Inequality, Taxation, and Sovereign Default Risk*

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Abstract

Income inequality and its interactions with migration significantly affect sovereign default risk. With income inequality, a government imposes progressive taxes, which redistribute income but discourage labor supply and induce emigration. Lower labor supply and smaller high-income workforce erode the current and future tax base, reducing the government's ability to repay debt. I develop a sovereign default model with endogenous non-linear taxation and heterogeneous labor to quantify this effect. In the model, the government chooses the optimal combination of tax and debt, considering its impact on workers' working and migration decisions. With the estimated model, I find that income inequality and its interactions with migration explain one-third of the average U.S. state government spreads.

Keywords: Sovereign default risk, Income inequality, Migration, Tax progressivity
JEL Codes: F34, F41, E62, H74

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1 Introduction

What determines governments' capacity to repay their debt? Previous sovereign default literature focuses on the aggregates such as total debt and GDP. Governments make default decisions based on the aggregates. However, this does not provide a complete picture of the real-world sovereign debt and default risk for at least two reasons. First, in addition to issuing debt, governments have other crucial responsibilities that may conflict with the repayment goal. For example, a distortionary tax is widely used to reduce income inequality, which however, is not the best for increasing GDP. Second, imagine a government tries to increase tax to repay the debt, workers respond to it—a highly progressive tax may lead to the emigration of the high-income workforce. All of those—redistribution motives and endogenous responses of the workers—would affect government default risk. A standard sovereign default model, however, is silent on the above discussions.

This paper aims to improve understanding of sovereign debt and default risk by incorporating government redistributive motives and endogenous labor choices (including migration) into a sovereign default model. Think of an economy where the government imposes progressive taxes to reduce income inequality. However, progressive taxes are distortionary to labor supply, affecting the tax base and governments' repayment capacity. Moreover, with labor mobility, the high-income workforce's emigration reduces both current and future tax base. By introducing the role of *income inequality* and its interactions with *migration*, this paper provides a framework to study defaultable government debt and progressive taxation in a context where workers are heterogeneous and can migrate.

Empirical evidence emphasizes the role of income inequality and migration on sovereign spreads. Berg and Sachs (1988), Aizenman and Jinjarak (2012) and Jeon and Kabukcuoglu (2018) find that high inequality is associated with high sovereign default risk and spreads using cross-country data. This paper also finds that an increase in the Gini index by 0.1 is associated with a 0.5 percentage points increase in government spreads for a sample of 36 countries. Moreover, I find a stronger positive correlation between inequality and government spreads using U.S. state-level data: increasing the Gini index by 0.1 is associated with an increase of about 0.8 percentage points in the state government spreads. I show that the high level of labor mobility across the states explains the stronger correlation between income inequality and government spreads. Recent literature shows the interaction between migration and government default risk. Gordon and Guerron-Quintana (2019) studies the interactions between regional borrowing, migration, and default using U.S. county-level data. Alessandria, Bai, and Deng (2020) finds that countries at the core of the European debt crises, Spain, Ireland, Portugal, and Greece, experienced a substantial labor outflow, and emigration intensifies default risk by lowering tax base and investment.

To quantify the effect of inequality and its interaction with migration on sovereign risk, I develop a quantitative sovereign default model with inequality and migration. In the model, workers are heterogeneous in labor productivity. They supply labor elastically and consume after-tax labor income. They can also migrate by paying an idiosyncratic migration cost. The redistributive government chooses a non-linear tax scheme, government debt, and whether to default. The optimal combination of taxation, debt, and default policies depends on income inequality and labor mobility in this economy. A progressive tax redistributes income but reduces labor supply and increases the high-income labor's emigration, eroding the tax base and the government's ability to repay its debt. Higher debt spreads ensue. Thus, the government faces a *redistribution–spreads* tradeoff. In an economy where inequality is a key concern, the government opts for more redistribution and suffers higher spreads.

This paper's framework provides a tool to study the interactions between income distribution, taxation, borrowing, and default risk, which applies to both national and subnational governments. As an application of the model, I parametrize the model using U.S. state-level data. As Arellano, Atkeson, and Wright (2016) documented, there were sharp increases in government debt spreads in Europe and the U.S. states. An advantage of using U.S. state-level data is that the measures for income inequality, tax progressivity, and migration flows are more comparable across the states and consistent over time. The key data moments for estimating the model parameters include the Gini index, tax revenues and state-to-state migration flow of workers with heterogeneous income, and the first- and second-order moments related to state government debt and spreads.

The estimated model shows that income inequality and its interaction with migration account for one-third of the average U.S. state government spreads. Inequality itself accounts for 23% of the government spreads. In the model, labor is elastic in both intensive margin—through labor supply choices—and extensive margin—through migration. The impact magnitude of inequality on government spreads relies on labor elasticity. With more elastic labor, the equilibrium tax progressivity is lower. It is because, with higher Frisch elasticity for labor supply or lower migration cost and thus higher migration rates, the distortions from progressive taxes are higher. Thus, in the equilibrium, the government chooses a less progressive tax.

Moreover, impulse response functions show that the government spreads spike in recessions for an economy with severe income inequality concerns. Facing an adverse productivity shock, a government has incentives to lower tax progressivity to encourage labor supply and reduce high-income workforce outflow. However, lower tax progressivity conflicts with government redistributive motives. This tension between redistribution and sovereign spreads happened during the recent European sovereign debt crisis. The Greek government adopted rather regressive austerity measures (Matsaganis and Leventi (2014)), which raised concerns of fiscal burden on low-income households.

Related literature. The model builds on sovereign default model pioneered by Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), and Arellano (2008). Recent literature had paid attention to the distortionary taxation with sovereign default, but in a closed economy setting (Pouzo and Presno (2014), Karantounias (2019)) or with no redistribution motives (Cuadra, Sanchez, and Sapriza (2010)). A growing body of sovereign default literature focuses on the distributional issues of default decisions (D'Erasmo and Mendoza (2016), D'Erasmo and Mendoza (2020), Tran Xuan (2020)), where government default has a distributional effect because government has heterogeneous holdings of public debt across households. This paper shares the emphasis on explicit default options and distortionary taxes, but focuses on government redistribution motives in an open economy with external debt. This paper shows that default on external debt is in fact redistributive because of endogenous progressive taxation.

This paper closely relates to the literature that focuses on inequality and sovereign spreads, and default risk. Empirically, Berg and Sachs (1988), Aizenman and Jinjarak (2012) and Jeon and Kabukcuoglu (2018) find that high inequality is associated with high sovereign default risk and spreads using cross-country data. This paper confirms the finding using updated cross-country data and provides further evidence using cross-state data. Theoretically, literature has improved the understanding of inequality on sovereign default risk using endowment economy models with exogenous taxation (Jeon and Kabukcuoglu (2018)), political economy models where the government needs voters' support to implement a fiscal program (Andreasen, Sandleris, and Van der Ghote (2018)), and heterogeneous-agent overlapping generation models (Dovis, Golosov, and Shourideh (2016)). This paper focuses on an explicit sovereign default option and redistributive taxation by developing a sovereign default model with heterogeneous agents and endogenous non-linear taxation. This paper is closely related to Ferriere (2014). We share the focus on studying the effect of inequality and progressive taxation on sovereign default risk. However, the mechanism is different in that Ferriere (2014) focus on after-tax inequality encourages default. This paper focuses on the considerations and endogenous constraints when the government faces pre-tax inequality. This paper also emphasizes and quantifies the interaction between inequality and migration on sovereign spreads.

This paper relates broadly to the literature that focuses on inequality and debt dynamics. Azzimonti, De Francisco, and Quadrini (2014) show that when rising income inequality is associated with an increase in individual income risk, higher risk results in more public debt. Arawatari and Ono (2017) show that higher inequality increases pressure on politicians to shift the fiscal burden from the present generation to future generations, thus incentivizing politicians to finance a part of government expenditure by issuing public debt. This paper focuses on government default risk and debt spreads rather than the debt level.

Layout. The rest of this paper proceeds as follows. Section 2 describes empirical findings that motivate the theoretical analysis. Section 3 presents the model, defines the equilibrium, and highlights the model mechanism. Section 4 discusses the model's parametrization and quantitative findings. Section 5 concludes. The Online Appendix provides data details, model proofs, solution method, and additional empirical and quantitative results.

