Transfer-Induced Debt Dynamics in Sovereign Default

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Abstract

During the 2010s, the Greek sovereign debt crisis necessitated unprecedented EU financial aid accompanied by austerity conditions. Despite reforms to government spending and taxation, limited consolidation of social transfers led to unexpected expansions in transfer payments. This paper constructs a strategic sovereign default model, calibrated to Greek data, to examine the effects of transfer shocks on sovereign debt spreads. Under high financial stress (e.g., the elevated spreads at the onset of the 2010 Economic Adjustment Program), positive transfer shocks exacerbate already excessive absorption and significantly raise spreads. Under milder stress, these shocks initially produce negligible increases in spreads but lead to persistently higher spreads over the longer term. Stricter transfer-side austerity can mitigate crises and may avert default.

Keywords: Social transfers, Greek sovereign default, Long-term debt, Economic adjustment program

JEL Codes: F34, F41, H63, E62

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1 Introduction

The Greek sovereign debt crisis of the 2010s was rooted in fiscal imbalances and structural weaknesses that had accumulated over the preceding decade. By 2009, overspending and weakening revenues resulted in a general deficit of 14% of GDP, while the government debt-to-GDP ratio reached 90%. Among the most critical contributors to these fiscal imbalances was the unreformed social benefit system. Social transfer payments (as a share of GDP) rose from 14% to 20% in the years leading up to 2010, while social contributions stagnated around 13%.[1] The 2010 Economic Adjustment Program (EAP) acknowledged this unsustainable trajectory and called for substantial reforms to transfer payments. For instance, government pension payments were to be cut by 4.5 billion euros (approximately 2% of 2010 GDP) by 2012. The program projected a restrained 1.3% growth in the transfer-spending-to-GDP ratio, 1.7% lower than a no-adjustment scenario.

Despite the EAP's emphasis on transfer-side austerity, efforts were largely ineffective. Contrary to the projections, social transfer payments increased by 3.1% of GDP by 2013. Pension reforms, for example, faced significant obstacles including waves of early retirement and strong political resistance that ultimately led to further increases in government transfer spending. The second EAP (European Commission, 2012) acknowledged that only partial progress had been made in consolidating transfers, and that further bold cuts were necessary. Given the substantial flow of external support and sovereign debt financing into such an unsustainable system, a natural question arises:[2] How did the international market react to the continued expansion of transfers despite the required austerity measures?

More broadly, as Figure 1 shows, the GIIPS (Greece, Ireland, Italy, Portugal, and Spain) which faced significant sovereign debt risks in the early 2010s experienced expansions in government transfer spending prior to the Greek default. These expansions were accompanied by sizable increases in sovereign debt spreads. Meanwhile, other fiscal variables, namely government consumption expenditure and total tax revenues, exhibit less pronounced deviations from the pre-crisis levels. Motivated by the above policy discussion and empirical evidence,

[1] In this paper, the corresponding data for transfer payments are "social transfer payments other than in kind", as reported by Eurostat.

[2] According to Chodorow-Reich et al. (2023), 40% of the financial aid in the 2010 EAP aims at financing general government budgetary needs. In the 2010 May EAP paper, the three-year financial aid would be 27.5 (12.3% GDP) in year 2010, 29 (14.3% GDP) in 2011, 17.6 (9.24% GDP) in 2012, and 5.9 (3.28% GDP) billion euros in 2013.

this paper constructs a strategic default model to examine how transfer payments influence default decisions and debt spreads. It seeks to provide a rationale for these patterns and assess whether stricter transfer-side austerity could have altered the path of spreads and default risk.

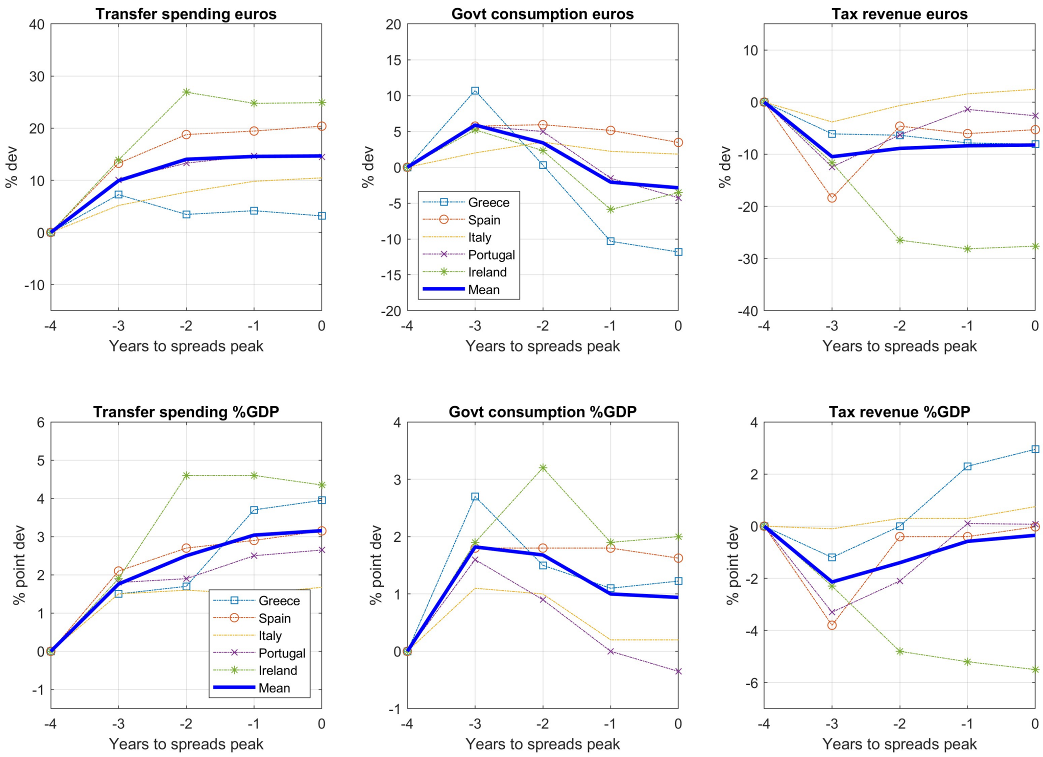

Figure 1: Changes in key fiscal indicators: transfer spending, government consumption expenditure and total tax revenues, from their levels four years prior to each country's peak in sovereign debt spreads. The changes are reported both in euros and as ratios to GDP for GIIPS countries. The sovereign debt peak occurred in 2012 Q2 for Greece, Italy, Portugal, and Spain, and in 2011 Q2 for Ireland. Tax revenues include (1) current taxes on income, wealth, etc., (2) value-added taxes, (3) production and import taxes, and (4) capital taxes. The solid blue line denotes the average across all five countries.

Transfer payments are modeled as exogenous shocks, reflecting the limited government control over austerity measures during the Greek debt crisis. The government funds transfers and consumption expenditures by raising revenues from distortionary taxes and issuing long-term unsecured bonds to foreign creditors. Households view transfers as an exogenous source of income and make optimal decisions regarding consumption and labor supply based on that income. Observing the state of the economy, the government chooses whether to repay or default, while foreign creditors incorporate default probabilities when setting spreads in yield to maturity.

During the Greek debt crisis, positive shocks to transfer income had limited potential to stimulate economic growth because of structural constraints. The post-2008 productivity decline, combined with weak growth expectations, high repayment obligations, limited export competitiveness, and a strained banking sector, hindered economic expansion. Moreover, a decade of generous yet unequal social benefits distorted labor markets: waves of early retirement and declining labor force participation further diminished the stimulative effect of transfers. As a result, the model emphasizes the income effect of transfer shocks, demonstrating that these shocks, alongside a deteriorating fiscal condition, exacerbated already oversized absorption and reduced working hours.

The model's quantitative results reveal that the impact of positive transfer shocks on debt spreads depends on the state of the economy. In high-stress periods, such as after the second quarter of 2010 when spreads on 10-year government bonds were above 5.5%, positive transfer shocks increase international borrowing and elevate spreads by 150 basis points immediately.[3] Conversely, in low-stress periods before mid-2009 when spreads were below 2.4%, the same positive transfer shock raises spreads by only 10 basis points initially. In both cases, the rise in spreads is persistent. Under high stress, spreads remain 100 basis points higher after 20 quarters. Under low stress, spreads continue to rise and eventually reach 40 basis points after 20 quarters. The key mechanism lies in the expansion of absorption and the worsening fiscal imbalance that prompt further debt accumulation despite a steepening spread curve. This finding highlights the importance of ensuring timely transfer-side austerity to reassure the sovereign debt market.

