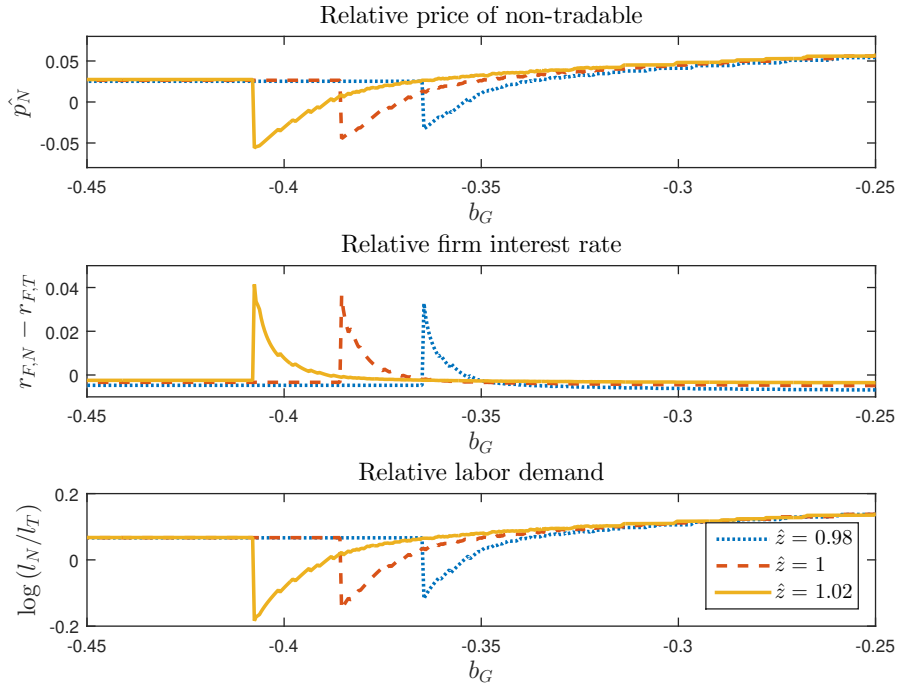
Finally, note that the interest rate on debt issued by firms is also defined in the region of the state space where sovereign default occurs. The interest rate on government debt is not defined in that region, as the government does not have access to international financial markets, whereas the interest rate on firms' debt is determined there by the level of aggregate productivity and by the tax rate set in autarky to balance the government budget constraint,

[33] I define the interest rate as the inverse of the debt price, minus one. For ease of exposition, I consider annual interest rates, obtained by taking the fourth power of the debt price: $r_G = \frac{1}{q_G^4} - 1$. The firms' interest rate displayed is a weighted average of the interest rate paid by firms in the tradable and non-tradable sectors.

[34] This is a standard result in the endogenous sovereign default literature, as in, for example, Arellano (2008)

according to (24). In particular, the default cost has no bearing on firms' interest rate, as it determines only a reduction in household welfare. Sovereign default has no adverse impact, per se, on financial frictions faced by firms in this model. Instead, default risk and the incentive for the government to avoid default by increasing taxation disrupt firms' performance.

Figure 8: Heterogeneous firm-level effects of sovereign debt



The three panels display equilibrium values of variables as a function of the state variables of the model, government-held assets b_G and aggregate productivity, $\hat{z}$. The top panel displays the relative price of non-tradable goods, expressed as the deviation from its ergodic mean. The middle panel displays the difference between the interest rates paid on debt by firms in the non-tradable and tradable sectors. The bottom panel displays the logarithm of relative labor input of firms in the two sectors.

Heterogeneous firm-level effects of sovereign debt. Sovereign debt has heterogeneous effects on the two sectors of firms that inhabit the economy, those producing tradable and non-tradable goods. High sovereign debt has more severe detrimental effects on firms in the non-tradable sector. These firms are exposed to fluctuations in domestic demand, as they cannot export and are confined to selling their production locally. Domestic demand is lower when sovereign debt is higher, as the economy runs a current account surplus to eschew the high costs of external borrowing.[35] Figure 8 graphically presents the heterogeneous effects of sovereign debt on the relative price of goods, on firms' interest rates, and on labor demand.

First, a high amount of government debt causes a fall in the relative price of non-tradable goods. Domestic demand for consumption goods is lower when government debt is high.

[35] A current account surplus follows uniquely in this model from the presence of a government surplus, as the government is the only agent trading in intertemporal assets with foreign lenders.

Hence, a lower relative price of non-tradables is necessary to induce a rebalancing of consumption towards this good. As relative consumption of non-tradable to tradable goods rises, firms in the non-tradable sector are able to sell the entirety of their production domestically. An increase in government debt from 34% to 38% of GDP causes a 6% fall in the relative price of non-tradable goods, when aggregate productivity is equal to its unconditional mean. The upper panel of Figure 8 presents the equilibrium relative price of non-tradable goods, as a function of the state variables, aggregate productivity and government-held assets.

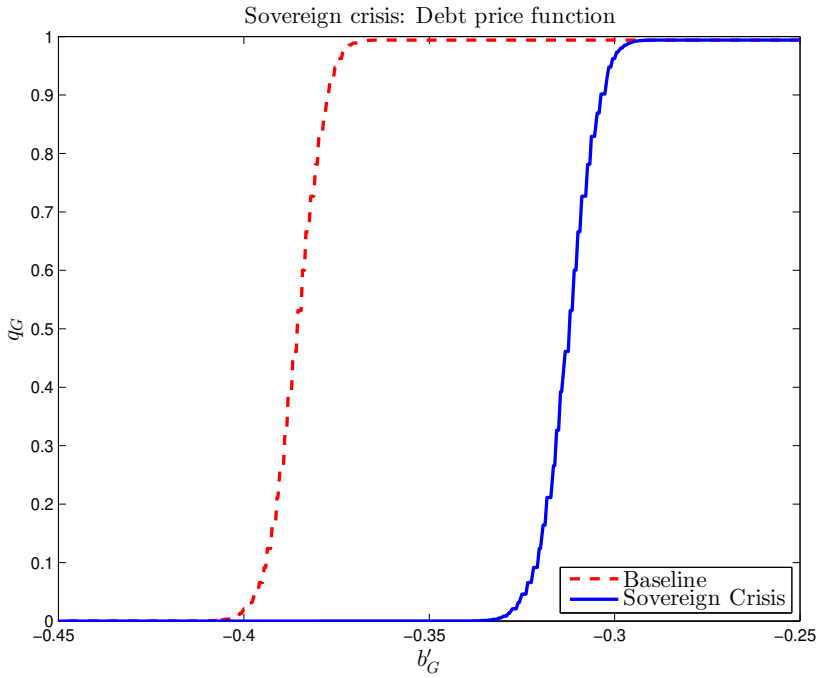
Second, firms in the non-tradable sector pay a higher interest rate than their tradable-sector counterparts when sovereign debt is high. The low relative price of output hinders the performance of firms in the non-tradable sector, in addition to the high taxes that depress the performance of all firms. Low relative demand interacts with high taxes, leading to a higher than average rise in the default probability of non-tradable firms and in their borrowing costs. Thus, fiscal policy transmits sovereign default risk to firms to a heterogeneous degree, with firms that are more exposed to domestic demand suffering from a stronger contagion of sovereign risk. The difference between the interest rate paid by non-tradable and tradable sector firms rises by 140 basis points as debt rises from 34% to 38% of GDP, and the relative price of non-tradable goods falls by 6%. The middle panel of Figure 8 shows the difference between the interest rates paid by firms in the two sectors.