2 Empirical Findings

This section documents empirical relationships between income inequality, migration flows, tax progressivity, and sovereign spreads using U.S. state-level data. U.S. states are sovereigns under the U.S. Constitution. The states can formulate and implement their tax systems and issue bonds to finance operations. The states can also repudiate their debts without bondholders being able to claim assets in a bankruptcy process.[1] Thus, the states within the U.S. have sovereign immunity just as countries within the Eurozone (Ang and Longstaff (2013)). Compared with national government spreads, state government spreads received limited attention – an exception is that Arellano, Atkeson, and Wright (2016) analyze sovereign spreads data both in Europe and the U.S. states.

Besides filling the literature gap, there are also advantages of using state-level data because data measures are more comparable and consistent over time. For example, in terms of income inequality, sources and methods used for calculation may vary tremendously across countries. Atkinson and Brandolini (2001) show that both levels and trends in

[1] States are sovereigns and can not declare bankruptcy. Cities and municipalities can declare bankruptcy under Chapter 9 of the U.S. bankruptcy code. Detroit, for example, filed for Chapter 9 bankruptcy in 2013.

distributional data can be affected by data choices in different countries. Thus, this section mainly focuses on the results using U.S. state-level data.[2] All data resources and details are available in the Online Appendix.

Income inequality and tax progressivity. One commonly used measure for income inequality is the Gini index. Here I use the pre-tax Gini index to proxy the severity of inequality, and it also shows the extent to which the government urgently needs to redistribute. According to the Gini index in 2019, examples for states with high income inequality are New York, Connecticut, California, and Illinois, while Utah, Idaho, South Dakota, and Wisconsin have lower income inequality.

In most states, individual income taxes are a major source of state government revenue, accounting for 37% of state tax collections.[3] Income tax is the major instrument for the government to fulfill redistribution; other taxes (including federal payroll and excise taxes and state sales taxes) are either less progressive or regressive. Thus, this paper focuses on income tax progressivity both in the data and the model. The degree of progressivity varies widely across the states. For instance, the state marginal income tax rates in California range from 1% to 13.3% in 2019, while in North Dakota, they range from 1.1% to 2.9%. The maximum state income tax rate measures the income tax progressivity.

Migration flows. State-to-state migration flow data shows that in 2019, the top three outbound states are Illinois, California, and New Jersey. The top three inbound states are Idaho, Arizona, and South Carolina. Besides climate, job opportunities, and other considerations, state policies also affect household migration decisions. In 2012, California enacted legislation that increased marginal income tax rates, especially for high-income households. Using data from the California Franchise Tax Board for all taxpayers, Rauh and Shyu (2019) find that high-income earners increased their rate of out-migration from California by 0.8 percentage point in response to the tax increase. They also find a substantial decrease in taxable income, which appears in 2012 and persists through the last year of their analysis in 2014. Using income inequality and state-to-state migration data, I further illustrate that income inequality and migration are tightly related to state government spreads.

[2]Online Appendix provides additional results with cross-country data and more discussions about state government finances, including balance budget rules and the role of the federal government.

[3]Source: U.S. Census Bureau, "State and Local Government Finance," the Fiscal Year 2016.

Relation between inequality and government spreads. I use five-year credit default swap spreads to measure state government default risk. A credit default swap (CDS) is a derivative contract in which the buyer purchases default protection on underlying security from a seller. With higher default risk, the CDS spreads are higher.[4] A key advantage of using CDS spreads data is that it provides a more direct measure for a sovereign's default risk than debt spreads. Unlike CDS spreads, debt spreads are not only driven by default risk, but also by changes in interest rates, supply of underlying bonds, liquidity in the secondary market, and other factors. The drawback is that CDS spreads data is limited to post-2008 and not available for all U.S. states.

The daily spreads on five-year maturity CDS obtained from Bloomberg span from July 1, 2009 to February 15, 2019. The states with valid data are California, Connecticut, Delaware, Florida, Illinois, Maryland, Michigan, Minnesota, Nevada, New Jersey, New York, North Carolina, Ohio, Rhode Island, South Carolina, Texas, Utah, Washington, and Wisconsin.

Table 1 provides summary statistics for five-year CDS spreads for the states in the sample. Units are percentage points. The average CDS spreads range widely across the states: from a low of 0.35 percentage points for South Carolina to a high of 2.37 percentage points for Illinois. On average, the CDS spreads of Utah (0.41 percentage points) are lower than one-half of Connecticut's (0.99 percentage points). As for the maximum values during the sample period, California CDS spreads reached 3.60 percentage points in 2009, and Illinois CDS spreads reached 4.10 percentage points in 2016. The CDS spreads for the states are of similar magnitude as that for European countries.[5]

To estimate the correlation between income inequality and government spreads, I use the following specification:

$$spread_{jt} = \beta_0 + \beta_1 ineq_{j,t-1} + \Gamma' Z_{j,t-1} + \alpha_t + \epsilon_{jt}, \tag{1}$$

where $spread_{jt}$ denotes the CDS spreads for state j in year t. For yearly spreads, I use the average spreads in each year.[6] $ineq_{j,t-1}$ is income inequality for state j in year $t-1$, and it is proxied by state pre-tax Gini index. When calculating the Gini index, household

[4] Note that the state government CDS spreads in the data are tied to default events on the underlying bond, not potential missed pension payments. Pension payment is beyond the scope of this paper. Nevertheless, governments with large debt are more likely to have large unfunded pension liabilities in the data. Including unfunded pension liabilities as another source of government fiscal burden intensifies the result of this paper.

[5] Ang and Longstaff (2013) compared the CDS spreads for U.S. states and the Eurozone countries. They show that many of the average Eurozone country CDS spreads are smaller than those for the states, and many of the maximum values for the Eurozone countries are comparable to those for the states.

[6] Using rolling-window averages or the last daily observation in each year does not change the results.

Table 1: Summary statistics for state CDS spreads (in percentage points)

State	Mean	Std.Dev.	Min	Max
California	1.20	0.85	0.24	3.60
Connecticut	0.99	0.25	0.47	1.67
Delaware	0.41	0.16	0.21	1.05
Florida	0.67	0.43	0.25	1.99
Illinois	2.37	0.77	0.81	4.10
Maryland	0.49	0.25	0.20	1.28
Michigan	0.89	0.59	0.30	2.88
Minnesota	0.45	0.22	0.25	1.09
Nevada	0.83	0.55	0.21	2.33
New Jersey	1.33	0.50	0.45	2.89
New York	0.77	0.61	0.23	2.91
North Carolina	0.42	0.22	0.21	1.08
Ohio	0.75	0.41	0.25	1.78
Rhode Island	0.71	0.40	0.34	1.72
South Carolina	0.35	0.16	0.21	0.94
Texas	0.52	0.22	0.24	1.34
Utah	0.41	0.11	0.20	0.73
Washington	0.49	0.23	0.24	1.11
Wisconsin	0.57	0.34	0.16	1.47

Note: This table reports summary statistics for the five-year CDS spreads for the U.S. states in the sample. Units are percentage points. The sample consists of daily observations from July 1, 2009, to February 15, 2019.

income is defined as income received regularly (exclusive of certain money receipts such as capital gains) before payments for personal income taxes, social security, union dues, and Medicare deductions. $Z_{j,t-1}$ is a vector of control variables, including state total output, debt-to-output ratio, and political party control of state legislatures. Political party control is a set of indicator variables {Democratic, Split, Republican} and refers to which political party holds the majority of seats in the State Senate and State House.[7] α_t is a time fixed effect. Coefficient β_1 captures the correlation between income inequality and government spreads, where the variations mainly come from differences across the states.

Table 2 reports the results for empirical specification (1), and shows that high pre-tax income inequality is positively associated with high spreads. The regression uses annual spreads. Columns (1) and (2) use the average spread in each year, and columns (3) and (4) use the last daily observation in each year. The results are robust to both measures. Increasing the Gini index by 0.1 (e.g., Utah to Connecticut) is associated with CDS spreads increases of about 0.8 percentage points. This effect is quite large. The average CDS spread in the sample is 0.86 percentage points. A one standard deviation increase in the Gini index is associated with CDS spread increases of 0.16 percentage points, which is about a 20% increase from the mean. The results also show that the states with Democratic legislature control are more likely to have higher spreads than those with Republican legislature control. It may reflect the larger income redistribution preference of the Democrats. Higher redistributive motives, i.e., lower tolerance for income inequality, tilt the *redistribution–spreads* tradeoff towards more redistribution and thus higher spreads. The coefficients of other control variables are consistent with standard predictions of sovereign default models: total output negatively correlates with spreads. A higher debt-to-output ratio is associated with higher spreads.