To shed light on how constraining transfer payments can help mitigate the Greek debt crisis, I experiment with various degrees of austerity at the onset of the Economic Adjustment Program. The benchmark simulation reveals increasing transfer payments, rising spreads, and eventual default. Counterfactual reductions in transfers flatten the spread curve and decrease the probability of default in 2012 Q2, while a bold 3.5% reduction relative to GDP can prevent the 2012 Q2 default. Unfortunately, in reality, Greek transfer payments failed to meet the austerity requirements proposed by the EAP, ultimately mirroring the benchmark scenario.

The rest of this paper is organized as follows. Section 1.1 reviews relevant literature. Section 2 explains model details. Section 3 takes the structural model to data and discusses

[3]A typical default-event analysis in Figure 2 indicates that high spreads are mainly driven by low productivity (z_t), in line with existing sovereign default literature such as Arellano and Bai (2017).

the mechanism and impact of transfer shocks on debt dynamics. Section 4 draws conclusions.

1.1 Literature review

This paper contributes to the literature on fiscal policy and sovereign debt, particularly the strand of research in the strategic-default framework pioneered by Eaton and Gersovitz (1981). The study most relevant to mine is Arellano and Bai (2017), which shows that higher distortionary tax rates can reduce default probabilities and spreads by generating additional revenues to service debt. They argue, however, that Greece's large outstanding debt in 2012 made default difficult to avert solely through higher taxes. My paper extends their analysis by highlighting the role of government transfer payments and the associated austerity challenges, while also incorporating the intratemporal substitution between consumption and labor, long-term sovereign debt (Chatterjee and Eyigungor, 2012), and a debt-renegotiation mechanism following Mihalache (2020).

On the tax side, Cuadra et al. (2010) demonstrate that when higher default risks due to recessions depress bond issuance prices, governments optimally raise tax rates during recessions. Similarly, Liu and Shen (2022) show that committing to higher taxes reduces the government's future refinancing needs and lowers default risk. Their analysis for the Greek case indicates that a one-period-ahead contingent tax commitment can significantly reduce both the default probability and average debt spreads.

With respect to government consumption expenditures, Bianchi et al. (2023) endogenize government spending and find that expanded expenditures are generally suboptimal, even under strong concerns for stabilization and inequality. Hatchondo et al. (2022) propose a "spread-brake" mechanism—arguably superior to conventional "debt-brake" approaches—for limiting sovereign borrowing in a monetary union. Under exogenous debt issuance rules, Anzoategui (2022) show that spending-based austerity is unlikely to be self-defeating, even when fiscal multipliers are reasonably large. Other recent papers examining fiscal policy within similar default frameworks include Niemann and Pichler (2020), Conesa and Kehoe (2024), and Pouzo and Presno (2022). Other recent studies examine the consequences of fiscal austerity without explicitly modeling strategic default include House et al. (2020) and Kuang and Mitra (2025), among others.

On the empirical side, Born et al. (2020) find that unexpected government consumption cuts can increase spreads in a state-dependent manner, whereas David et al. (2022) report that fiscal consolidation announcements tend to lower spreads. Beetsma et al. (2021) provide empirical evidence that both revenue-based and spending-based austerity announcements raise long-term government bond yields, with revenue-based measures showing a stronger effect. Rho and Saenz (2021) find fiscal vulnerabilities have a stronger impact on sovereign default spreads during periods of high financial stress than during tranquil times.

Although the literature on fiscal austerity and sovereign default is extensive, relatively few studies focus specifically on transfer-side fiscal policy. A recent exception is Dovis et al. (2016), who incorporate sovereign default into an overlapping-generations model with endogenous political regime shifts. In one regime, the government borrows externally to finance transfer payments and reduce inequality, but eventually transitions to another regime where austerity measures, such as cutting transfers, become optimal due to debt-sustainability concerns. However, their analysis does not directly address the relationship between transfer policies and sovereign debt spreads.

Regarding Greece's social transfer issues specifically, the first Economic Adjustment Program (European Commission, 2010) emphasized the need for pension and healthcare reforms. However, the 2012 EAP acknowledged that these reforms were largely unimplemented or only partially realized. Political resistance, early retirement schemes, and widespread protests undermined austerity efforts, while a costly and distortive pension system discouraged labor force participation (Kangur et al., 2021). According to Fernández-Villaverde et al. (2013), this inertia dates back to the pre-crisis boom (2002–2008), when Greece relied on the arrival of the euro to pursue unsustainable fiscal policies, particularly in pensions. Using a structural model to estimate fiscal rules, Martin and Philippon (2017) identify a significant positive political-bias term reflecting Greece's excess growth in transfer spending.

Finally, the discussion of labor supply's income elasticity is also instructive. In my model, positive transfer shocks introduce an income effect that reduces working hours, especially during recessions. For example, Imbens et al. (2001) find that income elasticities average around -0.1, with larger effects for individuals aged 55–65. Surveying the broader literature, Keane (2011) point to empirical estimates of approximately -0.3. In addition, Chetty (2006) demonstrate that social insurance benefits significantly affect unemployment duration and labor participation, particularly among older workers and women.

2 The Model

We consider a discrete-time, infinite-horizon model with a representative household, a representative firm, and a benevolent government. The firm produces final goods using working hours h_t with a production technology $y_t = z_t h_t$. The household derives utility from consumption c_t and government consumption expenditure g_t, and experiences disutility from supplying working hours h_t. The benevolent government's objective is

$$\max_{c_t,h_t,g_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t, g_t), \tag{1}$$

where the preference follows the King–Plosser–Rebelo (KPR) form (King et al., 1988):

$$U(c_t, h_t, g_t) = \log(c_t) - v\frac{h_t^{1+\chi}}{1+\chi} + \log(g_t), \tag{2}$$

with v governing the disutility from supplying labor and χ representing the reciprocal of the Frisch elasticity. The household faces a flow budget constraint

$$(1+\tau_c)c_t = (1-\tau_h)w_t h_t + f_t, \tag{3}$$

where τ_c and τ_h are respectively consumption and income tax rates, w_t is the wage per unit of working hours, and f_t denotes transfer payments from the government. In equilibrium, the firm's optimal condition implies $w_t = z_t$. The logarithm of productivity z_t follows an AR(1) process,

$$\log(z_t) = \rho_z \log(z_{t-1}) + \varepsilon_t^z, \tag{4}$$

with $|\rho_z| < 1$ and $\varepsilon_t^z \sim i.i.d. N(0, \sigma_z^2)$.

The equilibrium condition for the household and firm reflects an intratemporal substitution between consumption and working hours:

$$h_t = \left[\frac{(1-\tau_h)}{(1+\tau_c)v} \cdot \frac{z_t}{c_t}\right]^{\frac{1}{\chi}}, \tag{5}$$

which implies an income effect of transfers on labor supply. Since 2001, Greece's domestic absorption expanded without commensurate gains in productivity or labor participation, leading to oversized domestic absorption and widening trade imbalances reflected in sizable fiscal deficit and a rising external government debt-to-GDP ratio. Rapid wage growth and generous social benefits, including low retirement ages and high replacement rates, contributed to significant labor market rigidity (European Commission, 2010), prompting a bundle of labor market reforms to reduce real wages. By incorporating this income effect, the model captures the risk that additional social transfer income could further intensify these existing problems.

2.1 Fiscal constraints

The government finances its consumption and transfer expenditures by issuing unsecured, long-maturity bonds b_t and collecting revenues from distortionary taxes. The maturity and coupon structure of these bonds follows Chatterjee and Eyigungor (2012): in each period, a fraction λ of the outstanding debt matures, while the remaining $(1-\lambda)$ fraction is subject to a coupon rate $\eta > 0$. Given the auction price of sovereign bonds q_t, the government's revenue from debt issuance is $q_t[b_{t+1} - (1-\lambda)b_t]$, and the debt repayment obligation is $[\lambda + (1-\lambda)\eta]b_t$. The government finances consumption expenditure (g_t) and transfer spending (f_t) with tax revenues and net external borrowing:

$$g_t + f_t \leq \tau_c c_t + \tau_h z_t h_t + q_t[b_{t+1} - (1-\lambda)b_t] - [\lambda + (1-\lambda)\eta]b_t, \tag{6}$$

where f_t follows an AR(1) process in levels with a constant term ψ_0^f, and ε_t^f denotes the persistent transfer-shock component:

$$f_t = \psi_0^f + \varepsilon_t^f, \quad \varepsilon_t^f = \rho_f \varepsilon_{t-1}^f + \epsilon_t^f, \quad \epsilon_t^f \sim i.i.d. N(0, \sigma_\epsilon^2). \tag{7}$$

We treat transfer payments as exogenous to government discretion to reflect the substantial political frictions (e.g., public protests against pension cuts) in Greece around the 2010s that limited the feasibility of transfer-side austerity.

