Sovereign Default and Inequality*

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Abstract

This paper examines how income inequality affects the sovereign default risk. I study fiscal policies in a sovereign default model with heterogeneous agents and distortionary taxation. I quantify the model in the case of Spain and find that inequality worsens the debt crisis by increasing the government's incentive to default. This mechanism is quantitatively consistent with the positive correlation between income inequality and sovereign spread across countries.

Keywords: Inequality; Redistribution; Sovereign default; Taxation
JEL Classifications: E62; F34; F41; H23; H63

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Introduction

In this paper, I introduce a sovereign default framework with heterogeneous agents and quantify the effect of income inequality on sovereign debt and spread.

I incorporate heterogeneous labor productivity, endogenous labor supply, and distortionary taxation into the canonical sovereign default model. The small open economy faces an aggregate productivity shock. The government redistributes resources via affine taxes (marginal labor tax and lump-sum tax) and borrows internationally with state-uncontingent bonds. The government can default on its bond under the cost of productivity losses and some period of exclusion from the international financial market. The bond prices incorporate a risk premium to compensate international lenders for their default losses.

The government's debt choices interact with inequality via its redistributive goals. Conditional on repayment, the higher the debt is, the higher marginal taxes the government needs to levy in order to repay its debt. Therefore, the benefit of default is to increase the amount of resources transferred to private workers and reduce the marginal labor tax, which in turn lowers the distortion. On the other hand, the benefit of repayment is using international financial markets to smooth out aggregate fluctuations and distortions. Absent of inequality, default does not reduce distortion, so the benefit of default is low.

I quantify the model using Spanish data and examine how inequality contributes to the sovereign debt crisis. I calibrate the model to match key macroeconomic statistics of Spain. To evaluate the role of inequality/redistributive motive, I compare the benchmark model to the model with no inequality.

The findings are as follows. First, inequality worsens the crisis by increasing the default probability. Both average and volatility of spreads are higher in the benchmark model than the no-inequality model. Second, default risk generates a deep and long decline in output. The government's motive for redistribution mitigates the debt crisis with smaller drop in output and lower sovereign spread at the cost of higher labor taxes. Lastly, average sovereign debt and spread vary non-linearly to income inequality.

Related Literature The model builds on the sovereign default model developed by Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), and Arellano (2008). The contribution is a framework that highlights the interaction between government's default, debt, and redistributive policies. In contrast to an endowment economy like most work in the literature, labor supply is endogenous, which generates the distortionary cost of policies.

This research also contributes to the public finance literature that studies the trade-off between debt management and redistribution such as Werning (2007), Bhandari, Evans, Golosov, and Sargent (2016), and Bhandari, Evans, Golosov, and Sargent (2017) by introducing strategic defaults and quantifying the relationship between inequality and sovereign spread.

Outline The paper is organized as follows. Section 1 describes a model of sovereign default and inequality. Section 2 defines the recursive equilibrium of the government. Section 3 presents the quantitative analysis. Lastly, Section 4 concludes.

1 Model of Sovereign Default and Inequality

This section describes the model of sovereign default, income inequality, and distortionary taxation. I consider a small open economy with a continuum of workers that are differentiated by their labor productivities, a production technology, and a benevolent government. The government borrows noncontingent bonds internationally and can default with punishment of lower productivity and temporary exclusion from the international markets. This model departs from the canonical sovereign default model by introducing worker heterogeneity, endogenous labor supply, and distortionary taxes that act as redistributive policies.

1.1 Environment

A small open economy faces publicly observed aggregate productivity shocks $z_t \in S$ in period t, where Z is some finite set. The exogenous risk-free international interest rate for borrowing is r^*. A history of shock is $z^t = (s_0, s_1, ..., z_t)$. Allocation, government policies, and prices depend on histories of shock. For convenience, I suppress the notation z^t.

Workers. The worker's productivities are$(\theta^i)_{i \in I}$, which are publicly observable. The fraction of workers with productivity θ^i is π^i, where $(\pi^i)_{i \in I}$ and $(\theta^i)_{i \in I}$ are normalized such that $\sum_{i \in I} \pi^i = 1$ and $\sum_{i \in I} \pi^i \theta^i = 1$. All workers have the same discount factor β and the static utility $U(c, n)$ over consumption c and hours worked n. The utility of agent with productivity θ^i over consumption $c^i_t \geq 0$ and efficiency-unit labor $l^i_t \geq 0$ is

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U^i(c^i_t, l^i_t) \tag{1}$$

where $U^i(c, l) = U\left(c, \frac{l}{\theta^i}\right)$.