Relation between migration and government spreads. Migration is also a critical factor shaping government spreads. Alessandria, Bai, and Deng (2020) show that high government spreads accompanied large labor outflows during European debt crises. Using U.S. state-level data, I find that high government spreads are also associated with labor outflows. Figure 1 plots the state-level migration and government spreads. The y-axis shows the ratio of in-migrants to out-migrants, where a higher value indicates more in-migration and a

[7] "Democratic" indicates that both legislative chambers have Democratic majorities, "Split" indicates that neither party has majorities in both legislative chambers, and "Republican" indicates both legislative chambers have Republican majorities. Since political parties hold different views towards income redistribution, the indicator variables' coefficients also provide information on the correlation between redistribution preference and government spreads.

Table 2: Regression of government spreads on inequality

	(1)	(2)	(3)	(4)
Gini	8.08***	8.13***	7.71***	7.96***
	(2.26)	(2.70)	(2.29)	(2.76)
Political (=“Split")		0.25		0.29
		(0.18)		(0.19)
Political (=“Democratic")		0.46***		0.44***
		(0.13)		(0.13)
Year FE	Yes	Yes	Yes	Yes
Controls		Yes		Yes
N	147	147	147	147
R^2	0.324	0.436	0.418	0.507

Standard errors in parentheses
* p<.1, ** p<0.05, *** p<0.01
Note: This table reports regression results for the cross-state sample. After merging all variables, the final panel data spans from 2009 to 2017. For annual spreads, columns (1) and (2) use the average spread in each year; columns (3) and (4) use the last daily observation in each year.

lower value indicates more out-migration. The x-axis shows the government CDS spreads. Each dot represents a state-year observation. It shows that (in-)migration negatively correlates with government spreads.

According to emigrants’ characteristics provided by Database on Immigrants in OECD and non-OECD Countries (DIOC-E), higher educated and wealthier workers are more likely to emigrate. It is because migration involves migration costs, and high-income workers are more able to cover the cost. Alessandria, Bai, and Deng (2020) does not model income heterogeneity, thus was silent on this phenomenon. When the economy has income inequality with considerable labor mobility, the government has to consider the potential impact of its progressive taxation. A progressive tax may induce outflows of high-income workers, thus depressing the government’s tax base, increasing government default risk and spreads.

In summary, empirical evidence emphasizes the role of income inequality and migration in shaping government spreads.[8] Although suggestive, it provides elements that are

[8] Online Appendix provides additional empirical results regarding state-level income inequality, tax progressivity, migration, and government spreads.

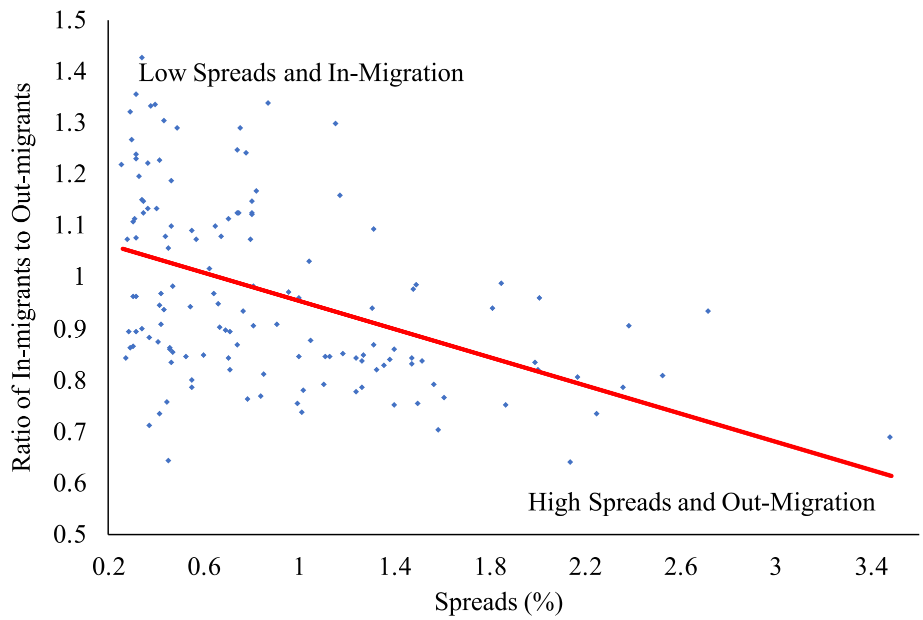


Figure 1: Government spreads and migration

Note: This figure plots migration pattern (ratio of in-migrants to out-migrants) and government CDS spreads using U.S. state-level data. Each dot represents a state-year observation.

necessary to include in the model. In the next section, I present a theory of inequality, migration, and sovereign default risk.

3 Model

I now describe my model of sovereign default, endogenous non-linear taxation, income inequality, and migration. Consider a small open economy with a production technology, heterogeneous workers, and a benevolent government. The aggregate output Y is produced with aggregate labor L using $Y = AL$, where A is the stochastic aggregate productivity. The government imposes non-linear taxation, borrows state-uncontingent bonds, and can default on them. If the government defaults, the economy suffers from a productivity loss and is temporarily excluded from the credit market. The main departure from the canonical sovereign default model is the introduction of an endogenous labor supply and progressive taxation that aims to reduce income inequality. The endogenous labor supply comes from both labor supply choices and migration decisions.

3.1 Workers

There is a continuum of workers with heterogeneous labor productivity z_i. Each worker i has preferences over consumption c_i and labor ℓ_i given by

$$u(c_i, \ell_i) = \frac{c_i^{1-\sigma}}{1-\sigma} - \frac{\ell_i^{1+\gamma}}{1+\gamma},$$

where σ is the risk aversion parameter, and $1/\gamma > 0$ is the Frisch elasticity of labor supply. Consumption c_i is bounded by after-tax labor income.

Each period, a worker makes a discrete choice to stay or emigrate. The worker migration setup closely follows Alessandria, Bai, and Deng (2020). If the worker emigrates, he receives an exogenous and constant value W^m, but also has to pay the stochastic and idiosyncratic migration cost δ. If the worker stays, he chooses labor supply ℓ_i, pays taxes (or receives transfers, if taxes are negative), and consumes the after-tax labor income.

The migration cost δ follows an exponential distribution with cumulative distribution function (henceforth, CDF) $F(x) = 1 - e^{-\zeta(z)x}$, where $\zeta(z)$ is a parameter that depends on labor productivity.[9] Rather than one constant parameter value, this reflects that the mean and volatility of migration costs for the high-income and the low-income are different. There is also an exogenous inflow of workers. The exogenous immigration rate for heterogeneous workers is constant.[10]

3.2 Government

The government is benevolent and maximizes social welfare function, which is the sum of the utility of domestic workers with a set of Pareto weights:

$$W = \int u(c_i, \ell_i)\omega_i di, \tag{2}$$

where $u(c_i, \ell_i)$ is the utility and ω_i is the Pareto weight for worker i.

[9]For example, for worker 1 with labor productivity z_1, he draws migration cost from exponential distribution with CDF $F(x) = 1 - e^{-\zeta_1 x}$, and worker 2 with labor productivity z_2 draws migration cost from exponential distribution with CDF $F(x) = 1 - e^{-\zeta_2 x}$. Quantitatively, I discipline $\zeta(z)$ to match emigration rates by income.

[10]What essentially matters is the *net emigration rate*, which is (emigration rate - immigration rate). Alternatively, I could assume exogenous immigration rates are different for heterogeneous workers, and recalibrate $\zeta(z)$ to match the net emigration rates (or net migration rates).