The government may either honor or default on its debt obligations. If repays, the country remains in good financial standing and can continue issuing new bonds. If defaults, the economy enters bad financial standing, where no further borrowing is possible. With probability μ in each period, however, the economy receives an opportunity to renegotiate a debt haircut and re-enter international capital markets. While in bad standing, the economy suffers from a productivity loss $L(z_t)$, which follows a quadratic form as in Chatterjee and Eyigungor (2012):

$$L(z_t) = \max\left\{0, a_1 z_t + a_2 z_t^2\right\}, \tag{8}$$

where productivity in the bad financial standing is $z_t^a = z_t - L(z_t)$. Such endowment (productivity) losses are commonly employed in sovereign default models to discourage default when z_t is high, since $L(z_t)$ is non-negative and increases with z_t.

2.2 Default, renegotiation and debt pricing

Let $\mathbf{s} = (z, \varepsilon^f)$ be the vector of exogenous shocks. In each period, the benevolent government chooses whether to repay or default:

$$V(b, \mathbf{s}) = \max_{d(b,\mathbf{s})\in\{0,1\}} \quad [1 - d(b, \mathbf{s})]\, V^r(b, \mathbf{s}) + d(b, \mathbf{s})V^d(b, \mathbf{s}), \tag{9}$$

where $V^r(b, \mathbf{s})$ is the value of repaying the debt and hence staying in good financial standing, and $V^d(b, \mathbf{s})$ is the value of defaulting and entering bad financial standing. The binary indicator $d(b, \mathbf{s})$ equals 1 if the government defaults and 0 otherwise. If the government repays, its value function is

$$V^r(b, \mathbf{s}) = \max_{c,h,g,b'} U(c, h, g) + \beta\mathbb{E}_{\mathbf{s}'|\mathbf{s}}V(b', \mathbf{s}'), \tag{10}$$

subject to the economy-wide resource constraint

$$c \leq zh + q[b' - (1 - \lambda)b] - [\lambda + (1 - \lambda)\eta]b - g, \tag{11}$$

as well as the government's fiscal constraint (6). The optimal debt issuance is denoted as $b' = \mathcal{B}(b, \mathbf{s})$. If the government defaults, its value function is

$$V^d(b, \mathbf{s}) = \max_{c^a,h^a,g^a} U(c^a, h^a, g^a) + \beta\mathbb{E}_{\mathbf{s}'|\mathbf{s}}\Big[(1 - \mu)V^d(b, \mathbf{s}') + \mu V^r(\gamma, \mathbf{s}')\Big], \tag{12}$$

where γ is the restructured debt owed to foreign creditors after a Nash bargaining game, as in Mihalache (2020). Recall μ is the probability of being able to renegotiate and re-enter. The variables c^a, h^a, g^a are consumption, working hours and government consumption expenditure after default and prior to reentry (autarky), subject to the productivity loss $L(z)$. Under autarky, the fiscal constraint (6) becomes

$$g^a \leq \tau_c c^a + \tau_h z^a h^a - f, \tag{13}$$

and the aggregate resource constraint (11) becomes

$$c^a \leq z^a h^a - g^a. \tag{14}$$

During a debt renegotiation, the value of remaining in autarky $V^a(\mathbf{s})$ is the borrower's (government's) threat point:

$$V^a(\mathbf{s}) = \max_{c^a, h^a, g^a} U(c^a, h^a, g^a) + \beta \mathbb{E}_{\mathbf{s}'|\mathbf{s}} V^a(\mathbf{s}'). \tag{15}$$

The creditors' threat point is full repudiation where $\gamma = 0$. The sovereign's surplus from renegotiation is the difference between the value of repaying γ after the haircut and staying in autarky:

$$\Delta^{\mathbf{s}}(\gamma, \mathbf{s}) = V^r(\gamma, \mathbf{s}) - V^a(\mathbf{s}). \tag{16}$$

Creditors' surplus is the market value of restructured debt:

$$\Delta^c(\gamma, \mathbf{s}) = \Big[\lambda + (1-\lambda)(\eta + q(\gamma', \mathbf{s}))\Big]\gamma, \tag{17}$$

where $\gamma' = \mathcal{B}(\gamma, \mathbf{s})$ is the debt issuance given restructured debt. The Nash Bargaining game for overdue debt is:

$$\Gamma(\mathbf{s}) = \arg\max_{\gamma} \Big[\Delta^{\mathbf{s}}(\gamma, \mathbf{s})\Big]^{\alpha} \Big[\Delta^c(\gamma, \mathbf{s})\Big]^{1-\alpha}, \quad \text{subject to} \quad \Delta^{\mathbf{s}} \geq 0 \text{ and } \Delta^c \geq 0, \tag{18}$$

where α is a parameter measuring the sovereign's bargaining power. Because the restructured amount γ does not depend on the volume of debt in default, the value of default (12) can be rewritten as:

$$V^d(\mathbf{s}) \equiv V^d(\Gamma(\mathbf{s}), \mathbf{s}) = \max_{c^a, h^a, g^a} U(c^a, h^a, g^a) + \beta \mathbb{E}_{\mathbf{s}'|\mathbf{s}} \Big[(1-\mu)V^d(\mathbf{s}') + \mu V^r(\Gamma(\mathbf{s}'), \mathbf{s}')\Big]. \tag{19}$$

Hence the default set is $\mathcal{D} = \{\mathbf{s} : V^r(b, \mathbf{s}) \leq V^d(\mathbf{s})\}$, i.e., the government defaults when repayment is less valuable than default.

International creditors are competitive, risk-neutral, and borrow at the risk-free interest rate r^*. They price defaultable debt by equating its expected payoff to that of a safe bond:

$$q(b',\mathbf{s}) = \frac{1}{1+r^*}\mathbb{E}_{\mathbf{s}'|\mathbf{s}}\Big\{[1-d(b',\mathbf{s}')]\Big[\lambda+(1-\lambda)(\eta+q(b'',\mathbf{s}'))\Big]+d(b',\mathbf{s}')q^d(b',\mathbf{s}')\Big\} \tag{20}$$

where $b'' = \mathcal{B}(b',\mathbf{s}')$ follows the policy function for debt issuance, and $q^d(b',\mathbf{s})$ is the expected recovery value of defaulted debt, which evolves according to

$$q^d(b',\mathbf{s}) = \frac{1}{1+r^*}\mathbb{E}_{\mathbf{s}'|\mathbf{s}}\Big\{(1-\mu)q^d(b',\mathbf{s}')+\mu\frac{\Delta^c(\gamma,\mathbf{s}')}{b}\Big\} \tag{21}$$

where $\gamma = \Gamma(\mathbf{s}')$ is the restructured debt in the renegotiation. The sovereign debt spread is then

$$rs(b',\mathbf{s}) = \frac{\lambda+(1-\lambda)\eta}{q(b',\mathbf{s})} - \lambda - r^* \tag{22}$$

Equations (20) and (21) do not necessarily admit a unique solution.[4] Following Gordon (2019), I introduce "taste shocks" to debt policy b', the default choice d and the restructured new debt γ to smooth the value functions and aid convergence in a value function iteration algorithm.[5] Such smoothing methods have since been adopted in recent sovereign default models with long-maturity debt, for instance by Arellano et al. (2020) and Anzoategui (2022).

Definition 1 (Model equilibrium)**.** Given exogenous shocks $\mathbf{s}$ and debt b, a recursive equilibrium of the model consists of policy functions for default d, output y, consumption c, working hours h, debt issuance b', government consumption expenditure g, and debt restructuring γ, value functions V, V^r, V^a and V^d, debt price q and recovery rate q^d. These must satisfy:

1. Benevolent government's problem: Taking q^d and q as given, the value functions (Equations (9), (10), (15), and (12)) solve the benevolent government's problem, determining the government's choices of d and b'.

2. Debt pricing: Given d, $\mathcal{B}$ and Γ, q^d and q satisfy the risk-neutral pricing rule (Equations (20) and (21)).

[4] Intuitively, during the numerical solution, a benevolent government may struggle to distinguish local from global solutions, causing convergence to fail. See Chatterjee and Eyigungor (2012) and Kuang and Shi (2026) for a detailed discussion of equilibrium multiplicity in this framework.

[5] Independently of Gordon (2019), Dvorkin et al. (2021) introduce similar state perturbations in sovereign default models. Related smoothing techniques are also employed in Mihalache (2020). Details of the implementation used here are provided in Appendix A.

3. Household equilibrium: The endogenous variables y, c and h are determined by the household's equilibrium conditions, taking fiscal policies (g, τ_h, τ_c and f) as given. Under autarky, y^a, c^a and h^a reflect the productivity loss specified in equation (8).