Firm. There is a representative firm that uses labor to produce a single final good. The production function is$F(z, L) = \bar{z}(z)L$, where L is the aggregate labor supply and $\bar{z}$ is the realized productivity that the economy receives.

Government. The benevolent government maximizes the social welfare

$$\mathbb{E}_0 \sum_{i \in I} \lambda^i \pi^i \sum_{t=0}^{\infty} \beta^t U^i\left(c^i_t, l^i_t\right),$$

where $\{\lambda^i\}_{i\in I}$ is the set of welfare weights ($\lambda^i > 0, \sum_{i\in I} \lambda^i = 1$). In every period, the government can levy a marginal tax rate on labor income τ^n, a lump-sum tax T, and borrows state-uncontingent B internationally. The government can default on these obligations. Denote d_t the default policy, where $d_t = 0$ implies default and $d_t = 1$ implies no default. The punishment for default includes a drop in productivity $z_d(z) \leq z$ and exclusion from international financial markets for some periods. With probability ψ, the country regains access to international financial markets with zero debt and is no longer subject to productivity loss. Following the sovereign default literature, I assume that only the government can participate in the international financial markets and redistribute the proceeds back to individuals in a lump-sum fashion.

International lenders. The international lenders are competitive and risk neutral, willing to lend to the government at the break-even price q_t that internalizes the government default decision .

Allocation. An allocation specifies consumption and labor: $\{c^i, l^i\}$. The aggregates are denoted by $C \equiv \sum_{i\in I} \pi^i c^i$ and $L \equiv \sum_{i\in I} \pi^i l^i$.

1.2 Competitive Equilibrium

I formally define competitive equilibrium given the government policies

Workers. Given the government's policies, the individual worker of type $i \in I$ maximizes their utility subject to the following budget constraint for every period t

$$c_t^i = (1 - \tau_t^n) w_t l_t^i - T_t \tag{2}$$

Firm. The representative firm pays each unit of efficiency-unit labor at a wage

$$w_t = \bar{z}_t = (1 - d_t) z_t + d_t z_d(z_t), \forall t \tag{3}$$

Government The government's budget constraint is

$$(1 - d_t) B_t \leq \tau_t^n w_t L_t + T_t + q_t B_{t+1} \tag{4}$$

Resource Constraint The resource constraint of the economy in every period is

$$C_t + (1 - d_t) B_t \leq F(z_t, L_t) + q_t B_{t+1} \tag{5}$$

Definition 1.1. A competitive equilibrium is competitive equilibrium with taxes for an open economy is individual worker's allocation $z^{H,i} = \{c_t^i, l_t^i\}$, $\forall i \in I$, the representative firm's allocation $z^F = \{L_t\}$, prices $p = \{q_t, w_t\}_t$, and government's policy $z^G = \{\tau_t^n, T_t, B_{t+1}\}$ such that

(i) Given policies and prices, $z^{H,i}$ solves individual i's problem that maximizes (1) subject to (2) and z^F solves firm's problem

(ii) The government budget constraint (4) and the resource constraint (5) are satisfied

(iii) p satisfies the international break-even rule and equation (3) given z^G

1.3 Characterizing Competitive Equilibrium

For any equilibrium, there exist a set of Neghishi (market) weights $\boldsymbol{\varphi}_t = (\varphi_t^i)_{i\in I}$, with $\varphi^i \geq 0$ and $\sum_i \pi^i \varphi^i = 1$, such that individual allocation solve a static problem

$$\begin{aligned} V(C_t, L_t; \boldsymbol{\varphi}_t) \equiv \max_{(c^i, l^i)_{i\in I}} & \sum_{i\in I} \varphi_t^i \pi^i U^i(c^i, l^i) \\ s.t. \qquad & \sum_{i\in I} \pi^i c^i = C; \quad \sum_{i\in I} \pi^i l^i = L \end{aligned}$$

This problem gives the policy functions for each individual i

$$h^i(C_t, L_t; \boldsymbol{\varphi}) = \Big(h^{i,c}(C_t, L_t; \boldsymbol{\varphi}),\ h^{i,l}(C_t, L_t; \boldsymbol{\varphi})\Big)$$

A competitive equilibrium allocation must satisfy $(c_t^i, l_t^i) = h^i(C_t, L_t; \boldsymbol{\varphi}_t)$ for all i. The associate competitive equilibrium prices can be computed as if the economy were populated by a fictitious representative agent with utility function $V(C_t, L_t; \boldsymbol{\varphi}_t)$. The envelope conditions of the static problem give

$$(1 - \tau_t^n) w_t = -\frac{V_L\left[h^i(C_t, L_t; \boldsymbol{\varphi}_t)\right]}{V_C\left[h^i(C_t, L_t; \boldsymbol{\varphi})\right]}$$