The government imposes a distortionary income tax/transfer policy to redistribute income. Following Heathcote, Storesletten, and Violante (2017), I study the optimal degree of progressivity with the tax and transfer policies defined by:

$$T_i(y_i) = y_i - \lambda y_i^{1-\tau}, \tag{3}$$

where T_i is the tax and y_i is the labor income for worker i. The parameter τ determines the degree of tax progressivity. If the ratio of marginal to average tax rates is larger than one for every level of income, then a tax scheme is progressive. The ratio of marginal to average tax rates for tax function (3) is given by:

$$\frac{T'(y)}{T(y)/y} = \frac{1 - \lambda(1-\tau)y^{-\tau}}{1 - \lambda y^{-\tau}}.$$

Note that the after-tax labor income is $\lambda y_i^{1-\tau}$. When $\tau = 1$, there is full redistribution with an after-tax income of λ for everyone. When $\tau = 0$, $T'(y) = \frac{T(y)}{y} = 1 - \lambda$, there is no redistribution with a flat tax rate $1 - \lambda$. When $\tau > 0$, $\frac{T'(y)}{T(y)/y} > 1$, thus the tax system is progressive. Higher τ implies that the tax rate increases faster with income, and thus the tax system is more progressive. Conversely, the tax system is regressive when $\tau < 0$. Given τ, the second parameter λ shifts the tax function and determines the average level of taxation. At the break-even labor income level $y^0 = \lambda^{\frac{1}{\tau}}$, the average tax rate is 0. If the tax system is progressive, workers with income lower than y^0 obtain net transfers rather than pay taxes. This is why tax function (3) is also called a tax/transfer policy.

The government can issue state-uncontingent bonds to the creditors and can default on them. The creditors recognize that the government may default and set the government bond price to break even. Thus, the bond price is endogenously determined and reflects the government default risk. If the government defaults, it is excluded from the borrowing market for a period of time. In the case of default, as is standard in the sovereign debt literature, I impose an exogenous cost that reduces the aggregate productivity: $A^d = f(A) < A$. The government regains the ability to borrow with probability θ. When making tax, debt, and default policies, the government will internalize the labor supply and migration decisions by heterogeneous workers.

3.3 Recursive formulation

Each period the economy starts with a level of government debt B, the aggregate shock A, the distribution of workers Φ, and an indicator variable aut that denotes whether the government is in financial autarky ($aut = 1$) or not ($aut = 0$). Thus, the aggregate state of the economy is summarized by $S = (B, A, \Phi, aut)$. Given the aggregate state, when the government is not in financial autarky, the government makes choices for borrowing, tax system, and whether to default, with decision rules given by $B' = H_B(B, A, \Phi)$, $\tau = H_\tau(B, A, \Phi)$, $\lambda = H_\lambda(B, A, \Phi)$, and $D = H_D(B, A, \Phi)$. The individual workers are heterogeneous in labor productivity z and idiosyncratic migration cost δ. The worker's state is (S, z, δ), which includes the aggregate state S and idiosyncratic states (z, δ). Let us omit the time subscript t and use x' to denote variable x in the next period.

The timing of the model is as follows. At the beginning of the period, the aggregate productivity shock A and idiosyncratic migration cost shocks δ and labor productivity z for each worker are observed. Given the aggregate state S and idiosyncratic state (z, δ), workers decide whether to emigrate. After the migration decision, the distribution of the workers becomes Φ'. The government then makes choices. If the government has access to the financial market, it decides whether to default, how much to borrow B', and the tax system $\{\lambda, \tau\}$. If the government is in financial autarky, it can only choose the tax system $\{\lambda, \tau\}$. Given taxation, the staying workers choose labor supply ℓ and consume c.

3.3.1 Worker's choice

A worker decides whether to stay or emigrate to maximize his value:

$$W(S, z, \delta) = \max\{W^s(S, z), W^m - \delta\}, \tag{4}$$

where $W^s(S, z)$ is the value of staying in the original place and W^m is the value after he pays the migration cost and emigrates. The worker staying in the original place chooses labor supply and consumption to maximize utility. Thus, the staying value $W^s(S, z)$ is:

$$W^s(S, z) = \max_{c,\ell}\{u(H_c(S, z), H_\ell(S, z)) + \beta \mathbb{E} W(S', z', \delta')\}, \tag{5}$$

where $H_c(S, z)$ and $H_\ell(S, z)$ are the consumption choice and labor supply choice depending on the aggregate state S and idiosyncratic state z.

The consumption and labor supply choice are subject to a budget constraint, which says that the consumption is bounded by the after-tax income:

$$c \leq \lambda y^{1-\tau}, \tag{6}$$

where c is consumption, $y = wz\ell$ is pre-tax labor income in which w is wage rate, z is labor productivity, and ℓ is labor supply. As illustrated in the tax/transfer function (3), λ and τ are chosen by the government.

A worker will choose to stay in the original place if and only if $W^s(S,z) \geq W^m - \delta$. Let $M(S,z,\delta) = 1$ denotes migration (to other places). As δ follows exponential distribution, the probability of staying in the original place for a worker is then given by:

$$Pr(\delta \geq W^m - W^s(S,z)) = e^{-\zeta(z)(W^m - W^s(S,z))} \tag{7}$$

3.3.2 Taxation, borrowing, and default

After the workers' migration choices, the distribution of workers becomes Φ'. Then government makes choices. The government is aware that its decisions on taxation, borrowing, and default affect the labor supply in the current period and migration decisions for the next period. The government chooses whether to repay or default on its debt:

$$V(B,A,\Phi') = \max\{V^c(B,A,\Phi'), V^d(A,\Phi')\}, \tag{8}$$

where $V^c(B,A,\Phi')$ is the repayment value, and $V^d(A,\Phi')$ is the default value. The government default policy can be characterized by default sets and repayment sets: the default set is $D(B,A,\Phi') = \left\{V^c(B,A,\Phi') < V^d(A,\Phi')\right\}$ and the repayment set is $R(B,A,\Phi') = \left\{V^c(B,A,\Phi') \geq V^d(A,\Phi')\right\}$.

If the government repays, it chooses a fiscal program with both borrowing and taxation $\{B',\tau,\lambda\}$ to maximize the social welfare function for domestic workers. The repayment value is given by:

$$V^c(B,A,\Phi') = \max_{B',\tau,\lambda}\{\int u(c_i,\ell_i)\omega_i di + \beta \mathbb{E} V(B',A',\Phi'')\}, \tag{9}$$

subject to the budget constraint:

$$B = \int_{\Phi'} T_i(y_i) di + q(B',A,\Phi')B', \tag{10}$$

where $\int_{\Phi'} T_i(y_i)di = \int_{\Phi'}(y_i - \lambda y_i^{1-\tau})di$ is the total tax revenue collected from all staying workers. $q(B', A, \Phi')$ is the bond price, which compensates the lenders for the government's future default risk. There are two main purposes for taxation here: first is to redistribute income, and second is to finance debt repayment.

If the government defaults, it is temporarily excluded from the financial market. The government chooses a fiscal program with only taxation $\{\tau, \lambda\}$ to maximize the social welfare function. With probability θ, the government returns to the financial market. The default value is given by:

$$V^d(A, \Phi') = \max_{\tau,\lambda}\{\int u(c_i^d, \ell_i^d)\omega_i di + \beta[\theta \mathbb{E} V(0, A', \Phi''_{aut=0}) + (1-\theta)\mathbb{E} V^d(A', \Phi''_{aut=1})]\}, \tag{11}$$

subject to the budget constraint:

$$0 = \int_{\Phi'} T_i(y_i)di, \tag{12}$$

where $u(c_i^d, \ell_i^d)$ is the utility of worker i when the economy is in financial autarky. During default, the government cannot borrow and does not service its debt. Thus, the only purpose for the taxation is to redistribute income.

The external lenders are competitive and risk-neutral. They face a risk-free interest rate r and are willing to lend to the government as long as they break even in expected value. The lenders are aware of the government's incentives to default on the bonds. Thus, in equilibrium, the break-even condition implies the bond price schedule $q(B', A, \Phi')$ satisfies:

$$q(B', A, \Phi') = \frac{\mathbb{E}[1 - D(B', A', \Phi''(B', A', \Phi'))]}{1+r}, \tag{13}$$

where $D(B, A, \Phi') = 1$ denotes default. As in standard sovereign default literature, the bond price depend on aggregate productivity shock A and borrowing B'. Here, the bond price also depends on the endogenous worker distribution Φ'. The government spread is defined as the inverse of the bond price minus the risk-free rate, $sp = 1/q(B', A, \Phi') - (1 + r)$.