3 Quantitative results

3.1 Calibration and statistics

The model is calibrated using Greek quarterly data from 1995 Q1 up to the period preceding its sovereign default in 2012 Q2. The first group of parameters (Table 1) is set independently of model simulation. The quarterly re-entry probability after default, μ, follows Chatterjee and Eyigungor (2012) and corresponds to an average six-year exclusion from international credit markets. The 5% annualized coupon rate on newly issued debt ($4 \times \eta$) targets the average coupon rate on Greek 10-year bonds, as reported by the Public Debt Management Agency. The debt maturity $1/\lambda = 28.6$ quarters is based on evidence in Mihalache (2020).[6] The Frisch elasticity $1/\chi = 1$ and productivity shock persistence $\rho_z = 0.9$ are standard in macroeconomic models. The labor disutility parameter v is calibrated so that steady-state working hours, in absence of sovereign debt, are normalized to one unit.

Table 1: Parameters independent of simulation

Description	Parameters	Value	Target
Probability of bargaining	μ	0.0385	Literature
Coupon rate	η	0.0125	Greek data
Reciprocal of maturity	λ	0.035	Greek data
Quarterly risk-free rate	r^*	1%	Literature
Frisch elasticity	$1/\chi$	1	Literature
Productivity shock AR	ρ_z	0.90	Literature
Transfer shock AR	ρ_f	0.95	2010 EAP
Disutility of labor	v	0.877	$\mathbb{E}(h^a) = 1$
Consumption tax	τ_c	0.15	Literature
Labor income tax	τ_h	0.33	Literature

[6] Under the perpetual zero coupon bond approach of (Hatchondo and Martinez, 2009) and Mihalache (2020), maturity is measured via Macaulay duration. Using the Chatterjee and Eyigungor (2012) framework, the median maturity simplifies to $1/\lambda$ in my paper.

For the fiscal policy parameters, the AR(1) persistence of transfer shocks ε_t^f, i.e., $\rho_f = 0.95$, is set to match the three-year reform period (2010–2013) for government transfers prescribed in the first EAP. Distortionary tax rates τ_c and τ_h follow the estimation in Mendoza et al. (2014), consistent with the Greek austerity analysis in Arellano and Bai (2017).

Table 2: Parameters calibrated to match statistics

Calibrated Parameters	Parameters	Value
Productivity loss parameter	a_1	-0.282
Productivity loss parameter	a_2	0.324
Subjective discount factor	β	0.9757
Borrower's bargaining power	α	0.64
SD of productivity shock	σ_z	1.95%
Mean transfer level	ψ_0^f	0.14
SD of transfer shock	σ_f	0.73%
Targeted Statistics	Data	Model
Mean spreads $\mathbb{E}(rs_t)$	2.6%	2.5%
External Debt-to-GDP $\mathbb{E}(b_t/y_t)$	73%	65%
SD of output $\sigma(y_t)$	2.9%	3.1%
Mean renegotiation haircut	40%	41%
Mean transfer-GDP ratio $\mathbb{E}(f_t/y_t)$	14.7%	14.1%
SD of transfer-GDP ratio $\sigma(f_t/y_t)$	2.8%	2.7%

Notes: rs_t represents sovereign debt spreads, i.e., the difference between the yield of government 10-year bonds and a risk-free rate (proxied by German 10-year government bond yield), $rs_t = r_t - r^*$. Data are from 1995 Q1 to 2012 Q1 and sourced from Eurostat and the St. Louis Fed. In simulation, default occurs on average 2.1 times per 400 quarters.

The second group of parameters, reported in Table 2, is calibrated to align simulation with key Greek statistics.[7] The transfer rule parameter ψ_0^f targets the average government social transfer payments to GDP ratio of 14.7%, and the standard deviation of transfer shocks σ_f aligns the simulated transfer-to-GDP volatility with the data. The productivity loss parameters during default $[a_1, a_2]$, the discount factor β, and the standard deviation of productivity shocks σ_z are jointly calibrated to match: (1) The average spread on Greek 10-year government debt relative to Germany; (2) The net external debt-to-GDP ratio; and (3) The standard deviation of HP-detrended output in logarithm. Following Arellano and Bai (2017), the bargaining

[7]Simulated moments are computed from 500 independent simulation chains, excluding periods after default. Each chain contains 5000 periods and the first 800 periods are excluded from the calculation of moments.

Table 3: Non-targeted moments from data and simulation

Business cycle	Data	Simulation
$\sigma(c_t)/\sigma(y_t)$	0.93	0.83
$\sigma(h_t)$	0.024	0.017
$\sigma(z_t)$	0.021	0.042
$\mathbb{E}(g_t/y_t)$	0.201	0.284
$\sigma(g_t/y_t)$	0.035	0.043
$\rho(y_t, c_t)$	0.87	0.86
$\rho(y_t, h_t)$	0.69	0.31
$\rho(y_t, z_t)$	0.74	0.73
$\rho(y_t, g_t)$	0.65	0.26
$\rho(y_t, y_{t-1})$	0.89	0.86
$\rho(c_t, c_{t-1})$	0.83	0.88
$\rho(z_t, z_{t-1})$	0.68	0.85
$\rho(h_t, h_{t-1})$	0.90	0.93
$\rho(g_t, g_{t-1})$	0.47	0.36
Debt related	Data	Simulation
$\sigma(rs_t)$	5.2	3.1
$\rho(rs_t, y_t)$	-0.24	-0.50
$\rho(rs_t, c_t)$	-0.13	-0.39
$\rho(rs_t, h_t)$	-0.14	-0.14
$\rho(rs_t, z_t)$	-0.38	-0.45
$\rho(rs_t, b_t/y_t)$	0.76	0.38
$\rho(rs_t, tby_t)$	0.12	0.27

Notes: z_t data corresponds to the real labor productivity per hour worked, h_t data corresponds to thousand hours worked by employed persons. c_t, y_t, g_t are in logarithm and HP-detrended. tby_t denotes trade-balance-to-GDP ratio, which reflects net borrowing income in our model.

power parameter α reproduces the 40% haircut rate in Greece's 2012 debt restructuring. In addition to the targeted statistics, Table 3 presents a number of non-targeted moments that also reasonably match data. For example, output is positively correlated with consumption, hours, and productivity, while spreads move positively with the debt-to-GDP ratio and the trade-balance-to-GDP ratio, and negatively with output, productivity, consumption, and working hours.

In the numerical implementation, productivity and transfer shocks are each discretized into 25 equally spaced grid points, spanning 3.8 standard deviations above and below their medians. The probability transition matrices for these shocks are approximated via the Tauchen

(1986) method, following sovereign default literature. I set the lower bound of debt price to 0.40 to limit the peak spreads within 30 percentage points. This method follows Hatchondo et al. (2016) with the aim of avoiding a pre-crisis consumption boom that arises due to the debt dilution incentives in a long-maturity debt framework. The debt space is discretized into 250 grid points equally spaced over interval $[0.35, 0.95]$. Most debt realizations lie within this range during simulation, while the extremes are rarely visited. The parameters governing taste shocks, σ_b, σ_d and σ_γ, are set to 0.0025 to ensure the value function iteration algorithm completes within 1000 iterations. The iterative solving procedure is terminated when the maximum absolute difference (sup norm) in value functions and price schedules between successive iterations falls below 10^{-6}.[8]

3.2 Typical default episodes

We simulate the average dynamics around default events and display them in Figure 2. In the Greek data, within four years before the default, the HP-detrended GDP and private consumption expenditure in logarithm declined by 9% and 7%, respectively, from their peaks to the trough in 2012 Q2. The model implies declines of 11% and 8% (Panels (a) and (b)) in a typical simulated default event. Other variables show near-monotonic changes in the data. Real labor productivity fell by 20% (versus 10% in Panel (c)), the social transfer payments-to-GDP ratio rose by 4.5 percentage points (3 in Panel (d)), external government debt relative to GDP increased by 45 percentage points (40 in Panel (e)), sovereign debt spreads climbed by 23 percentage points (30 in Panel (f)), and the trade-balance-to-GDP ratio rose by 9 percentage points (12 in Panel (g)).

In the model, government consumption expenditure falls by 17% prior to default (Panel (h)), while HP-detrended data in logarithms indicate a 15% decline between 2008 Q2 and 2012 Q1.[9] The sharp rise in g_t on period -1 in the model reflects the short-term benefits of halting debt repayments while continuing to borrow, a pattern also evident in the tby_t trajectory. A similar spike in net borrowing income one period ahead of default is documented in the literature (e.g., Uribe and Schmitt-Grohé, 2017).

[8] Appendix B reports robustness checks using a finer grid for the debt state and a larger magnitude of taste shocks. The resulting simulated moments are quantitatively similar to the benchmark specification.

[9] Original non-seasonally-adjusted or calendar-adjusted data is adjusted via Seasonal-Trend decomposition using LOESS (STL).