Furthermore, the budget constraint for individual i in period t can be written as

$$V_C(C_t, L_t; \boldsymbol{\varphi}_t) h^{i,c}(C_t, L_t; \boldsymbol{\varphi}_t) + V_L(C_t, L_t; \boldsymbol{\varphi}_t) h^{i,l}(C_t, L_t; \boldsymbol{\varphi}_t) + V_C(C_t, L_t; \boldsymbol{\varphi}_t) T_t = 0 \tag{6}$$

Equation (6) is the individual implementability constraint.

One has the following characterization proposition.

Proposition 1.1. *An allocation $\{C_t, L_t\}$ can be supported as an aggregate allocation of an open economy competitive equilibrium with taxes if and only if the resource constraint (5) holds, and there exist market weights $\boldsymbol{\varphi}_t = (\varphi^i)_{i\in I}$ and lump-sum tax T_t such that the implementability constraints (6) hold for all $i \in I$.*

Proposition 1.1 implies that instead of choosing the policies and letting the private sector responds optimally, the government can directly choose the aggregate allocation and the individual allocating rule (the set of market weights) that take into account the distortionary cost of policies, as captured by the implementability constraints.

The social welfare function for every period t becomes

$$W(C_t, L_t; \boldsymbol{\varphi}_t) = \sum_{i \in I} \lambda^i \pi^i U^i \left(h^i(C_t, L_t; \boldsymbol{\varphi}_t) \right)$$

2 Recursive Equilibrium

In each period, the aggregate state of the economy consists of a level of aggregate productivity z and public debt B. Denote the government value conditional on repayment by the function $V^R(z, B)$, its value conditional on default by the function $V^D(z)$, and its optimal value by the function $V(z, B)$.

The repayment value is

$$\begin{aligned} V^R(z, B) = & \max_{C, L, B', \boldsymbol{\varphi}, T} W(C, L; \boldsymbol{\varphi}) + \beta \mathbb{E}_z V(z', B') \\ & s.t. \qquad C + B = zL + q(z, B')B' \\ & \qquad\qquad C, L, \boldsymbol{\varphi}, T \text{ satisfy implementability constraints} \end{aligned}$$

The default value is

$$\begin{aligned} V^D(z) = & \max_{C, L, B', \boldsymbol{\varphi}, T} W(C, L; \boldsymbol{\varphi}) + \beta \left\{ \psi \mathbb{E}_z V(z', 0) + (1 - \psi) \mathbb{E}_z V^D(z') \right\} \\ & s.t. \qquad C = z_d(z) L \\ & \qquad\qquad C, L, \boldsymbol{\varphi}, T \text{ satisfy implementability constraints} \end{aligned}$$

Finally, the government chooses between repayment and default in every period, i.e.

$$V(z, B) = \max \left\{ V^R(z, B), V^D(z) \right\}$$

I assume that the government repays if it is indifferent between repayment and default. Therefore, the government defaults if and only if $V^D(z) > V^R(z, B)$. The default decision rule is $d(z, B)$ and the borrowing decision rule when repayment happens is $B'(z, B)$.

Equilibrium bond price. Since the international financial market is competitive, the unit price of debt is consistent with zero profits adjusting for the probability of default, i.e.

$$q(z, B) = \frac{\mathbb{E}_z \left[1 - d(z', B'(z, B)) \right]}{1 + r^*}$$

I formally define the recursive equilibrium of the government:

Definition 2.1. A Markov recursive equilibrium consists of the value functions $V(z,B)$, $V^R(z,B)$, $V^D(z)$, the policy functions $C(z,B)$, $L(z,B)$, $T(z,B)$, $\boldsymbol{\varphi}(z,B)$, $d(z,B)$, $B'(z,B)$ and the bond price $q(z,B)$ such that

(i) Given the bond price function, the policy functions and value functions satisfy the government's optimization problem.

(ii) Given the policy functions, the bond price reflects the government's default probabilities and are consistent with expected zero profits of the international lenders.

3 Quantitative Analysis

This section presents the quantitative properties of the model. I calibrate the model to the Spanish economy. I illustrate how tax and debt policies respond to different levels of aggregate productivity in the presence of income inequality. I then analyze the impulse responses to a negative productivity shock for the benchmark model and the alternative model where there is no income inequality. Lastly, I consider how average taxes, public debt, and spread respond to different levels of income inequality.