3.3.3 Recursive equilibrium

The recursive equilibrium consists of the government policy functions for borrowing $B'(B, A, \Phi')$, tax system $\{\tau(B, A, \Phi'), \lambda(B, A, \Phi')\}$, default set $D(B, A, \Phi')$; the government value functions $V(B, A, \Phi')$, $V^c(B, A, \Phi')$, and $V^d(A, \Phi')$; the worker decisions on migration $M(S, z, \delta)$, consumption $c(S, z)$, labor supply $l(S, z)$; wage rate $w(S)$ and aggregate labor $L(S)$; and the worker value functions $W(S, z, \delta)$, $W^S(S, z)$ such that:

1. Taking as given the government policies, a worker's migration choice $M(S, z, \delta)$, consumption $c(S, z)$, labor supply $l(S, z)$ and value functions $W(S, z, \delta)$, $W^S(S, z)$ solve the worker's problem (4).

2. Taking as given the worker's choices, the government's choices of borrowing $B'(B, A, \Phi')$, tax system $\{\tau(B, A, \Phi'), \lambda(B, A, \Phi')\}$, default set $D(B, A, \Phi')$ and its value functions $V(B, A, \Phi')$, $V^c(B, A, \Phi')$, and $V^d(A, \Phi')$ solve the government's problem (8).

3. Government bond price schedule (13) reflects the government default probability and satisfies the external lenders' break-even condition.

4. Consistency. Future government decision rules $H_B = B''(B', A', \Phi')$, $H_\mu = \mu'(B', A', \Phi')$, $H_\lambda = \lambda'(B', A', \Phi')$, and $H_D = D'(B', A', \Phi')$ are consistent with the government policies. Future distribution of workers $H_\Phi(S) = \Phi'(S')$ is consistent with the workers' migration decision rules.

5. Labor market clears: $L(S) = \int_\Phi z_i \ell_i(S, z_i) di$.

3.4 Model mechanism

When the government makes policies, it internalizes that workers decide their labor supply based on policies and can also migrate. Here I explain how these considerations change government policies and how income inequality plays a role in shaping government policies.

Consider a one-period version of the model for now; the advantage is that it has analytical solutions. Assume the government has exogenous debt stock B_0. The government chooses the tax system and whether to default on debt B_0. Given the government tax system, the workers choose labor supply and consumption.

There are two types of workers with an equal mass of unity.[11] Let $z_L = \bar{z} - \sigma_z$ denote labor productivity for workers with type L, and $z_H = \bar{z} + \sigma_z$ denote labor productivity for workers with type H, where $0 < \sigma_z < \bar{z}$. Thus, σ_z measures labor productivity heterogeneity

[11] Note that this is a one-period version of the model. After analyzing the endogenous labor supply and consumption choices, we will focus on the migration choice and its impact on government policies.

without changing the average labor productivity level in this economy. Higher σ_z brings higher income inequality.

Assume worker's utility function is $u(c, \ell) = \log c - \frac{\ell^{1+\gamma}}{1+\gamma}$. Under the logarithmic utility, we can obtain closed-form solutions for optimal labor choices and use the solutions to establish important properties relating tax progressivity and default risk.[12] The optimal labor and consumption choices for workers are:

$$\ell_L = (1-\tau)^{\frac{1}{1+\gamma}}, \quad \ell_H = (1-\tau)^{\frac{1}{1+\gamma}}, \tag{14}$$

$$c_L = \lambda(wz_L\ell_L)^{1-\tau}, \quad c_H = \lambda(wz_H\ell_H)^{1-\tau}, \tag{15}$$

where λ and τ are determined by the government. The functional form for labor supply (14) indicates that high tax progressivity τ discourages labor supply.[13] Note that with logarithmic utility, the tax level parameter λ has no impact on labor supply.

If the government decides to repay B_0, it collects taxes to finance the debt repayment. Assume equal weights (0.5 for each type of worker) in the government social welfare function. The repayment value is given by:

$$V^c(B_0, A) = \max_{\tau,\lambda}\{0.5u(c_L, \ell_L) + 0.5u(c_H, \ell_H)\} \tag{16}$$

subject to the budget constraint:

$$T_L + T_H = B_0, \tag{17}$$

where $T_L = wz_L\ell_L - \lambda(wz_L\ell_L)^{1-\tau}$ and $T_H = wz_H\ell_H - \lambda(wz_H\ell_H)^{1-\tau}$ are the taxes (transfers, if negative) collected from workers of type L and type H, respectively. Because the government budget constraint must be satisfied, the government in effect chooses τ and then λ is pinned down by the budget constraint:

$$\lambda = \frac{wz_L\ell_L + wz_H\ell_H - B_0}{(wz_L\ell_L)^{1-\tau} + (wz_H\ell_H)^{1-\tau}}. \tag{18}$$

If the government decides to default, there is no repayment of the outstanding debt. The government chooses the tax policy $\{\tau^d, \lambda^d\}$ to maximize the social welfare. The superscript

[12] Online Appendix derives the optimal choices of labor supply under constant relative risk aversion (CRRA) utility and shows that the main results stay unchanged.

[13] With the logarithmic utility, high tax progressivity discourages labor supply equally for the low-income and the high-income. With more general CRRA utility, high tax progressivity still discourages labor supply, but disproportionately for different workers.

d denotes the variables under government default. The defaulting value is given by:

$$V^d(A) = \max_{\tau^d, \lambda^d} \{0.5u(c^d_L, \ell^d_L) + 0.5u(c^d_H, \ell^d_H)\} \tag{19}$$

subject to the budget constraint:

$$T^d_L + T^d_H = 0. \tag{20}$$

The budget constraint (20) shows that without debt payment, the government taxes purely for redistribution. Denote $\alpha \equiv (z_L^{1-\tau})/(z_L^{1-\tau} + z_H^{1-\tau})$ and $\alpha^d \equiv (z_L^{1-\tau^d})/(z_L^{1-\tau^d} + z_H^{1-\tau^d})$. After applying the assumed utility functional form, substituting the budget constraints and optimal conditions, the government's payoff under repayment (16) can be rewritten as:

$$V^c(B_0, A) = \max_{\tau} \Big\{ \underbrace{\log\left(A\bar{z}\ell(\tau) - B_0\right)}_{\text{consumption}} - \underbrace{\frac{1-\tau}{1+\gamma}}_{\text{disutility from working}} + \underbrace{\frac{1}{2}\log[\alpha(1-\alpha)]}_{\text{redistribution}} \Big\}. \tag{21}$$

Each term of the value function has an economic interpretation and captures one of the forces determining the optimal tax progressivity τ^*. The first component $\log(A\bar{z}\ell(\tau) - B_0)$ represents the total consumption. High tax progressivity discourages labor supply and thus decreases the total output and consumption. Thus, the first term of (21) is *decreasing* in τ.[14] The second term $\frac{1-\tau}{1+\gamma}$ shows the disutility from working. Higher tax progressivity discourages labor supply, thus brings lower disutility from working. Thus, the second term, together with the negative sign, is *increasing* in τ. The first two terms show the tradeoff between consumption and leisure: high tax progressivity τ discourages labor supply, lowers consumption, but reduces disutility from working.

With redistribution incentives, high tax progressivity τ brings extra benefit shown as the third term in (21). When $\tau = 1$, which implies $\alpha \equiv (z_L^{1-\tau})/(z_L^{1-\tau} + z_H^{1-\tau}) = 1/2$, there is highest welfare from redistribution. The optimal tax progressivty τ^* is determined by equaling the marginal cost and the marginal benefit of increasing τ.