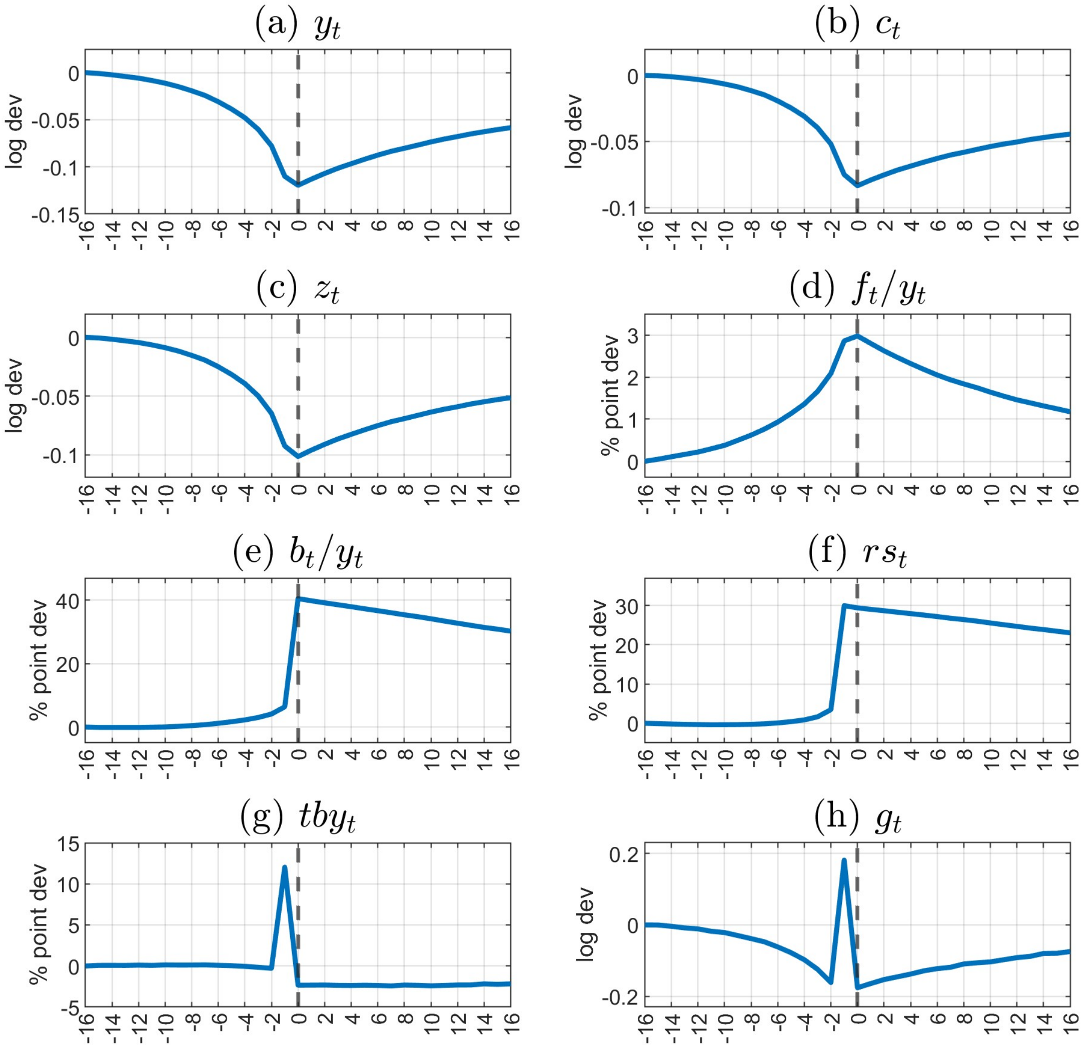

Figure 2: Typical default episodes from the model simulation. These trajectories show mean paths around all default events. The horizontal axis denotes quarters before (negative values) and after (positive values) a default, which is normalized to quarter 0.

3.3 Model mechanism

In a typical default analysis in Figure 2, default is associated with expansions in government transfer spending. Approximately one-third of the simulated rise in the f_t/y_t ratio is driven by a sequence of positive transfer innovations ϵ^f, compounded by the contemporaneous slump in productivity. These innovations accumulate through the AR(1) process (7), raising the persistent component ε^f from 0.005 at period -16 to 0.015 at period 0. If positive transfer shocks contribute to default, then they can raise default probability and thus increase spreads when the sovereign is still in good financial standing.

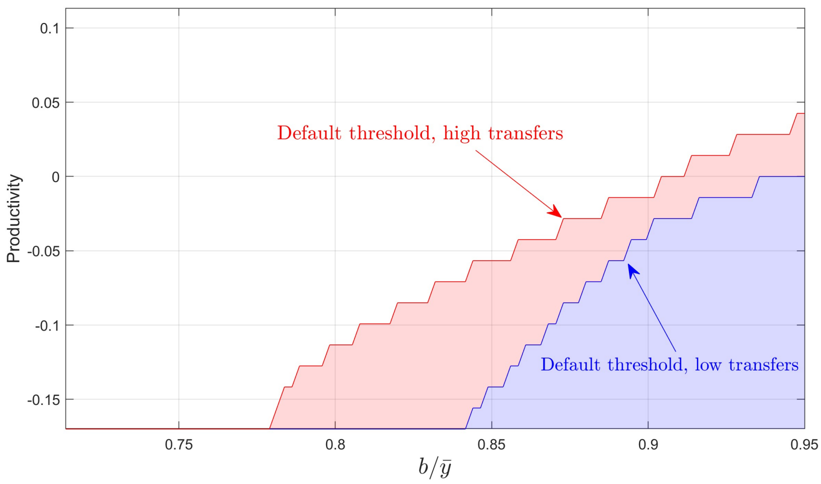

Figure 3: Default sets under different levels of transfer shock ε^f. For a low transfer (-0.037), the default region is depicted in blue, while the remainder is the repayment region. For a high transfer (0.037), the default region is the combination of red and blue areas, with the rest being the repayment region. Debt levels below $b/\bar{y} = 0.75$ and productivities above $z = 0.1$ do not lead to default and hence not depicted. As is common in sovereign default models, for a given transfer shock, the default regions lie at coordinates of low productivity z and high debt levels $b/\bar{y}$.

To investigate this mechanism, fix a transfer realization ε_t^f and define the default region in (b_t, z_t) as

$$\mathcal{D}(\varepsilon_t^f) = \{(b_t, z_t) : V^d(\mathbf{s}_t) \geq V^r(b_t, \mathbf{s}_t)\}, \quad \mathbf{s}_t = (z_t, \varepsilon_t^f). \tag{23}$$

Under the taste-shock specification described in Appendix A, the probability of default is given by

$$P(d_t = 1 \mid b_t, \mathbf{s}_t) = \frac{1}{1 + \exp\{-[V^d(\mathbf{s}_t) - V^r(b_t, \mathbf{s}_t)]/\sigma_d\}}, \tag{24}$$

where $\sigma_d > 0$ governs the degree of smoothing in the default decision. As shown in Figure 3, the default region under a low transfer shock is strictly contained within that under a higher transfer shock. Moreover, the value gap $V^d - V^r$ is increasing in ε_t^f. Therefore, conditional on debt and productivity, higher transfer realizations increase the probability of default.

Positive transfer shocks operate through the intratemporal substitution between consumption and labor supply in equation (5). As transfers rise, the household increases consumption and reduces labor supply, causing domestic output to fall. Meanwhile, higher transfer shocks divert resources away from government consumption, reducing the utility derived from g_t (Panels (d.1) and (d.2)). In response, the government may issue more debt (see Figure 4, Panels (b) and (c)). The decline in output and the rise in future debt both undermine repayment capacity, incentivizing future default especially when the productivity is low. Anticipating this, foreign creditors demand higher yield spreads, as reflected in Panel (a) of Figure 4.