Finally, the low relative price of non-tradable goods induces a relative contraction in the production of these goods, when government debt is high. Firms in the non-tradable sector individually contract their production so that, on aggregate, a higher fraction of labor input flows towards the tradable sector. Relative labor demand by non-tradable sector firms falls by 16 percentage points, as debt rises from 34% to 38% of GDP, when aggregate productivity is equal to its unconditional mean. The bottom panel of Figure 8 presents the relative labor input of firms in the non-tradable sector. Individual firms in the non-tradable sector would find it optimal to reallocate towards production of tradable goods, as domestic demand is low and expected dividends are higher in the tradable sector. Were such reallocation to be possible, the shift in relative supply would ensure the absence of fluctuations in the relative price of goods. The inability of firms in this model to choose the type of good that they produce results in an incomplete reallocation of factors of production, in fluctuations in the relative price of non-tradable, and in equilibrium heterogeneity in firm size across sectors. In the presence of decreasing returns to scale, as implied by $\alpha < 1$, the heterogeneity in firm size caused by the constraint on firms' reallocation is costly from an aggregate welfare perspective.

4.2 Sovereign Debt Crisis

This section describes a sovereign debt crisis episode, and its implications for the conduct of fiscal policy and the performance of firms. First, we introduce the crisis episode, consisting of a shock to default incentives that reduces the amount of sustainable sovereign debt. Second, we analyze the implications of the crisis for fiscal policy variables—namely, for the amount of government borrowing and the tax rate on labor income. Third, we show that the crisis is transmitted to the private sector, through its effect on fiscal policy. In particular, we show that the crisis leads to a rise in the cost of borrowing for firms, as well as for the government. Finally, we discuss the heterogeneous effects of the crisis for firms in the two sectors. The crisis causes a sharper contraction in credit and output for non-tradable firms, by inducing a fall in domestic demand.

Figure 9: Sovereign debt crisis



Shift in sovereign debt price function due to the shock to the welfare cost of default. The dashed, red line represents the sovereign debt price function under the baseline calibration of this model, for aggregate productivity equal to its ergodic mean. The solid blue line represents the same sovereign debt price function after the sovereign crisis shock, as implied by the lower welfare cost of default.

Sovereign crisis shock. A sovereign crisis in this model is a shock that causes a contraction in lending to the government. The supply of funds to the government is expressed by the debt price function (26), which is determined, in turn, by the incentive for the government to default and by the optimality condition of lenders. In the model, a decrease in the welfare cost of sovereign default leads to a contraction in the supply of funds to the government. A

weaker incentive for the government to repay causes a rise in the probability of default for any given level of debt. In turn, a higher probability of default reduces the price at which foreign lenders are willing to purchase sovereign debt, i.e. to a contraction in the sovereign debt price function.

Analyzing the euro area sovereign debt crisis through the lens of this model, the implementation of the Greek sovereign debt bailout in the summer of 2011 may have constituted an external shock that caused a contraction in lending to other euro area economies with high debt, such as Italy.[36] In the initial phase of the crisis, European Commission officials reassured financial markets, stating: "In the euro area, the default does not exist."[37] Losses imposed on private-sector lenders as part of the bailout package partly disproved such statements and showed that default in the euro area did, indeed, exist. Thus, lenders to other euro area countries may have reconsidered the likelihood of default by euro area governments, and contracted their lending accordingly.

In the model, a fall in the welfare cost of default leads to an increase in a country's default probability that is independent of economic fundamentals, such as the level of government debt or aggregate productivity. We introduce a sovereign debt crisis as an entirely unexpected shock amounting to a fall in the welfare cost of default. The fall in default costs implies that a lower level of sovereign debt is sustainable in equilibrium. We model the sovereign crisis as a shock leading to a fall in the mean level of sovereign debt consistent with the new default cost to 28% of yearly GDP, as opposed to 36% in the baseline calibration. The sovereign debt crisis shock amounts to a shift in the sovereign debt price function that causes a rise in government borrowing costs. Figure 9 displays this shift, for aggregate productivity equal to its ergodic mean.

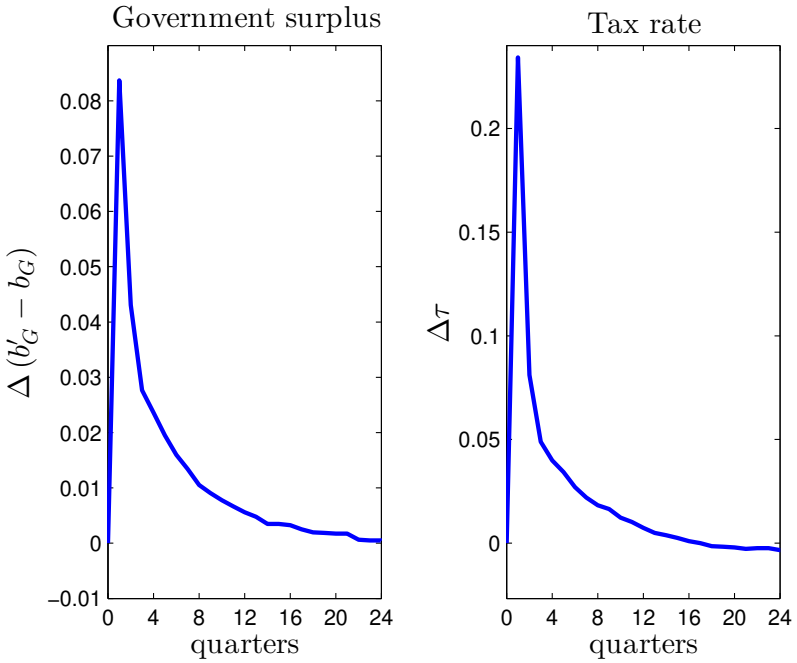
In the remainder of this section, we analyze the implications of the sovereign crisis shock for fiscal policy and for variables of interest in the competitive equilibrium of the model. First, the effects of the crisis on equilibrium differ according to the state of the economy at the time of the shock, due to the presence of non-linearities in the policy functions that characterize the solution of the model. We consider here a crisis episode that hits the economy while aggregate productivity is at its ergodic mean and while sovereign debt equals 31% of yearly GDP. Second, the dynamic implications of the crisis that emerge from a simulation of the model economy may differ, depending on the particular path of exogenous shocks that is considered. This issue is due, again, to the non-linear nature of the solution of the model. To address this concern, we consider a large number of draws for the path of exogenous aggregate productivity shocks after the initial period. We compute the median path of each