3.1 Calibration

I assume the following distributional and functional forms. The economy is populated by two types of agents with labor productivity $\{\theta^H, \theta^L\}$, where $\theta^H \geq \theta^L > 0$ and $\pi^H = \pi^L = 0.5$. The planner is utilitarian, i.e. $\lambda^H = \lambda^L$. I consider the following parametric form of the utility

$$U(c,n) = \frac{c^{1-\sigma}}{1-\sigma} - \frac{l^{1+\nu}}{1+\nu},$$

where $\sigma > 0$ is the risk aversion, and $\nu > 0$ is the inverse labor elasticity. I assume that the productivity shock z follows a logged first-order autoregressive process:

$$\log z_t = \rho_z \log z_{t-1} + \epsilon_t^z,\ \epsilon_t^z \sim \mathcal{N}(0, \sigma_z),$$

where ρ_z, σ_z are the auto-correlation and the residual standard deviation, respectively. I discretize the productivity process into a Markov chain using Tauchen's method with 21 evenly-spaced nodes. The loss in the productivity during default takes a form as in Chatterjee and Eyigungor (2012), i.e. $z_d(z) = z - \max\{d_0 z + d_1 z^2, 0\}$ with $d_0 < 0 < d_1$.

A period is one year in the model, and we parametrize it to match the key properties of the Spanish economy from 1980 to 2017. I consider the cyclical properties relative to a long-run trend (HP smoothing parameter of 10^5) in annual data.

Table 1 reports the parameter values and targets from the calibration exercise. The first group of parameters are externally calibrated. I set the risk-free rate r^* at 4% and the risk aversion σ

Table 1: Calibrated Parameters and Targets

Parameter	Description	Value	Target
Externally calibrated parameters			
r^*	Risk-free rate	0.04	Standard literature value
σ	Risk aversion	2	Standard literature value
$1/\nu$	Labor elasticity	0.5	Standard literature value
θ^H/θ^L	Wage ratio	3.51	Average wage Gini
ρ_z	Auto-corr. of prod.	0.9	Standard literature value
ψ	Recovery rate	0.25	Standard literature value
Internally calibrated parameters			
σ_z	Std. dev. of prod. res.	0.048	Std. dev. log GDP
β	Discount factor	0.91	Std. dev. trade balance/GDP
d_0	Default cost parameter	-0.4	Average spread
d_1	Default cost parameter	0.5	Std. dev. spread

Note: The table describes the parameters, their values, and the targets in the calibration exercise. Statistics are annual. The wage ratio θ^H/θ^L is set to match the wage Gini, which is the author's calculation from the cross-sectional data set by Pijoan-Mas and Sanchez-Marcos (2010). The recovery parameter is chosen to be consistent with the finding in Gelos et al. (2011). The auto-correlation and standard deviation of GDP cover the period of 1980-2017.

at 2, which are standard values in the sovereign default literature. The labor elasticity is 0.5, which implies that $\nu = 2$. The wage ratio θ^H/θ^L is set to match the wage Gini of 28% from the cross-sectional data set by Pijoan-Mas and Sanchez-Marcos (2010). The persistence of the productivity shock is set to be 0.9, similar to values set by other international business cycle studies. The recovery rate is 0.25, which implies that the defaulting countries are excluded from international financial markets for four years on average, consistent with the finding in Gelos et al. (2011).

The second group of parameters are internally calibrated to match key business cycle statistics of Spain. The standard deviation σ_z in the productivity process, the discount factor β, and the default cost parameters d_0 and d_1 are set to jointly target the volatility of aggregate GDP of 6.6%, the volatility of trade-balance-to-GDP of 3.4%, and the average and volatility of spreads of 1% and 1.2%.

3.2 Findings

Table 2 shows the moment matching exercise of the benchmark and the data. The first column reports the statistics from the Spanish data in the period of 1980-2017. The second and third column reports the statistics from simulating the models and taking the long-run averages.[1] The benchmark statistics are close to the data statistics. In the alternative model without inequality, trade balance volatility is higher, while average and volatility of spreads are lower than the

[1]All model statistics are long-run averages of simulating the economy for 10000 periods and discarding the first 500 periods.

Table 2: Targeted Statistics: Data and Models

Statistics (%)	Data	Benchmark	No inequality
Std. dev. log GDP	6.62	6.49	6.49
Std. dev. trade balance/GDP	3.44	3.44	3.70
Average spread	1.02	1.00	0.97
Std. dev. spread	1.20	1.20	1.01

Note: The table describes the targeted statistics from the calibration exercise. The first column reports data statistics which are across the period of 1980-2017. The second and third columns report the statistics derived from the model simulation for 10000 periods and excluding the first 500 periods. Column "No inequality" corresponds to the model in which $\theta^H = \theta^L$.

benchmark values.