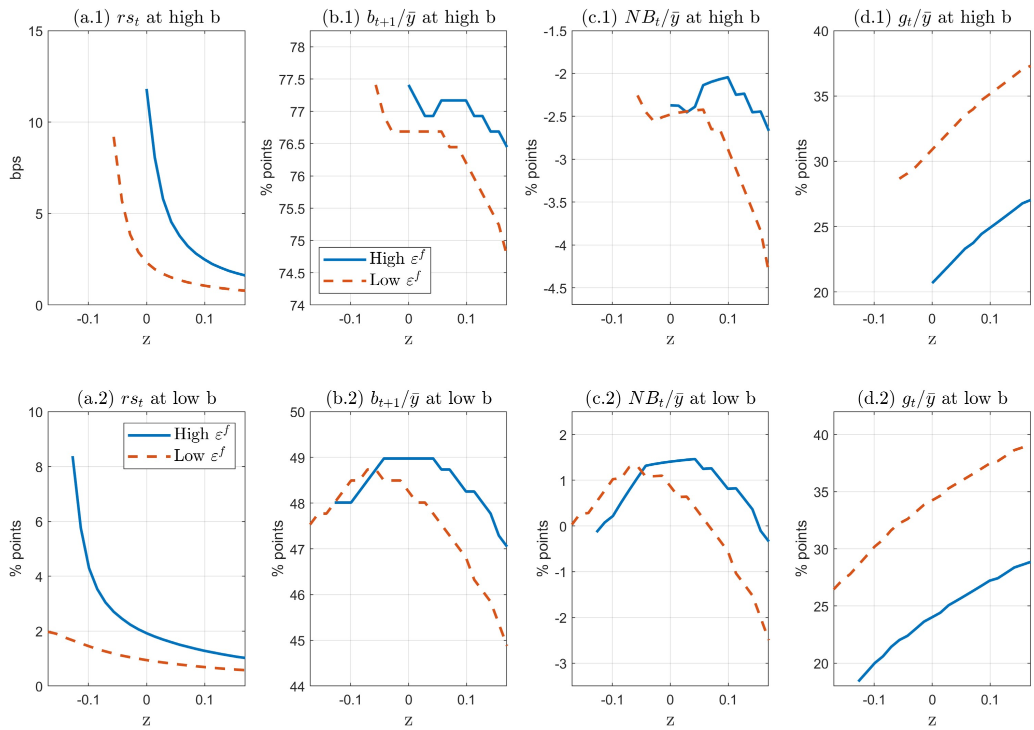

Figure 4: Policy functions for different levels of the transfer shock (ε_t^f) and outstanding debt ($b_t/\bar{y}$), conditional on repayment. The upper panels show policies at a high debt level ($b_t/\bar{y} = 78.2\%$), while the lower panels correspond to a lower debt level ($b_t/\bar{y} = 46.8\%$). A high transfer shock ($\varepsilon_t^f = 0.044$) is two standard deviations above the process's unconditional mean, and a low shock ($\varepsilon_t^f = -0.044$) is two standard deviations below. Here, b_{t+1} denotes debt issuance and NB_t denotes net borrowing, i.e., $q_t[b_{t+1}-(1-\lambda)b_t]-[\lambda+(1-\lambda)\eta]b_t$.

The policy functions in Figure 4 offer further insight into how positive transfer shocks shape debt dynamics. At high productivity levels, where the debt spread schedule is relatively flat, the government can increase net borrowing NB_t (Panels (c)) to partially offset the drop in g_t caused by a transfer payment expansion. By contrast, at low productivity and high debt-to-GDP ratios (upper panels), default risk is significant and a positive transfer shock substantially steepens the debt spreads schedule as we have explained. In this case, even increasing debt issuance (Panel (b.1)) fails to produce higher net borrowing (Panel (c.1)).

When debt-to-GDP levels are relatively low (lower panels), default risk is less acute, and we can see the regions where a positive transfer shock leads to higher net borrowing are larger (Panel (c.2)). However, a large positive transfer shock can still significantly steepen the spread curve. As indicated by the decreasing $b_{t+1}/\bar{y}$ and $NB_t/\bar{y}$ in low z regions, the government reduces borrowing to avoid default as the default cost is unacceptable compared with the high debt-to-GDP case. Meanwhile, the government cuts consumption expenditures to bolster solvency and avert a debt spiral (Panel (d.2)).

Overall, during recessions, it is generally feasible to rely on default-sensitive international creditors to raise public funds in response to transfer shocks, especially when the outstanding debt level is low. By contrast, when the debt-to-GDP ratio is already high, foreign lenders anticipate that the sovereign may find it optimal to issue additional debt and then default, prompting them to charge higher spreads. In the latter case, external bailouts from the EU and IMF are especially critical for restoring stability in the debt market.

Transfer shocks also influence sovereign debt spreads through the renegotiation mechanism. Higher transfer realizations reduce the sovereign's repayment capacity, lowering the continuation value of repayment relative to autarky. As a result, the sovereign's surplus from renegotiation declines, and the Nash bargain implies a smaller restructured debt level γ, corresponding to a larger haircut. In other words, holding productivity fixed, the restructured debt level is decreasing in the transfer realization.

A smaller post-restructuring debt level also strengthens incentives for debt dilution. Because the sovereign can immediately reissue long-term debt after restructuring, a larger haircut raises the incentive to borrow again, anticipating partial future dilution of existing creditors. This prospect makes long-term debt more expensive.[10]

Taken together, although the sovereign obtains more favorable restructuring terms ex post, higher transfer obligations weaken fiscal fundamentals and amplify dilution concerns upon reentry. Consequently, debt prices remain lower and spreads higher after renegotiation.

3.4 Impulse responses

To analyze the model's dynamics following a positive transfer shock, I compute generalized impulse response functions (IRFs) via simulation, which is appropriate for the model's nonlinear structure.

Specifically, I simulate 6000 independent sample paths of length 650 periods. From periods 1 to 600, all shocks evolve according to their Markov chains so that the debt distribution

[10] In the baseline model, the sovereign regains full market access after restructuring and can optimally refuse a restructuring offer. Relaxing this assumption, Dvorkin et al. (2021) assume the probability of remaining excluded after restructuring is set at 70%, and show that limiting post-restructuring access reduces debt dilution incentives and increases long-term debt prices.

converges to its limiting distribution. At period 601, all *shocked* paths receive an additional positive transfer shock, which thereafter follows its conditional Markov chain. In parallel, an identical set of *unshocked* paths is generated using the same realizations of all shocks, except that no additional transfer shock is applied at period 601. A single IRF is computed as the average difference between the shocked and unshocked paths over periods 601–650, conditional on the economy being in good financial standing at period 600. From period 601 onward, the economy may repay, default, or re-enter international capital markets after a default. This procedure is repeated 500 times, and the reported IRFs are the averages across repetitions.

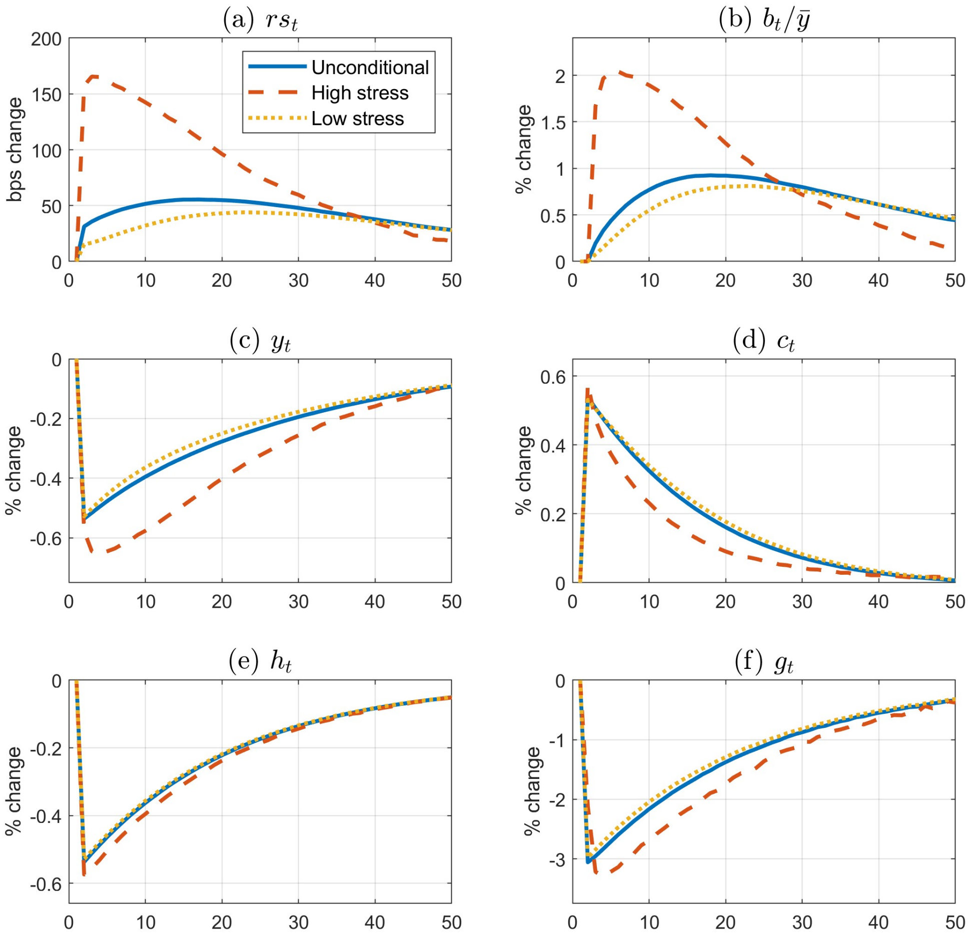

Figure 5: IRFs of spreads rs_t, outstanding debt b_t, output y_t, consumption c_t, working hours h_t, and government consumption expenditure g_t following a positive transfer shock. The shock to ε_1^f is set to 0.78% of the unconditional mean of output, approximately one-third of the standard deviation of the ε^f process. "High Stress" and "Low Stress" IRFs condition on initial states.