[36] For a detailed analysis of the Greek bailout, see Ardagna and Caselli (2014)

[37] Mr. Joaquin Almunia, then European Commissioner for Economic and Financial Affairs made this statement in January 2010. See Reuters article.

endogenous variable across the individual simulations that are consistent with each draw, and we show the difference between the median path after the sovereign crisis and the one in a baseline economy with no crisis. The baseline economy is not subject to the sovereign debt crisis shock, while it receives the same aggregate productivity shocks as the crisis economy, and it starts from the same initial value of sovereign debt.[38]

Figure 10: Surplus and tax rate response to sovereign crisis



Government surplus and labor income tax rate after a crisis episode that hits the economy at $t = 1$. The series displayed are computed as the difference between the median path of variables across the simulations of the economy with and without crisis.

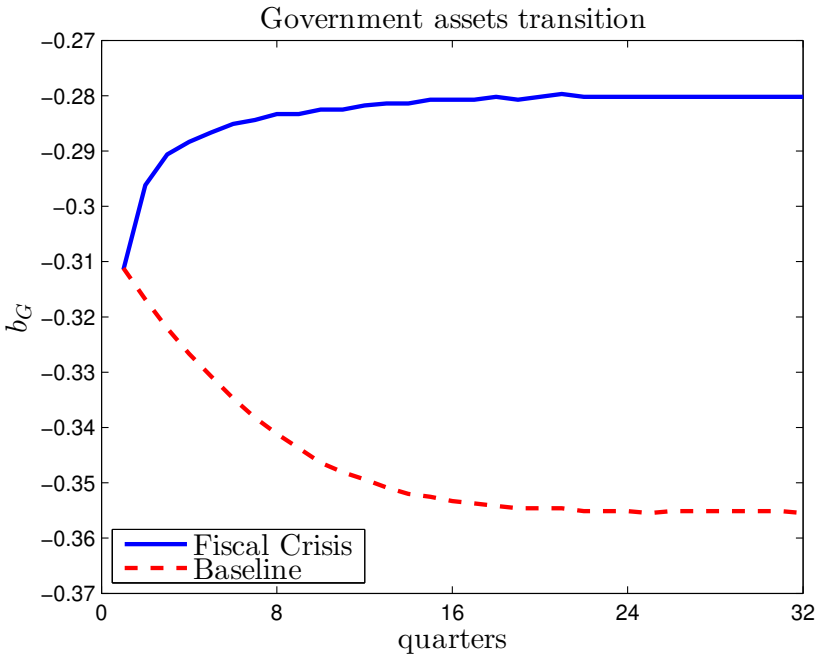
Fiscal policy in a sovereign crisis. The optimal reaction of the fiscal authority to a sovereign crisis is to reduce the reliance of the domestic economy on international financial markets, increasing government surplus and taxes. Figure 10 displays the effects of the sovereign debt crisis on government surplus and on the labor income tax rate.[39] Government surplus rises on impact by 8% of quarterly GDP when the crisis hits. The higher cost of borrowing implied by the crisis makes it less desirable for the government to have a large debt position. Hence, it is optimal for the planner to run a surplus, thus reducing the amount of external liabilities owed by the government. The increase in government surplus then gradually falls, as the stock of debt falls, too.

[38] See Appendix B.2 for further details.

[39] We analyze here the impact of the crisis by studying the difference in the path of key fiscal policy variables between the crisis economy and the baseline no-crisis one.

The fiscal planner sets a higher tax rate on labor income to achieve the increase in government surplus. The median increase in the tax rate is very large, amounting to an increase of 23.5 percentage points on impact. The increase in the tax rate is largest in the first period of the crisis, when the increase in government surplus is also the largest. However, the increase in the tax rate is proportionally larger than the increase in government surplus, due to the presence of a concave Laffer curve in tax revenue. After a sufficient number of periods following the crisis, the tax rate in the crisis economy is lower than in the baseline economy. Since the economy converges towards a new lower level of sovereign debt, a lower tax rate is eventually required to cover interest payments on debt and government expenditure.

Figure 11: Government assets transition



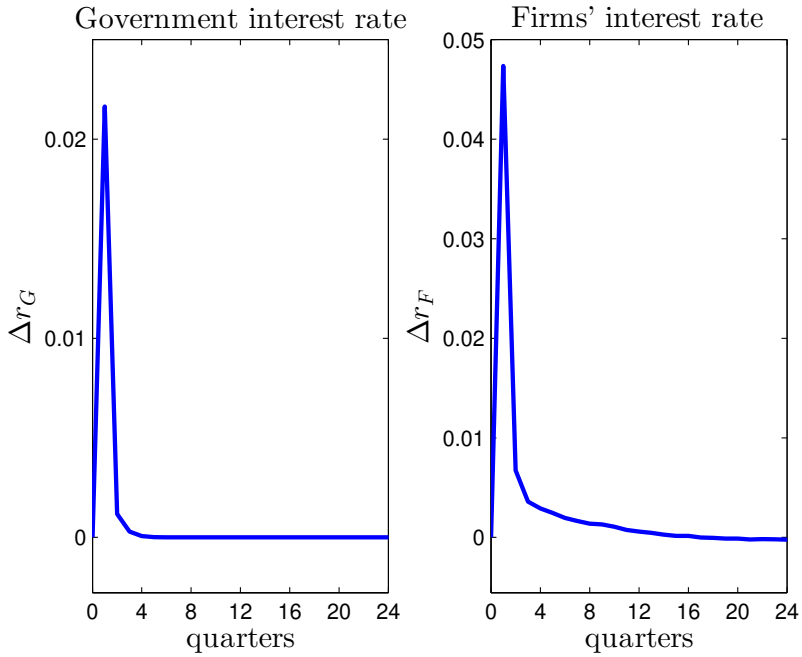
Transition of government-held assets in the crisis and in the baseline economy. The series displayed are the median across simulations for a large number of draws of exogenous aggregate productivity shocks.

Finally, the crisis and the baseline economies converge towards a stable level of government debt. The two levels differ across the two economies, given the differences in default incentives. Figure 11 presents the median transitions of government assets in the crisis economy and the baseline economy.

Government and firms' interest rates. The cost of borrowing rises for both government and firms in the event of a sovereign debt crisis. Figure **??** presents the effects of the crisis on interest rates paid by government and firms on their debt.