The next exercise evaluates the model's performance for non-targeted moments. Table 3 reports the non-targeted statistics for data, benchmark model, and the model with no inequality. The first column is from the Spanish data, and the second column is from the benchmark simulation. The third column reports the statistics from the model without inequality.

Table 3: Non-targeted Statistics: Data and Models

Statistics	Data	Benchmark	No inequality
Average external debt/GDP (%)	54	18	18
Std. consumption / std. GDP	1.02	1.00	1.17
Corr. spread & GDP (%)	-83	-41	-40
Corr. trade Balance/GDP & GDP (%)	-67	-9	-1
Corr. trade Balance/GDP & spread (%)	72	30	31

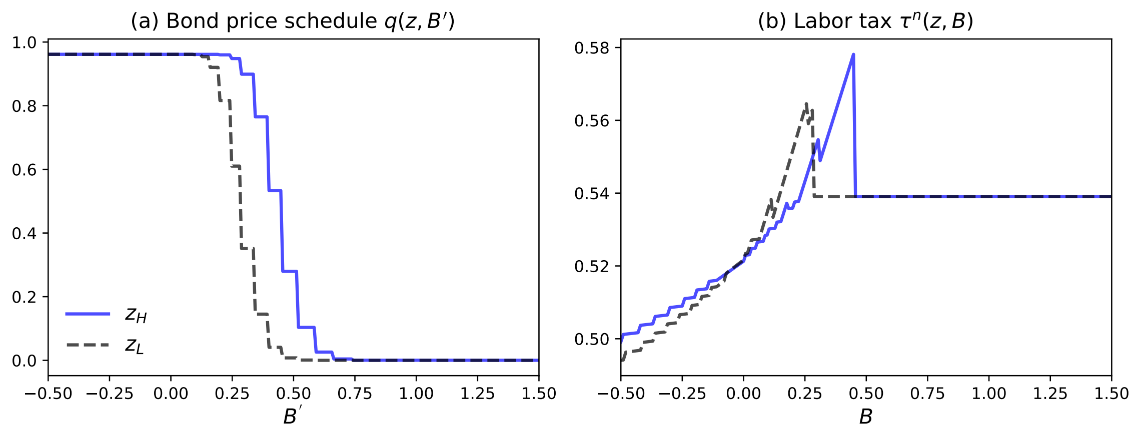
Note: The table describes the targeted statistics from the calibration exercise. The first column reports data statistics which are across the period of 1980-2017. The second and third columns report the statistics deriving simulations for 10000 periods and excluding the first 500 periods. Column "No inequality" corresponds to the model in which $\theta^H = \theta^L$.

The benchmark model qualitatively match the moments in the data with positive debt, high consumption volatility, negative correlations of spread and trade balance to output, and the positive correlation between trade balance and spread.

3.3 Policy Functions

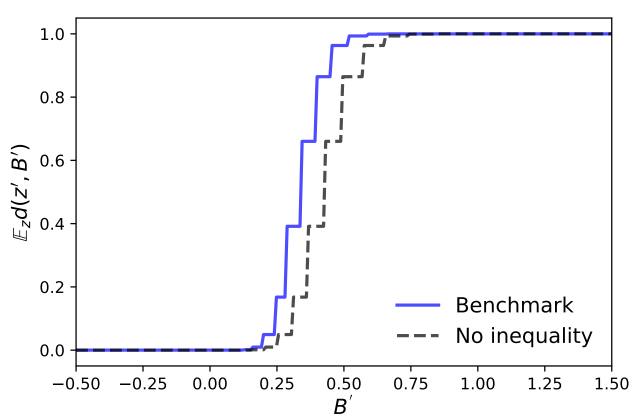
Figure 1 plots the bond price schedule $q(z, B^{'})$ and labor tax $\tau^n(z, B)$ across different levels of borrowing for high and low values of aggregate productivity (5% above and below the mean productivity, respectively). For a given level of debt $B^{'}$, higher aggregate productivity implies a better price q since the expected default probability is lower. The optimal labor taxes is increasing in the initial debt level until the government defaults and sets it constant. If the government starts the period with positive assets (B is negative), higher aggregate productivity implies higher labor taxes. If the initial debt is low, lower productivity leads to higher taxes until the government defaults.