Figure 5 presents IRFs for spreads, debt, output, and consumption from $t = 0$ (one period before the shock; simulation period 600) to $t = 50$ (simulation period 650). The blue solid lines plot *unconditional* IRFs that do not explicitly condition on initial productivity, debt, or spread levels. As in the mechanism discussion, a positive transfer shock raises consumption (Panel (d)) and reduces labor supply (Panel (e)), lowering output (Panel (c)). Although the government issues additional debt (Panel (b)) to help finance higher transfers, this only partly closes the spending gap – optimal government consumption g_t declines (Panel (f)). The deteriorating repayment outlook, featuring lower output and higher debt, leads creditors to demand higher spreads (Panel (a)). Over time, persistent output weakness and lower issuance prices induce further debt accumulation, with spreads continuing to rise and peaking roughly 15 quarters after the shock.

The dynamics of debt are state-dependent. I denote "high stress" as scenarios in which spreads exceed 5.5% at $t = 0$. This threshold corresponds to the Greek 10-year government bond spread observed in 2010 Q2, when the first Economic Adjustment Program began. Under high stress, marginal returns to labor are low due to weak productivity and substantial repayment obligations, causing a greater reduction in labor supply at $t = 1$ (Panel (e)). Moreover, the economy is already near its default threshold, so this transfer shock steepens the spread curve more than in the unconditional case (Panel (a)). Because issuance prices are low (the inverse of spreads), the sovereign must issue more debt to partially finance the increased transfers (Panel (b)), and government consumption must decrease.

Moreover, if the debt stock is already excessive, higher transfer obligations may cause the sovereign to ultimately default (as depicted in Figure 3) and receive a haircut during the next renegotiation. Given the higher probability of default and slow re-entry into capital markets (about 26 quarters on average), labor supply and output may fall further due to the associated productivity losses, and private consumption and government spending decline accordingly.

In contrast, "low stress" denotes states with spreads below 2.4% at $t = 0$, representing the period before mid-2009. Because the sovereign is farther from the default set, spreads react less strongly to an expansion in transfers, and the government issues fewer bonds (Panel (b)). However, a similar tightening of the fiscal constraint eventually demands comparable debt accumulation over the long run; by around $t = 30$, spreads increase by about 50 basis points and then mirror the unconditional path. Default events remain rare under this low-stress scenario, and the default probability is close to the unconditional case; hence other variables (Panels (c), (d), (e), and (f)) exhibit similar trajectories across the two cases.

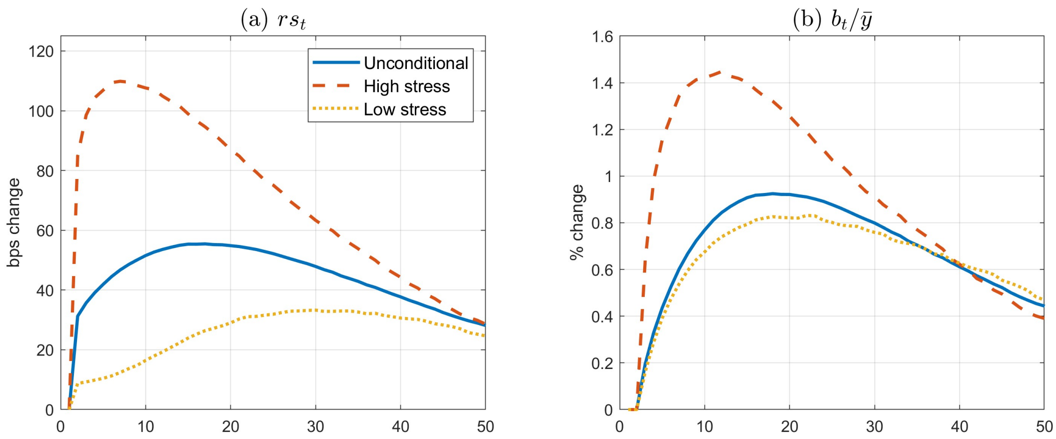

Figure 6: Generalized impulse response functions of spreads rs_t to a positive transfer shock under different financial stress levels, measured by $b_0/\bar{y}$ and z_0.

As a robustness check, I employ an alternative measure of financial stress to construct conditional IRFs: "high stress" alternatively denotes $b_0/\bar{y} > \mathbb{E}(b_t/y_t)$ and $\log(z_0) < -0.02$ (about half a standard deviation below mean productivity), capturing the fact that large debt stocks and low productivity jointly drive high spreads. Conversely, "low stress" is defined as $b_0/\bar{y} < \mathbb{E}(b_t/y_t)$ and $\log(z_0) > 0.02$. Figure 6 confirms that the conditional effects on spreads remain state-dependent. Under high stress, spreads initially jump by over 100 basis points and remain persistently above the pre-shock level (Panel (a)). Under low stress, spreads rise only modestly at first (by around 30 basis points) but converge to a higher level over time.[11] Meanwhile, the sovereign issues more bonds to meet increased public financing needs, with significantly higher debt accumulation under high-stress states.

3.5 Experiment: transfer-side austerity

During the 2010s, the Greek sovereign debt crisis was marked by insufficient transfer-side austerity. A natural question thus arises: could Greece have avoided default by effectively constraining government transfer expenditures? To explore this, I impose tighter limits on transfer shocks preceding the typical default event for a counterfactual analysis (Figure 2).

Specifically, I initialize the simulation at b_{-9} and z_{-9} (representing 2009 Q1) in accordance with the typical default path, and apply the same sequence of productivity shocks depicted in Figure 2 through $t = 0$ (representing 2012 Q2). From 2010 Q1 onward, however, I replace the

[11] Impulse responses for other endogenous variables are qualitatively similar to those in Figure 5. Additional figures are available upon request.

simulated typical transfer shocks with several series of lower, constant shocks, thereby reducing the $f_t/\bar{y}$ ratios through 2012 Q2. During these quarters, debt issuance evolves according to the policy function $b_{t+1} = \mathcal{B}(b_t, \mathbf{s}_t)$. I then compute the probability-weighted average spread path using the associated probabilities of each productivity-transfer-debt grid point visited.

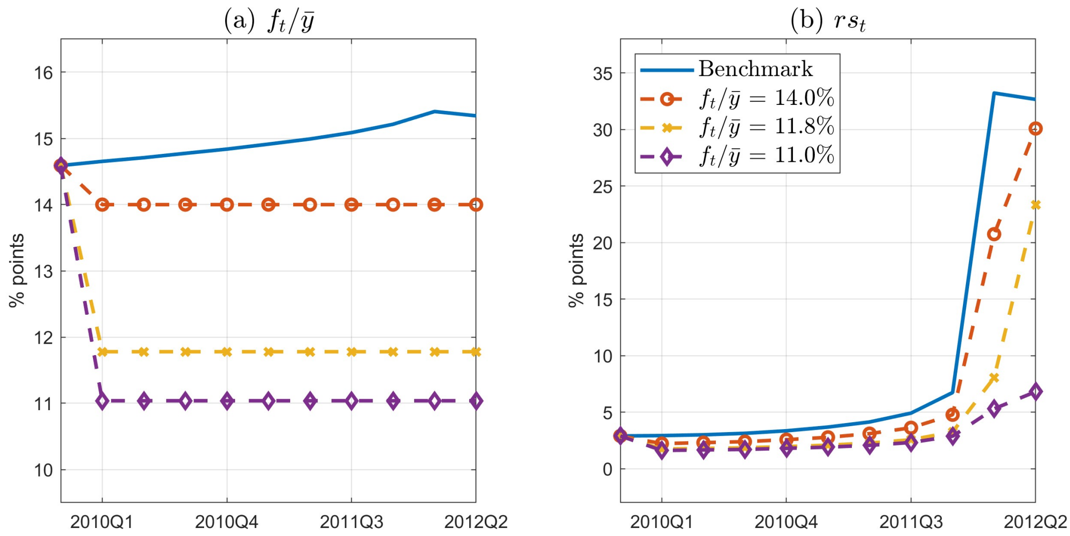

Figure 7: Counterfactual paths of transfer spending and the resulting outstanding debt and spreads, holding the productivity path equal to that in the typical default episodes (Figure 2).

Figure 7 shows that when $f_t/\bar{y}$ is lowered to 14.0% or 11.8%, debt spreads decline relative to the benchmark but default risk remains (with default probabilities of 60% and 15%, respectively). Reducing $f_t/\bar{y}$ further to 11.0% substantially lowers the peak spread in 2012 Q2 and fully eliminates the probability of default. Accordingly, while the 2010 EAP's proposed 1.7% reduction in the transfers-to-GDP ratio relative to a no-adjustment scenario (approximately the $f_t/\bar{y} = 14.0\%$ case) would likely have reduced spreads, it would not necessarily have avoided default. Within the model environment, stricter transfer-side consolidation improves debt sustainability metrics and reduces default probabilities. However, political resistance may constrain the feasibility of such adjustments.