Interest rates on government debt rise as a result of the interaction between fiscal policy choices and the crisis shock. On impact, the crisis causes a median increase of 215 basis points

Figure 12: Interest rate response to sovereign crisis



Government and firms' interest rates after a crisis episode that hits the economy at $t = 1$. The series displayed are computed as the difference between the median path of variables across simulations of the economy with and without crisis. In the series for the government interest rate, the median is computed only in the subset of draws where the government has access to international financial markets, as the interest rate on government debt is not defined otherwise. The interest rate for firms is computed as the weighted average of the interest rate paid by firms in the two sectors, with weights given by the relative masses of firms.

in the interest rate on sovereign debt. A direct implication of the sovereign crisis is a fall in the price of sovereign debt for any given amount issued—i.e., a shift in the sovereign debt price function. The planner responds to this shock by letting the government run a larger surplus, hence reducing the amount of debt issued, as discussed. The reduction in the amount of debt issued is not large enough to completely counteract the effects of the crisis, so the interest rate on government debt does rise in equilibrium. A larger increase in government surplus would be needed to completely offset the effects of the shock on government debt prices. A large government surplus would be accompanied by an extreme rise in taxation. Given the large welfare losses that would be associated with its distortionary effects, such an increase would not be optimal from the point of view of the benevolent planner.

The sovereign crisis is transmitted to the private sector through the action of fiscal policy, inducing a rise in the interest rate paid by firms on their debt. The median increase in firms' interest rate due to the crisis equals 470 basis points. The increase in taxes set by the planner in response to the crisis reduces the ability of firms to generate profits. Higher taxes result in a reduction in the probability of government default, by allowing for a higher government surplus. However, taxes transfer resources from the private sector to the government, increasing

the probability of default by firms, as their profits fall. In turn, the rise in the probability of firms' default results in an increase in the interest rate they pay on their debt.

Changes in the interest rate paid by firms are entirely due to changes in their default probability, caused, in turn, by the evolution of fiscal policy.[40] As discussed earlier, this paper abstracts from the transmission channel of a sovereign crisis to firms via the channel of domestic financial intermediaries, which has been analyzed in the previous literature.[41] However, the two transmission channels are likely to be complementary to each other—for example, if a fall in lenders' net worth causes a rise in risk premia, at a time when the severity of firms' default risk rises due to contractionary fiscal policy.

Finally, the rise in the interest rate on firms is more persistent that on the government. The steepness of the sovereign debt price function makes it optimal for the government to ensure that debt quickly reverts to a level that is compatible with low borrowing costs, after the crisis. Even after government borrowing costs have fallen to a low level in the median simulation, however, the planner continues to let the government run a positive surplus, in order to further reduce the level of debt. As long as taxes remain higher than in the baseline simulation, firms' performance is impaired, and their borrowing costs remain high.

Heterogeneous firm-level implications of a debt crisis. The sovereign crisis has heterogeneous implications for firms in the domestic economy, depending on the type of good they produce. I now discuss implications of the sovereign crisis shock for the relative price of non-tradable goods, for the difference between the interest rates paid by firms in the two sectors, and for their relative demand for labor input. Figure 13 presents a graphical representation of these effects.

First, the relative price of non-tradable goods falls in a crisis. The relative price of non-tradable goods falls by 8.5% on impact due to the crisis in the median simulation. Domestic absorption of goods contracts when the crisis hits, due to the increase in government surplus. Demand for all goods falls, but as domestic producers cannot export non-tradable goods, their relative price must fall for this market to clear. The fall in this relative price also follows from the fact that the relative supply of non-tradable goods does not sufficiently contract during the crisis. In particular, the inability of firms to choose the type of good they produce causes goods' relative prices to fluctuate.[42]

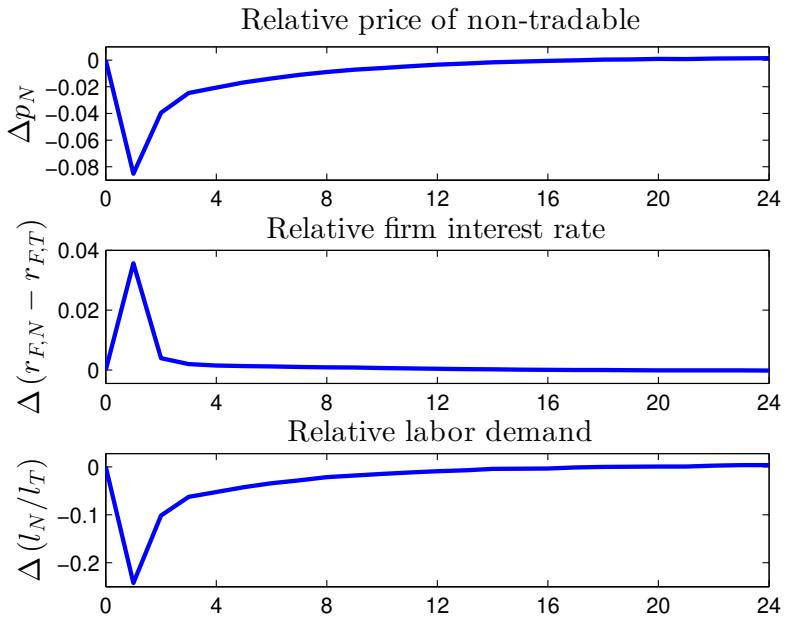
Second, the interest rate on firms' debt rises by more for firms in the non-tradable sector

[40] I can ignore shocks to aggregate productivity, as I analyze the median simulation from a large number of draws for the aggregate productivity process.

[41] Again, see Section **??** for a review of the literature in this field.

[42] As discussed, in the presence of perfect mobility of firms across the two sectors, the relative price of non-tradable goods would be unitary, independently of the state of the economy, by equalization of expected profits and wages across sectors.

Figure 13: Heterogeneous effects of a sovereign debt crisis



Relative price of non-tradable goods, difference in firms' interest rates across sectors and relative labor demand after a crisis episode that hits the economy at $t = 1$. The series displayed are computed as the difference between the median path of variables across the simulations of the economy with and without crisis. The relative price of non-tradable and the relative labor demand are presented in log-deviations from their ergodic mean.

than for those in the tradable sector. The median difference between the interest rates paid by firms in the two sectors is of 360 basis points when the crisis hits. The increase in nominal wage due to the rise in the labor income tax rate is the same across the two sectors. However, the fall in the relative price of the non-tradable goods causes the value of output of the firms producing these goods to fall, at a time when their production costs are high. Thius, their default probability rises by more than for tradable-sector firms, as their average profits fall by more, too. The non-linear interaction between the tax rate increase and the fall in the non-tradable good price contributes to a sharp increase in the interest rate on debt for firms in this sector.