Debt and tax progressivity. When the outstanding debt B_0 is high, the marginal cost of increasing tax progressivity τ is high, leading to a less progressive tax in equilibrium. Intuitively, the government internalizes that a less progressive tax encourages labor supply and makes it easier to finance debt repayment. When the government has a large debt to

[14] The derivations for monotonicity are straightforward and are provided in the Online Appendix.

repay, it adopts a less progressive tax.[15]

Incentives to default. Similar to the repayment value function decomposition, we can decompose the defaulting value function into three terms:

$$V^d(A^d) = \max_{\tau} \Big\{ \underbrace{\log\left(A^d \bar{z}\ell(\tau)\right)}_{\text{consumption}} - \underbrace{\frac{1-\tau}{1+\gamma}}_{\text{disutility from working}} + \underbrace{\frac{1}{2}\log[\alpha(1-\alpha)]}_{\text{redistribution}} \Big\}, \tag{22}$$

where A^d is lower than A, but there is no debt repayment. The government is facing a similar tradeoff when choosing the tax progressivity: higher tax progressivity distorts labor, lower consumption, but reduces disutility from working and increases welfare from redistribution. Comparing repayment value (21) and defaulting value (22), we can find that the marginal cost of high τ on consumption is higher with debt repayment B_0, while the marginal benefits of high τ are the same under repayment and default. Thus, the optimal tax progressivity τ^* is higher under default. We can also see this property by deriving the first-order condition with respect to tax progressivity τ. Formally, the optimal tax progressivity τ satisfies the first-order condition:

$$\frac{1}{2}\frac{(z_H^{1-\tau} - z_L^{1-\tau})(\ln z_H - \ln z_L)}{z_L^{1-\tau} + z_H^{1-\tau}} + \frac{1}{1+\gamma} = \frac{\bar{z}\frac{1}{1+\gamma}(1-\tau)^{\frac{1}{1+\gamma}-1}}{\bar{z}(1-\tau)^{\frac{1}{1+\gamma}} - \frac{B_0}{A}}, \tag{23}$$

where $\frac{B_0}{A} > 0$. The left-hand side of (23) is a decreasing function of τ and the right-hand side of (23) is increasing in τ. When government defaults, the debt B_0 is wiped out, and the aggregate producitivity A is reduced to A^d. The left-hand side of (23) keeps unchanged, and the right-hand side of (23) is decreased because $\frac{B_0}{A} > 0$. This leads to a higher τ^*. In other words, when government chooses to default, it can achieve a higher equilibrium tax progressivity.

Debt repayment constitutes a force toward lower tax progressivity. To repay the debt, the government has to encourage labor supply to finance the debt repayment. By defaulting on its debt, the government can avoid this force and implement a more progressive tax. In standard sovereign default models, when making default/repayment decisions, the

[15] If the government debt is non-defaultable and we reinterpret the debt repayment as government spending, this relation between debt and tax progressivity echoes a remarkable finding in the optimal taxation literature. The finding says that government spending constitutes a force toward a less progressive tax because the planner internalizes that a less progressive tax encourages labor supply and makes it easier to finance expenditure (Heathcote, Storesletten, and Violante (2017)).

government weighs the benefit of not paying and the costs of productivity losses and temporary financial autarky. With endogenous taxation, the government has another incentive to default: implementing a more progressive tax to achieve more redistribution.

Effect of inequality. The inequality level is the key determinant of optimal government policies when the government faces the tradeoff between debt repayment and redistribution. In a more unequal economy, the gap between z_H and z_L widens, which increases the redistribution benefit $\frac{1}{2}\log[\alpha(1-\alpha)]$. Thus, with large inequality, the government is more likely to choose default to achieve more redistribution.

We can also see this property by exploring the first-order condition (23) and then deriving the default set. Higher inequality means a larger gap between z_H and z_L. With higher inequality, the left-hand side of (23) increases, while the right-hand side does not change with inequality. Thus, a higher inequality results in higher optimal tax progressivity. Further, the default set is larger under higher inequality, for which the proof is in the Online Appendix.

Effect of migration. The one-period version of the model omit migration because migration is an intertemporal choice that affects the future. Nevertheless, we can illustrate the mechanism by revisiting the recursive problem. Recall that the government chooses $\{B', \tau, \lambda\}$ to maximize its value:

$$V^c(B, A, \Phi') = \max_{B', \tau, \lambda} \{ \int u(c_i, \ell_i)\omega_i di + \beta \mathbb{E} V(B', A', \Phi'') \},$$

subject to the budget constraint:

$$B = \int_{\Phi'} T_i(y_i) di + q(B', A, \Phi')B'.$$

With inequality, the government chooses an optimal set of policies, including a more progressive tax than without inequality. A more progressive tax discourages labor, reduces after-tax income and consumption, and increases emigration. Emigration changes the next-period distribution of workers Φ'. Worker distribution Φ' enters into the government's problem in two ways. First, it affects the tax base, shown as the first term at the right-hand side of government budget constraint. Second, it affects the government bond price $q(B', A, \Phi')$ by affecting future default risk. The emigration of workers, especially the high-income workers, lowers the government's future repayment capacity and lowers the bond price (pushes up the government spreads).

3.5 Transformed problem

The government's problem is not stationary with the permanent change in population. Here I detrend the model by population to obtain a stationary model in per-capita terms.[16] Denote the total population before migration choices is N, then $b = B/N$ is the per-capita government bond. Similarly, the aggregate variables in per-capita terms will be denoted by lower case letters.

With two types of workers (z_L, z_H), the distribution Φ can be represented by the fraction of workers with z_L. Denote the fraction of z_L workers as $f = N_L/N$, where $N = N_L + N_H$, N_L is the population with labor productivity z_L and N_H is the population with labor productivity z_H. Let the aggregate state be $s = (b, A, f, aut)$.

The value of a worker is given by $w(s, z, \delta) = \max\{w^s(s, z), w^m - \delta\}$. After the migration choices, the population of workers with z_i becomes N_i' ($i = L, H$). Denote the growth rate of the population with z_i as $g_i(s) = N_i'/N_i = e^{-\zeta(z_i)(w^m - w^s(s, z_i))}$ ($i = L, H$). The second equal sign comes from the exponential distribution for migration cost δ.

The growth rate of the total population is:

$$\frac{N'}{N} = \frac{N_L' + N_H'}{N_L + N_H} = g_L(s)\, f + g_H(s)\, (1 - f),$$

which is a weighted average of the growth rate of the population with z_L and z_H.

The fraction of workers with z_L after the migration choices is:

$$f' = \frac{N_L'}{N'} = \frac{N_L'}{N_L}\, \frac{N_L}{N}\, \frac{N}{N'} = \frac{g_L(s)\, f}{g_L(s)\, f + g_H(s)\, (1 - f)}.$$

Also, note that

$$\frac{B'}{N} = \frac{B'}{N'}\, \frac{N'}{N} = b'\, \frac{N'}{N} = b'\, [g_L(s)\, f + g_H(s)\, (1 - f)].$$

Taking as given the growth rate of the population $g_i(s)$, the government chooses whether to repay or default depending on the per-capita value of repayment $v^c(b, A, f')$ and de-

[16] I prove the equivalence of the transformed problem and the original problem in the Online Appendix.

faulting $v^d(A, f')$:

$$v(b, A, f') = \max\{v^c(b, A, f'), v^d(A, f')\}.$$

Let the default decision be $d(b, A, f') = 1$ if $v^c(b, A, f') < v^d(A, f')$. The repayment value is:

$$\begin{aligned} v^c(b, A, f') = \max_{b', \tau, \lambda} \{ & g_L\, f\, u(c_L, l_L)\omega_L + g_H\,(1-f)\, u(c_H, l_H)\omega_H \\ & + \beta\, [g_L\, f + g_H\,(1-f)]\, \mathbb{E} v(b', A', f'')\}, \end{aligned} \tag{24}$$

subject to the budget constraint:

$$b \leq g_L\, f\,(y_L - c_L) + g_H\,(1-f)\,(y_H - c_H) + [g_L\, f + g_H\,(1-f)]\, q(b', A, f')b',$$

where the bond price $q(b', A, f') = \frac{1}{1+r}\mathbb{E}[1 - d(b', A', f'')]$. The future fraction of workers with z_L is given by $f'' = \frac{g_L(s')\, f'}{g_L(s')\, f' + g_H(s')\,(1-f')}$, where g_L and g_H are consistent with workers' optimal migration choices.

The defaulting value is:

$$\begin{aligned} v^d(A, f') = \max_{\tau, \lambda} \{ & g_L\, f\, u(c^d_L, l^d_L)\omega_L + g_H\,(1-f)\, u(c^d_H, l^d_H)\omega_H \\ & + \beta\, [g_L\, f + g_H\,(1-f)]\, [\theta \mathbb{E} v(0, A', f''_{aut=0}) + (1-\theta)\mathbb{E} v^d(A', f''_{aut=1})]\}, \end{aligned} \tag{25}$$

subject to the budget constraint:

$$0 \leq g_L\, f\,(y_L - c_L) + g_H\,(1-f)\,(y_H - c_H),$$

where $f''_{aut=0} = \frac{g_L(0, A', f', aut=0)\, f'}{g_L(0, A', f', aut=0)\, f' + g_H(0, A', f', aut=0)\,(1-f')}$ denotes future fraction of workers with z_L when the government comes back to the financial market and $f''_{aut=1} = \frac{g_L(0, A', f', aut=1)\, f'}{g_L(0, A', f', aut=1)\, f' + g_H(0, A', f', aut=1)\,(1-f')}$ denotes f'' when the government is still in financial autarky.