4 Conclusion

This paper examines how government transfer payments influence sovereign debt dynamics, with a focus on Greece's debt crisis of the early 2010s. Transfer payments are modeled as exogenous to reflect political frictions that limit the government's ability to reduce social benefits during economic downturns. The analysis shows that default events coincide with elevated transfer payments, and positive transfer shocks can significantly increase debt spreads and default probabilities, especially under high financial stress. Even during low-stress periods, expanding transfer spending leads to greater debt accumulation and rising spreads over the longer term, thereby narrowing fiscal space. Beyond the direct public finance implications of higher transfer spending, the model highlights that increased transfers reduce labor supply and output, weakening fiscal capacity and moving the economy closer to default.

Quantitatively, the results suggest that transfer-side consolidation reduces spreads and default risk within the model environment. Larger reductions in transfer obligations substantially improve debt sustainability outcomes in the calibrated Greek scenario. These findings highlight the role of credible fiscal adjustment in managing sovereign risk, while recognizing that political frictions and limited foresight may constrain implementation.

A limitation of the framework is the absence of household heterogeneity. Transfers are modeled in reduced form and accrue to a representative household, which implies that the model does not permit welfare comparisons across different groups or normative ranking of alternative fiscal policy paths. The analysis is therefore primarily positive, focusing on the implications of transfer shocks for debt dynamics and sovereign spreads. Extending the framework to incorporate heterogeneous domestic households, such as workers and retirees, would allow a richer evaluation of distributional effects and welfare trade-offs associated with transfer-side fiscal adjustments. I leave such extensions for future research.

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Declaration

None.

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Appendices

A Solving the long-term debt dynamic programming problem with taste shocks

This section demonstrates how I incorporate taste shocks (Gordon, 2019) into the solving algorithm to achieve convergence with the value function iteration method. Taste shocks follow a Gumbel (Extreme Value Type I) distribution. Optimal debt policy (issuance) is denoted as $b' = \mathcal{B}(b, s)$. It is defined in a set of discrete grids of space. The government's optimization problem of repayment is rearranged as:

$$V^r(b, \mathbf{s}, \langle\varepsilon_{b'}\rangle) = \mathbb{E}_{\varepsilon_{b'}}\left[\max_{c,h,g,b'} \mathcal{W}(b', \mathbf{s}') + \sigma_b \varepsilon_{b'}\right], \tag{A.1}$$

where $\{\varepsilon_{b'}\}$ are i.i.d. Gumbel shocks and σ_b determines the magnitude of taste shocks imposed on $\mathcal{B}(b, s)$. When $\sigma_b = 0$, $V^r(b, s, \langle\varepsilon_{b'}\rangle)$ degenerates to the unperturbed case, which is subject to convergence issues during solving as reported in Chatterjee and Eyigungor (2012). Therefore, σ_b should be large enough to ensure convergence, and be small enough to minimize the influence on solutions. Here $\mathcal{W}$ represents the value of repayment:

$$\mathcal{W}(b, b', \mathbf{s}) = U(c, h, g) + \beta \mathbb{E}_{s'|s} V(b', \mathbf{s}'), \tag{A.2}$$

and the $\mathcal{W}$ associated with $\mathcal{B}$ is denoted as $\mathcal{W}^*(b, s) = \max_{b'} \mathcal{W}(b, b', s)$. Hence, the ex-ante probability of choosing a debt policy is:

$$\mathbb{P}(b' = i|b, \mathbf{s}) = \frac{\exp\left[(\mathcal{W}(b, i, \mathbf{s}) - \mathcal{W}^*(b, \mathbf{s}))/\sigma_b\right]}{\sum_{\tilde{i}} \exp\left[(\mathcal{W}(b, \mathbf{s}, \tilde{i}) - \mathcal{W}^*(b, \mathbf{s}))/\sigma_b\right]}. \tag{A.3}$$

Intuitively, the formula quantifies the proportion of normalized discrepancies between the lifetime utility of all possible grids of b' and the optimal one. If a candidate policy is distant from the optimal one, the numerator for the RHS will be small, and therefore the probability of selecting this policy will be negligible. Similarly, we introduce a taste shock $\varepsilon_{d=0}$ to the default decision d so the value of default option (equation 12) becomes:

$$V(b,\mathbf{s}) = \mathbb{E}_{\varepsilon_{d=1},\varepsilon_{d=0}}\left[\max_{d=0,1}\left\{V^r(b,\mathbf{s}) + \sigma_d\varepsilon_{d=0},\ V^d(\mathbf{s}) + \sigma_d\varepsilon_{d=1}\right\}\right], \tag{A.4}$$

and the probability of default is

$$\mathbb{P}(d=1|b,\mathbf{s}) = \frac{\exp\left[V^d(\mathbf{s})/\sigma_d\right]}{\exp\left[V^d(\mathbf{s})/\sigma_d\right] + \exp\left[V^r(b,\mathbf{s})/\sigma_d\right]}. \tag{A.5}$$

Similarly, I obtain the probability of renegotiated debt γ as $\mathbb{P}(\gamma|\mathbf{s})$, hence the recovery value of debt becomes

$$q^d(b',\mathbf{s}) = \frac{1}{1+r^*}\mathbb{E}_{\mathbf{s}'|\mathbf{s}}\left\{(1-\mu)q^d(b',\mathbf{s}') + \mu\frac{\sum_\gamma \mathbb{P}(\gamma|\mathbf{s})\Delta^c(\gamma,\mathbf{s}')}{b}\right\}, \tag{A.6}$$

and the price of sovereign debt conditional on repaying becomes:

$$q(b',\mathbf{s}) = \mathbb{E}_{\mathbf{s}'|\mathbf{s}}\left[\mathbb{P}(d=0|b',\mathbf{s}')\frac{\lambda + (1-\lambda)\left(\eta + \sum_{b''}\mathbb{P}(b''|b',\mathbf{s}')q(b'',\mathbf{s}')\right)}{1+r^*} + \mathbb{P}(d=1|b',\mathbf{s}')q^d(b',\mathbf{s})\right]. \tag{A.7}$$

So now the pricing rule is adjusted continuously, which facilitates convergence of solving. Without taste shocks, it is possible in some states, the benevolent government is indifferent between two candidate debt policies, making it difficult to obtain a stable solution.

B Numerical robustness

This section reports robustness checks with respect to the debt state grid and the magnitude of taste shocks. First, the benchmark specification uses $N_b = 250$ grid points for the debt state, balancing numerical accuracy and computational cost. As a robustness exercise, the model is re-solved using a finer grid with $N_b = 500$. and the resulting simulated moments are compared to the benchmark.

Second, the benchmark taste shock parameters are set to $\sigma_b = \sigma_d = \sigma_\gamma = 0.0025$, which ensure numerical stability while keeping the smoothing of policy functions limited. To assess the sensitivity of the results to the magnitude of taste shocks, the model is re-solved with larger shocks $\sigma_b = \sigma_d = \sigma_\gamma = 0.005$. For smaller values of taste shocks, the value function iteration does not converge reliably, reflecting the role of smoothing in ensuring numerical stability.

The resulting simulated moments are compared to the benchmark specification in Table B.1. Across specifications, differences in both targeted and non-targeted moments are economically negligible. These results indicate that using $N_b = 250$ grid points provides sufficient numerical precision and that the benchmark taste shock parameters $\sigma_b = \sigma_d = \sigma_\gamma = 0.0025$ strike a balance between numerical stability and minimal smoothing, without materially altering the model's quantitative results.

Table B.1: Robustness of simulated moments to grid refinement and taste shock magnitude

Moment	Benchmark ($N_b = 250$, $\sigma = 0.0025$)	$N_b = 500$	$\sigma = 0.005$
Defaults per century	2.1	2.1	2.1
$\mathbb{E}(rs_t)$	2.5%	2.5%	2.6%
$\sigma(rs_t)$	3.1%	3.1%	3.0%
$\mathbb{E}(b_t/y_t)$	65%	65%	64%
Mean haircut	41%	41%	42%
$\mathbb{E}(f_t/y_t)$	14.1%	14.1%	14.2%
$\sigma(f_t/y_t)$	2.7%	2.7%	2.7%
$\sigma(y_t)$	3.1%	3.1%	3.1%
$\sigma(c_t)/\sigma(y_t)$	83%	83%	83%
$\sigma(h_t)$	1.6%	1.6%	1.6%
$\mathbb{E}(g_t/y_t)$	28.4%	28.4%	28.4%
$\sigma(g_t/y_t)$	42.3%	42.5%	41.4%

Notes: All specifications use the same calibration as the benchmark, except for the number of debt grid points N_b or the magnitude of taste shocks. Simulated moments are computed from 2,100,000 simulated quarters and exclude default periods.