Finally, labor demand falls significantly for firms in the non-tradable sector as a consequence of the crisis. Relative median labor demand in the non-tradable sector falls by 24%. This larger fall in labor demand is due to the combination of a fall in the relative price of output and a larger rise in production costs, due to the larger increase in interest rates. First, as the relative price of non-tradable goods falls, equalization of marginal products of labor across the two sectors implies that the amount of labor employed in the non-tradable sector is relatively lower. Second, the higher interest rate on debt paid by firms in the non-tradable sector implies that production costs are higher for these firms. The combination of higher

production costs and lower marginal product of labor implies a strong contraction in labor demand by non-tradable firms. Finally, the reduction in labor demand implies a fall in the amount of non-tradable good that is produced domestically, as factors of production are partially reallocated towards the tradable sector. The fall in the amount produced of non-tradable good curbs the fall in its price.

5 Conclusion

This paper shows that fiscal policy can act as a powerful transmission channel of a sovereign debt crisis to firms. We develop a framework in which the government's actions to avert sovereign default cause firms' profits to deteriorate and default risk to be shifted to the private sector. We provide empirical evidence of this mechanism using a firm-level panel for 10 European economies and narrative fiscal consolidation shocks. Then, we study the mechanism quantitatively with a calibration to Italy.

In the model, no direct linkage is present between borrowing costs of the government and firms. However, a fundamental linkage is present between the two agents. The government and firms jointly rely on resources available domestically to satisfy their objectives. Domestic households represent the key source of productive inputs for firms. At the same time, the government relies on households' labor income as its tax base. Ultimately, the joint reliance of government and firms on the same pool of resources causes financial stress to be transmitted between the two.

Two main avenues for future research follow naturally from this paper. First, it would be promising to consider the role of domestic financial intermediaries in the model. This framework would allow for an analysis of the degree of complementarity between the crisis transmission channel through the balance sheet of domestic banks that has been studied in the literature and the channel through fiscal policy here considered. In light of the recent crisis, several policy proposals have been made to address both the issue of high sovereign debt in euro area countries and the governance of the banking system.[43] The framework introduced here, if suitably extended to allow for domestic banks, would support, for example, an analysis of the costs and benefits of government-funded bank recapitalization. While such recapitalization could strengthen the domestic banking sector, its cost could weaken the government's fiscal position. In turn, a higher level of government debt could increase the severity of financial frictions faced by firms.

Second, the model could be extended to allow for an endogenous choice on the amount of government expenditure. Cuts in public expenditure were an important feature of fiscal

[43] Notable examples are Corsetti et al. (2016) and Brunnermeier et al. (2016)

austerity measures in crisis-stricken countries of the euro area. The analysis conducted here would be enriched by allowing for direct effects of government actions on domestic demand, especially when considering heterogeneous implications for different types of firms. From a theoretical perspective, consideration of realistic forms of nominal rigidities would be of interest in this setting, in order to analyze aggregate demand externality effects of government expenditure.

References

Acharya, Viral V., Itamar Drechsler, and Philipp Schnabl. 2014. "A Pyrrhic Victory? Bank Bailouts and Sovereign Credit Risk." The Journal of Finance, 69: 2689–2739.

Aguiar, Mark, and Gita Gopinath. 2006. "Defaultable Debt, Interest Rates and the Current Account." Journal of International Economics, 69(1): 64–83.

Alesina, Alberto, and Francesco Giavazzi. 2011. "The Italian Situation: Clarification and a Prediction."

Alesina, Alberto, Omar Barbiero, Carlo Favero, Francesco Giavazzi, and Matteo Paradisi. 2015. "Austerity in 2009–13." Economic Policy, 30(83): 383–437.

Alesina, Alberto, Omar Barbiero, Carlo Favero, Francesco Giavazzi, and Matteo Paradisi. 2017. "The Effects of Fiscal Consolidations: Theory and Evidence." National Bureau of Economic Research Working Paper 23385.

Ardagna, Silvia, and Francesco Caselli. 2014. "The Political Economy of the Greek Debt Crisis: A Tale of Two Bailouts." American Economic Journal: Macroeconomics, 6(4): 291–323.

Arellano, Cristina. 2008. "Default risk and income fluctuations in emerging economies." American Economic Review, 98(3): 690–712.

Arellano, Cristina, and Narayana Kocherlakota. 2014. "Internal Debt Crises and Sovereign Defaults." Journal of Monetary Economics, 68: S68–S80.

Arellano, Cristina, Yan Bai, and Luigi Bocola. 2024. "Sovereign Default Risk and Firm Heterogeneity." National Bureau of Economic Research Working Paper 23314.

Arteta, Carlos O., and Galina Hale. 2008. "Sovereign Debt Crises and Credit to the Private Sector." Journal of International Economics, 74(1): 53–69.

Ağca, Şenay, and Deniz Igan. 2019. "Fiscal consolidations and the cost of credit." Journal of International Economics, 120: 84–108.

Bartelsman, Eric, John Haltiwanger, and Stefano Scarpetta. 2013. "Cross-Country Differences in Productivity: The Role of Allocation and Selection." American Economic Review, 103(1): 305–334.

Başkaya, Yusuf Soner, Bryan Hardy, Sebnem Kalemli-Ozcan, and Vivian Yue. 2023. "Sovereign risk and bank lending: evidence from 1999 Turkish earthquake." Bank for International Settlements BIS Working Papers 1093.

Benigno, Gianluca, Huigang Chen, Christopher Otrok, Alessandro Rebucci, and Eric R. Young. 2013. "Financial Crises and Macro-Prudential Policies." Journal of International Economics, 89(2): 453–470.

Bocola, Luigi. 2016. "The Pass-Through of Sovereign Risk." Journal of Political Economy, 124(4): 879–926.

Bofondi, Marcello, Luisa Carpinelli, and Enrico Sette. 2018. "Credit Supply During a Sovereign Debt Crisis." Journal of the European Economic Association, 16(3): 696–729.

Broadbent, Ben, Federico Di Pace, Thomas Drechsel, Richard Harrison, and Silvana Tenreyro. 2022. "The Brexit Vote, Productivity Growth and Macroeconomic Adjustments in the United Kingdom." CEPR Discussion Paper DP13993.

Broner, Fernando, Aitor Erce, Alberto Martin, and Jaume Ventura. 2014. "Sovereign Debt Markets in Turbulent Times: Creditor Discrimination and Crowding-out Effects." Journal of Monetary Economics, 61(C): 114–142.

Brunnermeier, Markus K., Luis Garicano, Philip R. Lane, Marco Pagano, Ricardo Reis, Tano Santos, David Thesmar, Stijn Van Nieuwerburgh, and Dimitri Vayanos. 2016. "The Sovereign-Bank Diabolic Loop and ESBies." American Economic Review, 106(5): 508–512.

Brutti, Filippo, and Philip Sauré. 2016. "Repatriation of Debt in the Euro Crisis." Journal of the European Economic Association, 14(1): 145–174.

Chari, V. V., Alessandro Dovis, and Patrick J. Kehoe. 2020. "On the Optimality of Financial Repression." Journal of Political Economy, 128(2): 710–739.