3.6 Discussion

Before moving forward, I discuss some assumptions in the model. In the model, the government borrows to smooth consumption, while workers do not borrow, although they make self-interested migration decisions.[17] The restriction is motivated mostly by tractability because my model's numerical solution with worker asset as an extra individual state variable and worker asset distribution as an extra aggregate state variable, while feasible, is substantially more involved. Besides, in the data, many households hold little wealth. In their Panel Study of Income Dynamics (PSID) sample, Aguiar, Bils, and Boar (2020) estimates that an average of 40.2% of the households are hand-to-mouth.[18] However, it is useful to emphasize that a modification with worker wealth would not alter the main results with worker income—because the government also has incentives to reduce wealth inequality with progressive taxation.

The model features external government debt. Applying to the state government case, it means that the government borrows from other states. Although there is no good source to know the exact holders of state government debt, we can infer from the ones that defaulted in history. When the state of Arkansas defaulted in 1933, 95 million out of 146 million (65%) of all debt are held by creditors from New England and Middle Atlantic, and the else is held by creditors from Midwest and South. Thus, for Arkansas at that time, the holding share from other states is undoubtedly more than 65%.[19] An extension of this model would be including internal government debt where the workers can also hold government debt. When the government also borrows internally, the wealthy workers hold a large fraction of government debt. When government defaults, it defaults on all debt. Thus the wealthier workers are hurt more. In that case, the redistribution effect from default is intensified.

Finally, the model assumes Heathcote, Storesletten, and Violante (2017) (HSV) tax function. It is important to emphasize, however, that the main results still hold without assuming the HSV tax function. An alternative tax regime such as a linear tax function with deductions and transfers for certain income levels can also generate the same tax rates for different workers as in the current model. The advantage of the HSV tax function is that it provides a parsimonious way to capture tax progressivity.

[17] In the sovereign default literature, many assume that only the government can borrow. The government then returns all proceeds to the workers. An alternative setting is that the workers can also invest, borrow and default. In this case, if the government imposes taxes or subsidies to domestic investment and capital flows due to pecuniary externality, the allocations in this alternative setting are the same as those that assume only the government can borrow.

[18] They treat households with low net worth or low liquid wealth as hand-to-mouth.

[19] The partition of the geographic regions of the United States is as follows. There are four regions: Northeast (with divisions of New England and Middle Atlantic), Midwest, South, and West. Arkansas is within the South.

4 Quantitative Analysis

In this section, I evaluate the quantitative properties of the model by taking the model to U.S. state-level data. After parameterizing the model, I study the quantitative role of income inequality and its interactions with migration in determining government spreads. I also study the role of inequality and migration during recessions. I then explore alternative government redistribution preferences and the elasticities of labor distortions.

4.1 Parameterization and moments

The model is in annual frequency. The aggregate productivity A follows a first-order autoregressive process: $\log(A_t) = \rho \log(A_{t-1}) + \varepsilon_t$, where ε_t follows a normal distribution of mean zero and standard deviation of σ. If the government defaults, the economy suffers a productivity loss. Following Chatterjee and Eyigungor (2012), the productivity loss takes a quadratic form $A_d = h(A) = A - \max\left\{d_1 A + d_2 A^2, 0\right\}$. The government cares about each type of workers equally ($\omega_i = 0.5$) in the social welfare function.[20]

I parameterize the model to match the key properties of state-level data in the U.S. from 2009-2019.[21] There are two groups of parameters. The first group parameters are assigned, and those in the second group are chosen to match relevant empirical moments jointly. The first group includes $\{r, \gamma, \theta, \rho\}$. The risk-free rate r is 4%. $\gamma = 2$ so that the Frisch elasticity ($1/\gamma$) is 0.5. This value is in line with microeconomic evidence (e.g., survey by Keane (2011)) and estimation by Heathcote, Storesletten, and Violante (2014). The return parameter θ is 0.25, so that defaulting government is excluded from financial markets for four years on average.[22] The persistence of the productivity process ρ is set to be 0.9.

The second group includes eight parameters $\{\sigma, \beta, d_1, d_2, \bar{z}, \sigma_z, \zeta_L, \zeta_H\}$. I choose these parameters to jointly target the following empirical moments: the volatility of GDP 3%, the average and volatility of spreads are 0.83% and 0.4%, the average debt-to-GDP ratio is 0.18, the average Gini index is 0.46, the average state income tax revenue as a share of GDP is

[20] Section 4.4 explores the results with alternative setting by letting the Pareto weights be $\omega_i = z_i^\eta / (\sum_I z_i^\eta)$, where $\eta = 0$ indicates equal weights in the social welfare function.

[21] I focus on quantifying the role of inequality and migration in explaining the variation in government spreads across the U.S. states. The model, however, is more general and can be parameterized to a country and quantify the role of inequality and migration in explaining government spreads for that country.

[22] State government default triggers financial exclusions. For example, after Arkansas defaulted in 1933, large financial centers remained closed to Arkansas for a while. In New York and Pennsylvania, the banks and trusts could not invest in Arkansas bonds until 1944 and not until 1954 for investors in Massachusetts and Connecticut.

1.8%, the average emigration rate of the low-income and the high-income: 4.0% and 2.8%. Even though the parameters are chosen jointly, we can give a heuristic description of how the sample moments included in the estimation inform specific parameters. The volatility of productivity shocks η mainly affects the volatility of GDP and spreads. The discount factor β and two parameters in the productivity loss function, d_1 and d_2, affect mostly the average debt-to-GDP ratio, the average, and volatility of spreads. The average Gini index and the ratio of income tax revenue to GDP provide information for labor productivity parameters $\{\bar{z}, \sigma_z\}$. The parameters in the migration cost distribution for the low-income and the high-income $\{\zeta_L, \zeta_H\}$ are estimated to match the respective average emigration rate in the Internal Revenue Service (IRS) Migration Dataset.[23] Table 4 reports the moments in the model and the data.

Table 3: Parameters values

Risk-free rate	r	4%
1/Frisch elasticity	γ	2
Return probability	θ	0.25
Productivity persistence	ρ	0.9
Productivity volatility	σ	0.02
Discount factor	β	0.87
Productivity loss	d_1	-0.4
	d_2	0.475
Labor heterogeneity	$\bar{z}$	0.45
	σ_z	0.414
Migration cost distribution	ζ_L	0.0027
	ζ_H	0.0044

4.2 Quantitative effects of inequality and migration

I focus on the effect of inequality on government spreads in a context where workers have labor mobility. As shown in the theoretical model, because government internalizes that

[23]Low-income is defined as income lower than the median, and high-income is defined as income higher than the median. The interstate migration data produced by IRS do not include households that do not file tax returns, thus missing 13% of the population. However, it is quite precise because they are not based on survey data, such as the migration data produced by U.S. Census Bureau. The emigration rates used in the calibration are the data in 2016.

Table 4: Moments in data and model

	Data	Model
Std. GDP	0.03	0.04
Avg. spread (%)	0.83	0.81
Std. spread (%)	0.40	0.61
Avg. debt-to-GDP	0.18	0.19
Gini index	0.46	0.46
Avg. income tax revenue/GDP (%)	1.8	1.35
Avg. emigration rate of low-income (%)	4.0	4.0
Avg. emigration rate of high-income (%)	2.8	2.8

Note: GDP in the table refers to per capita GDP.

workers decide on their labor supply and can also migrate based on government policies, the government faces a tradeoff between redistribution and debt repayment. Repaying debt is a force toward lower redistribution.

The magnitude that inequality affects government default risk (and thus government spreads) depends on the magnitude of labor distortions. The *intensive* margin of labor distortion depends on Frisch elasticity. With a more elastic labor supply, the ability to increase tax progressivity is lower, leading to a larger effect of inequality on government spreads.[24] The *extensive* margin of labor distortion depends on labor mobility. The impact of inequality on government default risk is lower if people are hard to move away even though there is a very progressive tax.