Figure 1: Bond price schedule and labor tax



Note: The figure plots the policy functions of the recursive equilibrium for high and low values of aggregate productivity z, which are 5% above and below its mean, respectively. Panel (a) plots the bond price schedule $q(z, \cdot)$ over the values of tomorrow's borrowing $B^{'}$. Panel (b) plots the labor tax $\tau^n(z, \cdot)$ over the values of today's debt obligation B.

Figure 2: Expected default probability and debt



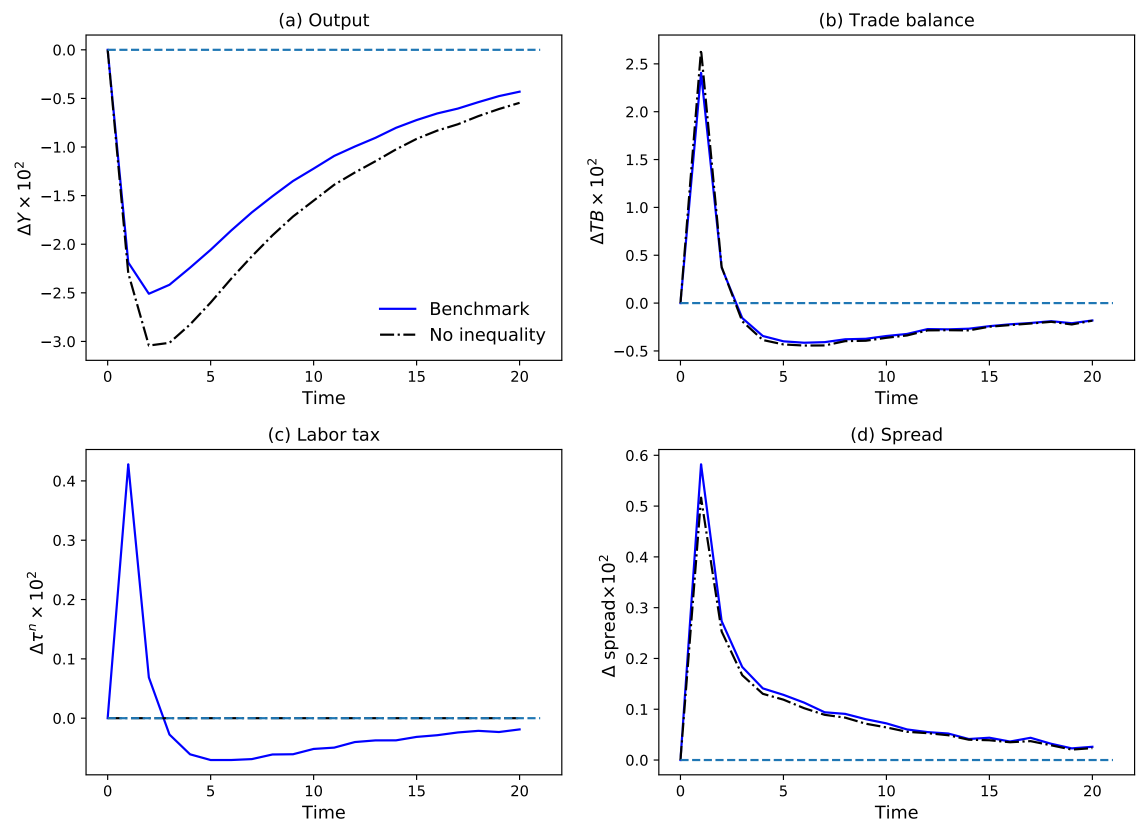
Note: The figure plots the expected default probability at the average aggregate productivity $\bar{z}$ with respect to next period borrowing $B^{'}$. "No inequality" corresponds to the model in which $\theta^H = \theta^L$.

Exposing to inequality increases the government's incentive to default. Figure 2 plots the expected default probability at the average aggregate productivity with respect to next period borrowing for the benchmark model and the no-inequality model. For a given level of borrowing, the government is more likely to default when it faces inequality than when it does not. Intuitively, higher the debt is, the higher marginal taxes the government needs to levy in order to repay its debt. Therefore, the benefit of default is to increase the amount of resources transferred to private workers and reduce the marginal labor tax, which in turn lowers the distortion. Absent of inequality, default does not reduce distortion, so the benefit of default is low, and the government is more likely to repay the debt.