Cole, Harold L., and Timothy J. Kehoe. 2000. "Self-Fulfilling Debt Crises." Review of Economic Studies, 67(1): 91–116.

Corsetti, Giancarlo, Keith Kuester, André Meier, and Gernot Müller. 2014. "Sovereign Risk and Belief-Driven Fluctuations in the Euro Area." Journal of Monetary Economics, 61: 53–73.

Corsetti, Giancarlo, Lars P. Feld, Philip R. Lane, Lucrezia Reichlin, Helene Rey, Dimitri Vayanos, and Beatrice Weder di Mauro. 2016. A New Start for the Eurozone: Dealing with Debt. Monitoring the Eurozone, London.

Cuadra, Gabriel, Juan Sanchez, and Horacio Sapriza. 2010. "Fiscal Policy and Default Risk in Emerging Markets." Review of Economic Dynamics, 13(2): 452–469.

De Santis, Roberto. 2012. "The Euro Area Sovereign Debt Crisis: Safe Haven, Credit Rating Agencies and the Spread of the Fever from Greece, Ireland and Portugal." European Central Bank Working Paper 1419.

Eaton, Jonathan, and Mark Gersovitz. 1981. "Debt with potential repudiation: Theoretical and empirical analysis." The Review of Economic Studies, 48(2): 289–309.

Gennaioli, Nicola, Alberto Martin, and Stefano Rossi. 2014. "Sovereign Default, Domestic Banks, and Financial Institutions." Journal of Finance, 69(2): 819–866.

Gilchrist, Simon, and Egon Zakrajšek. 2012. "Credit spreads and business cycle fluctuations." American Economic Review, 102(4): 1692–1720.

Greenwood, Jeremy, Zvi Hercowitz, and Gregory W. Huffman. 1988. "Investment, Capacity Utilization, and the Real Business Cycle." American Economic Review, 78(3): 402–417.

Guajardo, Jaime, Daniel Leigh, and Andrea Pescatori. 2014. "EXPANSIONARY AUSTERITY? INTERNATIONAL EVIDENCE." Journal of the European Economic Association, 12(4): 949–968.

Guerrieri, Luca, Matteo Iacoviello, and Raoul Minetti. 2013. "Banks, Sovereign Debt, and the International Transmission of Business Cycles." NBER International Seminar on Macroeconomics, 9(1): 181–213.

IMF. 2012. "Italy: 2012 Article IV Consultation." International Monetary Fund IMF Country Report No. 12/167.

Jordà, Òscar. 2005. "Estimation and Inference of Impulse Responses by Local Projections." American Economic Review, 95(1): 161–182.

Jordà, Òscar, Moritz Schularick, and Alan M. Taylor. 2015. "Betting the house." Journal of International Economics, 96: S2–S18. 37th Annual NBER International Seminar on Macroeconomics.

Kaas, Leo, Jan Mellert, and Almuth Scholl. 2020. "Sovereign and private default risks over the business cycle." Journal of International Economics, 123(C).

Lane, Philip R. 2012. "The European Sovereign Debt Crisis." Journal of Economic Perspectives, 26(3): 49–68.

Lombardo, G., and F. Ravenna. 2012. "The size of the tradable and non-tradable sectors: Evidence from input–output tables for 25 countries." Economics Letters, 116(3): 558–561.

Mallucci, Enrico. 2021. "Domestic Debt and Sovereign Defaults." Journal of Money, Credit and Banking, 54(6): 1741–1775.

Mendoza, Enrique G., and Vivian Z. Yue. 2012. "A General Equilibrium Model of Sovereign Default and Business Cycles." The Quarterly Journal of Economics, 127(2): 889–946.

Neumeyer, Pablo A., and Fabrizio Perri. 2005. "Business Cycles in Emerging Economies: the Role of Interest Rates." Journal of Monetary Economics, 52(2): 345–380.

Ottonello, Pablo, and Thomas Winberry. 2020. "Financial Heterogeneity and the Investment Channel of Monetary Policy." Econometrica, 88(6): 2473–2502.

Perez, Diego. 2018. "Sovereign Debt, Domestic Banks and the Provision of Public Liquidity." Mimeo, New York University.

Shambaugh, Jay C. 2012. "The Euro's Three Crises." Brookings Papers on Economic Activity, 44(1 (Spring)): 157–231.

Sosa-Padilla, César. 2018. "Sovereign defaults and banking crises." Journal of Monetary Economics, 99: 88–105.

Stockman, Alan C., and Linda L. Tesar. 1995. "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements." American Economic Review, 85(1): 168–185.

Tauchen, George. 1986. "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions." Economics Letters, 20(2): 177–181.

A Empirical Appendix

A.1 Data Construction

[add details for data construction]

A.2 Additional Results

[add additional results]

B Model Appendix

B.1 Market-clearing Conditions

In each sector X, where X corresponds to either T or N, the average amount of output produced by a firm is given by

$$\begin{aligned} y_X = & \int_{\hat{s}_X}^{\infty} \left[z s l_X^{1-\alpha} - \varphi \right] f_s(s)\, ds + \\ & \int_{\hat{\hat{s}}_X}^{\hat{s}_X} \left[z s l_X^{1-\alpha} - \varphi - (1-\xi)\left(z s l_X^{1-\alpha} - \varphi - (1-\zeta) w l_X \right) \right] f_s(s)\, ds + \\ & \int_{\frac{\varphi}{z l_X^{1-\alpha}}}^{\hat{\hat{s}}_X} \left[z s l_X^{1-\alpha} - \varphi - (1-\xi)\left(z s l_X^{1-\alpha} - \varphi \right) \right] f_s(s)\, ds = \\ = & \int_{\hat{s}_X}^{\infty} \left[z s l_X^{1-\alpha} - \varphi \right] f_s(s)\, ds + \xi \int_{\frac{\varphi}{z l_X^{1-\alpha}}}^{\hat{\hat{s}}_X} \left[z s l_X^{1-\alpha} - \varphi \right] f_s(s)\, ds + (1-\zeta) w l_X \Pr\left[s \in \left(\hat{\hat{s}}_X, \hat{s}_X \right) \right] \end{aligned} \tag{33}$$

where l_X is the amount of hours employed by a firm in sector X. Aggregate output equals aggregate output of non-defaulting firms, plus output net of liquidation costs of of defaulting firms.