To explore the quantitative role of inequality on government spreads, I compare the benchmark model with a reference model with no inequality (denoted as *no-inequality*). To explore the role of migration, I further shut down labor mobility to generate a reference model with no inequality and no labor mobility (denoted as *no-inequality-no-migration*).

In the no-inequality model, the labor productivity is the same for workers ($\sigma_z = 0$). In the no-inequality-no-migration model, $\sigma_z = 0$ and workers are not allowed to migrate. The no-inequality-no-migration model is similar to a canonical model in the sovereign default literature. Both reference models share the same parameter values as the benchmark. For each model, I simulate 3000 paths for 500 periods, then drop the first 100 periods to eliminate the influence of the arbitrary (reasonable though) choice of the initial guesses. I then

[24]Online Appendix tests for different Frisch elasticities.

take the average of government spreads across the paths conditional on the government not defaulting.

We now compare the government spreads generated in the benchmark model and reference models. In the benchmark, the average government spread is 0.81 percentage points. In the no-inequality model, the average spread is 0.62 percentage points. The average spread is even smaller—0.54 percentage points—in the no-inequality-no-migration model. Compared with the benchmark model, inequality accounts for 23% (= $(0.81 - 0.62)/0.81$) of the government spreads. Income inequality and its interaction with migration account for one-third (= $(0.81 - 0.54)/0.81$) of the government spreads.

4.3 Effects in a recession

To explore the effects of income inequality and migration on government spreads during a recession, I now analyze the impulse response functions (IRFs) of government tax and spreads to a negative productivity shock. I simulate 3000 paths for the model for 500 periods. From periods 1 to 400, the aggregate productivity shock follows its underlying Markov chain. In period 401, there is a 5 percent negative productivity shock. From period 401 on, the productivity shocks follow the conditional Markov process. The impulse responses plot the average, across the 3000 paths, of the variables conditional on the government not defaulting.

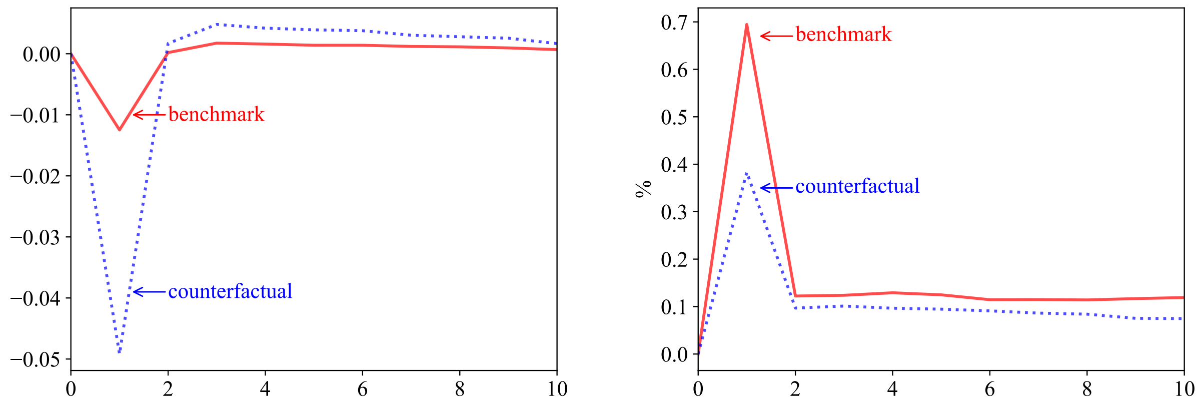
Figure 2 plots the IRFs for the benchmark model and the counterfactual case with no income inequality and labor mobility from period 400 to 410 (period 0 to 10 in the figure). Panel (a) plots for τ in the HSV tax/transfer function, and Panel (b) plots for government spreads. The solid lines are for the benchmark model, and the dotted lines are for the counterfactual case. I normalize each series by its value in period 0.[25]

When there is a bad shock, government decreases tax progressivity τ to encourage labor supply. In the benchmark model, the government only decreases tax progressivity by 0.012, because the government values the redistribution benefit from a progressive tax. While in the counterfactual model, the government could decrease tax progressivity by 0.05.[26] Although government decreases tax progressivity, spreads still go up (Panel (b)). This is because the productivity shock is negative and persistent. Lower productivity increases

[25]For example, the value for period 1 plots for the value in period 1 minus the value in period 0.

[26]Note that taxation in the benchmark model has two purposes. One is income redistribution, and another is debt repayment. Thus, in the counterfactual case where there is no income inequality, the government still imposes taxes and decreases τ to increase labor supply.

the probability that the government will default. The spreads rise to compensate for such default risk. In the counterfactual model, the spreads increase by 0.38 percentage points. For the benchmark economy, since the government cannot decrease tax progressivity to stimulate labor supply, as shown in Panel (a), the spreads increase by 0.7 percentage points.



(a) Tax τ (b) Spreads

Figure 2: IRFs to a decline in productivity: role of inequality and migration

Note: Panel (a) and (b) plot for the responses of tax τ and spreads when there is a decline in productivity in period 1. The solid lines plot for the benchmark model and the dotted lines plot for a counterfactual model with no income inequality and labor mobility.

4.4 Redistribution preference

Empirical evidence shows that governments with stronger redistribution preferences are more likely to have higher spreads. Here we explore the effects of redistribution preferences in the model by varying the Pareto weights in the government social welfare function. Let the Pareto weights be $\omega_i = z_i^\eta / (\sum_I z_i^\eta)$, where $\eta = 0$ corresponds to equal weights in the social welfare function as in the benchmark model. Higher η represents a lower redistribution preference.

Table 5 compares the statistics of model moments under different Pareto weights. With higher η, the government assigns lower weights on the low-income workers and imposes a less progressive tax (lower τ). A less progressive tax encourages labor supply and reduces the emigration rate of the high-income workers. The emigration rate of the low-income workers, however, increases. With a higher labor supply and less emigration of the high-income workers, the total output is larger. With a larger tax base, the government default risk reduces, and the government spread declines.

Table 5: Experiments with Pareto weights

	τ	labor supply	emig. rate ($i = L$)	emig. rate ($i = H$)	spread
$\eta = 0$	0.59	0.74	4.0%	2.8%	0.81%
$\eta = 0.4$	0.41	0.83	4.6%	2.4%	0.79%
$\eta = 0.7$	0.18	0.93	5.5%	2.1%	0.62%

Note: This table reports the results with Pareto weights. $\eta = 0$ is the benchmark model case. Higher η shows smaller redistribution preference from the government. The numbers in the table are the averages from model simulations.

5 Conclusion

Income inequality affects fiscal policies of taxation, government borrowings, and default. Empirical evidence shows that income inequality and migration play an important role in determining sovereign spreads, both across countries and U.S. states. This paper builds a sovereign default model with income inequality, migration, and endogenous taxation to capture and explain the interactions between tax, debt, and income inequality.

With high inequality and redistribution preference, the government imposes progressive taxation, which distorts labor supply and increases the high-income workers' emigration, eroding the tax base. Facing a tradeoff between redistribution and low spreads, the government is more likely to choose redistribution over low spreads in an economy where inequality is a serious concern. Quantitatively, income inequality and its interactions with migration explain one-third of the observed variation in debt spreads across the U.S. states.

The standard sovereign default literature usually assumes homogeneous agents and lump-sum transfers. Thus it is silent on the government's distributional incentives and their impact on government policies. Moreover, there are no distortions under lump-sum transfers, and default only involves wealth effect on the domestic agents. By introducing heterogeneous workers and endogenous taxation, this paper provides a framework to consider inequality and a rich set of fiscal policies, including taxation, government borrowings, and default.

Fruitful research can be done along this path. For example, we can use the framework to evaluate welfare gain or loss of austerity plans during a debt crisis. The proponents of austerity argue that by reducing the government's transfer, the country has a larger capacity to repay its debt, reducing sovereign spreads and alleviating the debt crisis. On the other hand, the opponents of austerity argue that austerity hurts low-income workers and reduces equality. An interesting future step is to address these two views with the model framework.

Moreover, the connection between the sovereign debt crisis and heterogeneous households is a major open question for macroeconomics. This paper helps to understand how income inequality constrains government policies, including taxation, borrowing, and default decisions. An important area for future work is understanding the details and channels for financial and fiscal links between sovereign debt crises and the labor market.

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