3.4 Impulse Response Functions

Figure 3 plots the impulse response functions of aggregate variables and tax policies with respect to a one standard deviation decline in productivity growth for both the benchmark and no inequality models. The impulse respond functions are computed via the local projection method.[2]

Figure 3: Impulse Response Functions to a Negative Productivity Shock



Note: The figure depicts the impulse respond functions (IRFs) of aggregates and policies to a one standard deviation decline in productivity growth. The IRFs are calculated using the local projection method as in Jordà (2005)

Default risk generates a deep and long decline in output, accompanying with increasing in

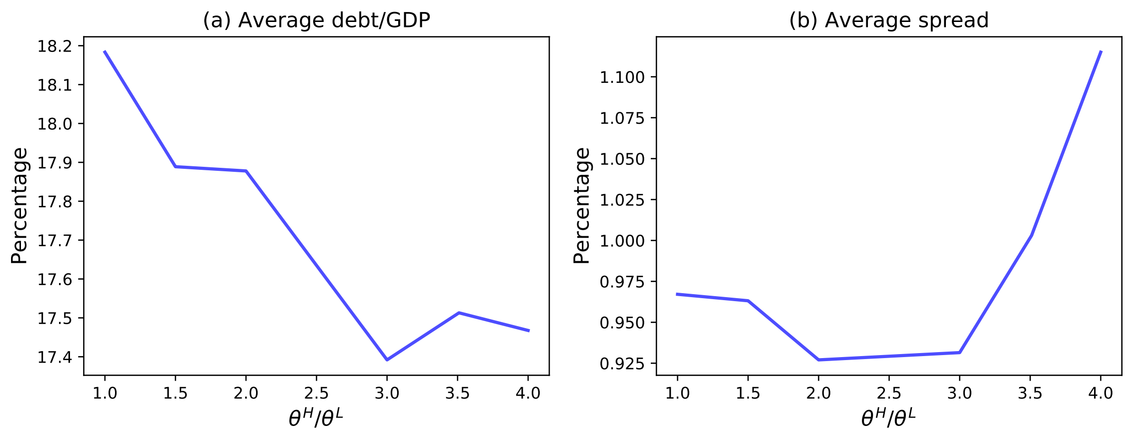
[2]The approach to calculate impulse respond functions is econometrically equivalent to the approach of Jordà (2005). I simulate the economy for 10000 periods with aggregate productivity shocks and exclude the first 500 periods. I then calculate the realized time series of shocks to productivity, ϵ_t^z. To compute the response of a variable X to the shock ϵ_t^z, I perform the OLS regressions $\Delta \log X_t = \alpha + \beta_k \epsilon_{t+k}^z + \eta_t$ to get the estimated $\hat{\beta}_k$. The horizontal τ IRF is then $IRF_\tau = \sum_{k=0}^{\tau} \hat{\beta}_t$. The effect of one standard deviation shock to ϵ_t^z is the responses $\sigma_z \times IRF_\tau$. Since labor and saving taxes can be zero or negative, the dependent variable in the OLS regressions are ΔX_t instead of $\Delta \log X_t$. To my best knowledge, Mongey (2019) is the first paper that applies this computational technique in calculating impulse responses.

sovereign spreads and labor taxes. The no-inequality model has a lower drop in output and lower sovereign spreads. Since there is no inequality, there is no need for the government to levy distortionary labor taxes to redistribute, so labor taxes are constant at zero. The government's motive for redistribution mitigates the debt crisis with smaller drop in output and lower sovereign spread at the cost of higher labor taxes.

3.5 Effect of Inequality

Figure 4 plots the average debt/GDP and the average spread for economies with different levels of inequality. While the economy with no inequality has higher debt and lower spread than an economy with inequality on average, as income inequality increases, the relationship becomes non-linear.

Figure 4: Bond price schedule and labor tax



Note: Panel (a) plots the average debt/GDP from model simulations given the value of θ^H/θ^L. Similarly, panel (b) plots the average spread.

4 Conclusion

This paper studies the impact of income inequality on sovereign default. The model is a sovereign default framework embed with heterogeneous agents, endogenous labor supply, and distortionary taxes. I quantify the model with Spanish data and find that inequality makes default more likely. When the government faces distortionary cost of redistribution, default can increase the amount of resources transferred to private workers and lowers the distortion needed to redistribute.

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Appendices

A Proof

A.1 Proof of Proposition 1.1

Proof. If $\{C_t, L_t\}$ is an aggregate allocation of an open economy competitive equilibrium with taxes, then it satisfies the resource constraint (5). Given any market weights $\boldsymbol{\varphi}$, $\{C_t, L_t\}$ satisfies

$$(1-\tau_t^n)w_t = -\frac{V_L\left[h^i(C_t, L_t; \boldsymbol{\varphi}_t)\right]}{V_C\left[h^i(C_t, L_t; \boldsymbol{\varphi})\right]}$$

Substituting for w_t in the individual worker's budget constraint gives the implementability constraint (6). $\boldsymbol{\varphi}$ is such that (6) holds $\forall i \in I$.