Firms whose productivity falls below the threshold $\hat{\hat{s}}_X$, as defined in (18), are unable to fully compensate their workers as promised. The aggregate amount of resources promised to workers by these firms, in each sector, is given by

$$w l_X (1-\zeta) \Pr\left[s < \hat{\hat{s}}_X \right].$$

The amount of goods that these firms are able to pay workers, after liquidation, is equal to

$$\xi p_X \int_{\frac{\varphi}{z l_X^{1-\alpha}}}^{\hat{\hat{s}}_X} \left[z s l_X^{1-\alpha} - \varphi \right] f_s(s)\, ds.$$

The loss suffered by workers in defaulting firms in each sector is denoted by h_X and it is given

by the difference between the two above defined terms:

$$\begin{aligned} h_X =& wl_X (1-\zeta) \Pr\left[s < \hat{\hat{s}}_X\right] + \xi p_X \varphi \Pr\left[s \in \left(\frac{\varphi}{z l_X^{1-\alpha}}, \hat{\hat{s}}_X\right)\right] \\ & -\xi z l_X^{1-\alpha} \Pr\left[s \in \left(\frac{\varphi}{z l_X^{1-\alpha}}, \hat{\hat{s}}_X\right)\right] \mathbb{E}\left[s | \, s \in \left(\frac{\varphi}{z l_X^{1-\alpha}}, \hat{\hat{s}}_X\right)\right]. \end{aligned} \tag{34}$$

Finally, the total loss suffered by workers in all sectors is given by

$$h = m_T h_T + (1 - m_T) h_N. \tag{35}$$

The aggregate amount of dividends paid by firms in sector X and is given by

$$\begin{aligned} d_X &= \int_{\hat{s}_X}^{\infty} \left[p_X \left(z s l_X^{1-\alpha} - \varphi\right) - (1-\zeta) w l_X - b_X\right] f_s(s) \, ds \\ &= \Pr(s \geq \hat{s}_X) \, p_X z l_X^{1-\alpha} \left[\mathbb{E}(s | \, s \geq \hat{s}_X) - \hat{s}_X\right]. \end{aligned} \tag{36}$$

It can be shown that, in each sector, aggregate output equals the sum of wage and dividend payments made by firms, net of losses suffered by workers

$$y_X = w l_X + d_X - h_X. \tag{37}$$

This follows from:

$$d_X = \Pr(s \geq \hat{s}_X) \, p_X \left[z l_X^{1-\alpha} \mathbb{E}(s | \, s \geq \hat{s}_X) - \varphi\right] - \Pr(s \geq \hat{s}_X) \, w l_X \left(1 - \zeta + \frac{\zeta}{q_{F,X}}\right)$$

so that

$$\begin{aligned} d_X + w l_X - h_X =& \Pr(s \geq \hat{s}_X) \, p_X \left[z l_X^{1-\alpha} \mathbb{E}(s | \, s \geq \hat{s}_X) - \varphi\right] \\ & + w l_X \left[1 - (1-\zeta) \Pr(s \geq \hat{s}_X) - \zeta \frac{\Pr(s \geq \hat{s}_X)}{q_{F,X}}\right] - h_X \\ =& \Pr(s \geq \hat{s}_X) \, p_X \left[z l_X^{1-\alpha} \mathbb{E}(s | \, s \geq \hat{s}_X) - \varphi\right] \\ & + w l_X \left[(1-\zeta) \Pr(s \leq \hat{s}_X)\right] \\ & + w l_X \zeta \frac{q_{F,X} - \Pr(s \geq \hat{s}_X)}{q_{F,X}} - h_X. \end{aligned}$$

Noting that $b_X = \frac{\zeta w l_X}{q_{F,X}}$,

$$w l_X \zeta \frac{q_{F,X} - \Pr\left(s \geq \hat{s}_X\right)}{q_{F,X}} = \xi \int_{\hat{\hat{s}}_X}^{\hat{s}_X} \left[p_X \left(z s l_X^{1-\alpha} - \varphi \right) - (1-\zeta) w l_X \right]$$

and imposing the definition of h_X, we obtain the desired result.

B.2 Numerical Solution Algorithm

The numerical algorithm to obtain the solution to the model of Section **??** is composed of two main blocks. First, I solve for the equilibrium interaction between households and firms, for a given policy set by the government. To do so, I construct a grid of values for aggregate productivity z and for the tax rate τ. These two variables are sufficient to obtain equilibrium consumption and labor that would arise, given aggregate productivity, for any government policy that implies the same value of the tax rate. This solution allows me to define a mapping from aggregate productivity and the tax rate into period utility of the representative household. In addition, the two variables are also sufficient to determine firm-level variables, such as interest rates and profits given government policy, as well as prices and wages.

Second, I obtain the optimal fiscal policy chosen by the government. The algorithm is analogous to the one introduced by Arellano (2008). The key difference is that, in this setting, the government does not have the possibility to set lump-sum taxes or transfer on the representative household. However, the government understands how each choice for b'_G implies a tax rate τ, given aggregate productivity and initial assets b_G. Hence, the government is able to choose the optimal policy, given the mapping from aggregate productivity and taxes into household welfare obtained in the first part of the algorithm.

I study the sovereign debt crisis of Section 4.2 according to the following method. First, I solve for the equilibrium of the crisis economy with low default costs, making use of the same algorithm above described. Second, I draw a large number of simulations for the autoregressive process that drives aggregate productivity. Third, I simulate both the baseline economy and the crisis economy for the same path of aggregate productivity shocks, starting from the same initial level of debt. Finally, I compare median simulations of selected endogenous variables across the two model economies. I report these comparisons in Section 4.2.

B.3 Additional Results

B.3.1 Sovereign Default

Figure 14 presents the policy function for sovereign default, as determined by the solution to (22). The pink, shaded area represents the subset of the state space where it is optimal to

Table 2: **Firm performance response to fiscal consolidation shock**.

		Year t	**Year** $t+1$	**Year** $t+2$	**Year** $t+3$
Real Revenue					
(1)	Fiscal shock$_t$	-0.73	-2.24**	-3.41***	-0.84
		(0.68)	(0.80)	(0.93)	(0.97)
(2)	Fiscal shock$_t$	-4.04***	-10.14***	-12.22***	-8.50***
		(1.03)	(1.49)	(1.74)	(0.97)
	Fiscal shock$_t$ × tradability	9.65**	22.80***	25.54***	21.78***
		(3.09)	(4.48)	(5.06)	(4.88)
	Observations	5411	5013	4568	4218
Employment					
(3)	Fiscal shock$_t$	-0.47	-1.19**	-1.37**	-0.33
		(0.39)	(0.46)	(0.53)	(0.55)
(4)	Fiscal shock$_t$	-1.71**	-3.48***	-4.06***	-2.77***
		(0.53)	(0.68)	(0.77)	(0.81)
	Fiscal shock$_t$ × tradability	3.57*	6.68**	7.87***	7.10**
		(1.68)	(2.07)	(2.30)	(2.34)
	Observations	5252	4852	4408	4070
Wages					
(5)	Fiscal shock$_t$	-0.61*	-2.46***	-3.43**	-2.99***
		(0.26)	(0.31)	(0.39)	(0.40)
(6)	Fiscal shock$_t$	-1.23***	-3.65***	-4.78***	-3.78***
		(0.30)	(0.41)	(0.50)	(0.49)
	Fiscal shock$_t$ × tradability	1.80*	3.38***	3.85***	2.15*
		(0.72)	(0.88)	(0.98)	(0.99)
	Observations	5436	5037	4590	4239

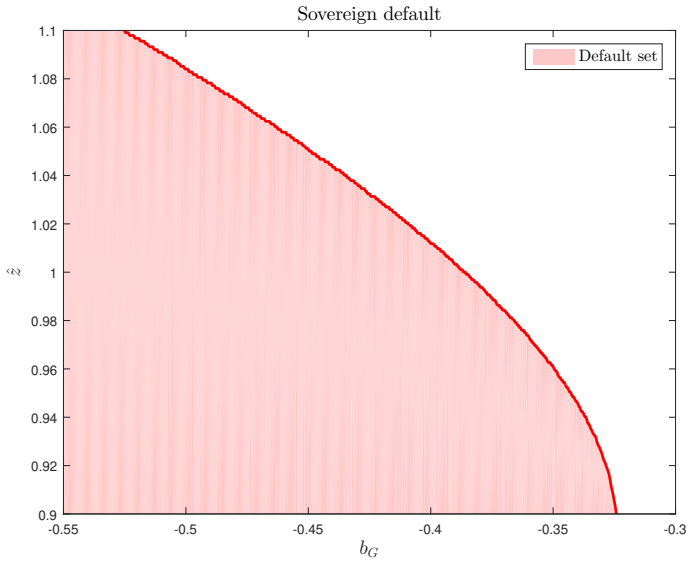


Figure 14: Policy function for sovereign default. The shaded area represents the region of the state space where it is optimal for the planner to default. $\hat{z}$ denotes aggregate productivity, expressed as the ratio to its ergodic mean; b_G denotes assets held by the government, with negative values denoting sovereign debt.

default, given aggregate productivity and sovereign debt. The horizontal axis displays assets held by the government, with negative values denoting sovereign debt.[44] The vertical axis displays aggregate productivity. The ratio of aggregate productivity to its ergodic mean is denoted by $\hat{z}$, so that, for example, $\hat{z} = 1.02$ implies that aggregate productivity is 2% above its unconditional mean.

Two main features of the default policy function are worth noting. First, the level of debt for which it is optimal to default is substantially higher than in most models of endogenous sovereign default in the literature. In this model, default is optimal for sovereign debt equal to 38.5% of yearly output, when aggregate productivity is at its ergodic mean. By way of comparison, mean debt is 6% of output in the seminal paper of Arellano (2008). As Aguiar and Gopinath (2006) emphasize, a high penalty for default is necessary to generate a high equilibrium level of debt. Indeed, the calibration strategy adopted when setting $\delta(z)$ follows indeed from this key insight.

Second, the highest sustainable level of debt is increasing in aggregate productivity. This result follows from the assumption that default costs are increasing in aggregate productivity, as in Arellano (2008). Therefore, the fact that default costs are specified as a reduction in welfare, rather than in output or productivity, has no implications for the standard result on the slope of the default threshold.

[44] Sovereign assets are a stock variable. Thus, I divide their value by four, for ease of comparison with empirical targets such as the debt-to-(yearly) GDP ratio. Note that I normalize to unity quarterly output of an average firm.

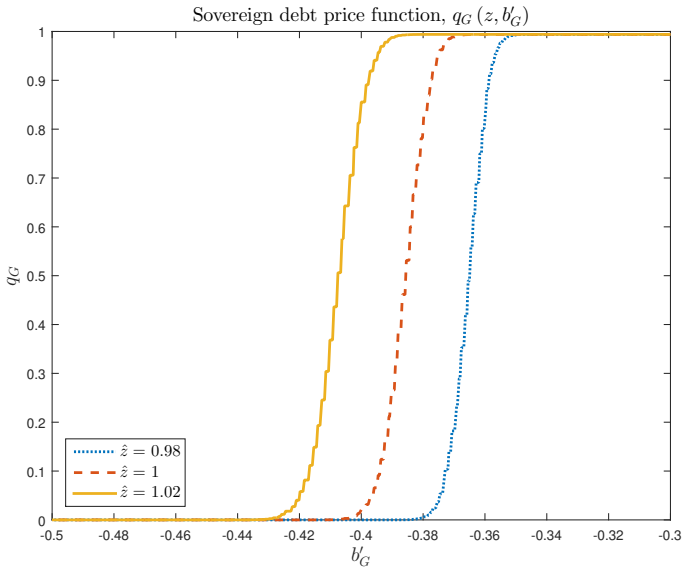


Figure 15: Sovereign debt price function, $q_G\left(z, b'_G\right)$, describing the price at which the government can issue debt on international financial markets, given the amount issued b'_G and current aggregate productivity $\hat{z}$, expressed as the ratio to its ergodic mean.

B.3.2 Sovereign Debt Price Function

The sovereign debt price function $q_G\left(z, b'_G\right)$ describes the price at which the government can issue debt on international financial markets, given the amount issued b'_G and current productivity z, following (26). Figure 15 displays this function for three values of aggregate productivity, corresponding to its ergodic mean and to a high and a low value, 0.7 standard deviations above and below the mean, respectively.

First, changes in the value of current productivity cause the function to shift. For a fall in productivity, the shift implies that a lower price of debt is compatible with any given choice of debt issued. Equivalently, the government must issue a lower amount of debt for the debt price to remain constant. The nature of the default policy function described above and the presence of autocorrelation in the process for z cause this shift. A low realization of current productivity implies that a similarly low realization is more likely in the following period. Lenders, thus, attach a high probability of default to low values of debt when current productivity is low, as default will be chosen for low values of debt if productivity will remain low in the following period. In turn, the increase in the default probability causes the price of sovereign debt to fall.

Second, the price at which debt is issued decreases in the amount of debt itself issued. This is a typical property of models of endogenous sovereign default, again following directly from the the properties of the default policy function. As the level of debt increases, default is chosen under a wider range of values for aggregate productivity. Hence, next-period default

becomes more likely as debt rises and international lenders are willing to purchase sovereign debt only at a lower price.

Finally, the fact that the function $q_G\left(z, b'_G\right)$ is decreasing in b'_G implies that the planner faces an upper bound on the amount of resources that it can obtain from international financial markets. In addition, the distortionary nature of taxes implies the presence of an upper bound on the amount of tax revenue. Jointly, these two bounds place a limit on the feasible amount of external debt repayment. The presence of a bound on the amount of debt that can be feasibly repaid influences default incentives for the planner. Importantly, the presence of financial frictions in the firms' problem affects the location of this bound, as it influences the amount of resources that can be raised by the planner via taxes. As the ability of the planner to raise tax revenues determines its incentive to default and the price of sovereign debt, the severity of financial frictions faced by firms, in turn, affects the severity of the constraint faced by the government.