Suppose that there exist $\boldsymbol{\varphi}$ and T such that $\{C_t, L_t\}, \boldsymbol{\varphi}, T$ satisfy (5) and (6). Then construct $\tau_t^n = 1 + \frac{1}{\bar{z}_t}\frac{V_L\left[h^i(C_t, L_t; \boldsymbol{\varphi}_t)\right]}{V_C\left[h^i(C_t, L_t; \boldsymbol{\varphi})\right]}$ and substitute in (6) gives the individual worker's budget constraint (2). Aggregating up (2) gives

$$C_t = (1-\tau_t^n)w_t L_t - T_t$$

Subtracting this equation from the resource constraint (5) gives the government's budget constraint (4) □

B Model with Separable Isoelastic Preference

B.1 Parametric forms

The individual allocation rule is $c_t^i = \psi_{c,t}^i C_t$, $l_t^i = \psi_{l,t}^i L_t$, where

$$\psi_{c,t}^i = \frac{\left(\varphi_t^i\right)^{1/\sigma}}{\sum_i \pi^i (\varphi_t^i)^{1/\sigma}}; \quad \psi_{l,t}^i = \frac{(\theta_t^i)^{1/\nu+1}\left(\varphi_t^i\right)^{-1/\nu}}{\sum_i \pi^i (\theta_t^i)^{1/\nu+1}\left(\varphi_t^i\right)^{-1/\nu}}$$

Furthermore, V is separable and isoelastic, i.e.,

$$V(C_t, L_t; \varphi_t) = \Phi_{C,t}^V \frac{C_t^{1-\sigma}}{1-\sigma} - \Phi_{L,t}^V \frac{L_t^{1+\nu}}{1+\nu}$$

where

$$\Phi_{C,t}^V = \left[\sum_i \pi^i (\varphi_t^i)^{1/\sigma}\right]^\sigma; \Phi_{L,t}^V = \omega\left[\sum_i \pi^i \left(\varphi_t^i\right)^{-1/\nu}(\theta_t^i)^{(1+\nu)/\nu}\right]^{-\nu}$$

The implementability constraint for worker i at time t becomes

$$\psi_{c,t}^i \Phi_{C,t}^V C_t^{1-\sigma} - \psi_{l,t}^i \Phi_{L,t}^V L_t^{1+\nu} + \Phi_{C,t}^V C_t^{-\sigma} T_t = 0 \tag{7}$$

Social wefare function is

$$W(C_t, L_t; \boldsymbol{\varphi}_t) = \Phi^W_{C,t}\frac{C^{1-\sigma}}{1-\sigma} - \Phi^W_{L,t}\frac{L^{1+\nu}}{1+\nu},$$

where

$$\Phi^W_{C,t} = \Phi^V_{C,t}\sum_{i\in I}\pi^i\frac{\lambda^i}{\varphi^i_t}\psi^i_{c,t}; \quad \Phi^W_{L,t} = \Phi^V_{L,t}\sum_{i\in I}\pi^i\frac{\lambda^i}{\varphi^i_t}\psi^i_{l,t}$$

B.2 Recursive Formulation

The repayment value is

$$\begin{aligned} V^R(z,B) = & \max_{C,L,B',\boldsymbol{\varphi},T} \Phi^W_C\frac{C^{1-\sigma}}{1-\sigma} - \Phi^W_L\frac{L^{1+\nu}}{1+\nu} + \beta\mathbb{E}_z V(z',B') \\ & s.t. \qquad C + B = zL + q(z,B')B' \\ & \qquad\qquad C, L, \boldsymbol{\varphi}, T \text{ satisfy } (7), \forall i \in I \end{aligned}$$

The default value is

$$\begin{aligned} V^D(z) = & \max_{C,L,B',\boldsymbol{\varphi},T} \Phi^W_C\frac{C^{1-\sigma}}{1-\sigma} - \Phi^W_L\frac{L^{1+\nu}}{1+\nu} + \beta\left\{\psi\mathbb{E}_z V(z',0) + (1-\psi)\mathbb{E}_z V^D(z')\right\} \\ & s.t. \qquad C + B = z_d(z)L \\ & \qquad\qquad C, L, \boldsymbol{\varphi}, T \text{ satisfy } (7), \forall i \in I \end{aligned}$$