Inequality, Taxation, and Sovereign Default Risk

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Abstract

Income inequality and worker migration significantly affect sovereign default risk. Governments often impose progressive taxes to reduce inequality, which redistribute income but discourage labor supply and induce emigration. Reduced labor supply and a smaller high-income workforce erode the current and future tax base, reducing 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 taxation and debt, considering its impact on workers' labor and migration decisions. Income inequality accounts for one-fifth of the average U.S. state government spread.

Keywords: Sovereign default risk, income inequality, migration, tax progressivity
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What determines government capacity to repay debt? Previous sovereign default literature generally focuses on governments making default decisions based on aggregates such as total debt and GDP. However, this does not provide a complete picture of real-world sovereign debt decisions. In addition to issuing debt, governments have other crucial responsibilities that may conflict with a repayment goal. For example, a distortionary tax is widely used to reduce income inequality, but it is not ideal for increasing GDP. Moreover, when government increases taxes to repay debt, workers change their behavior. In particular, a highly progressive tax may lead to emigration of high-income workers. These examples of redistribution motives and endogenous responses of workers affect government default risk. A standard sovereign default model, however, is silent on such conflicting priorities of government. This paper incorporates government redistributive motives and endogenous worker choices into a sovereign default model.

I first document some stylized facts on income inequality, migration, and government spreads using U.S. state-level data. U.S. states are sovereigns—they can formulate and implement tax systems, issue bonds, and may default on their bonds. The magnitudes of state government spreads are comparable with those of European countries, and there are also large variations in government spreads across states. Using U.S. state-level data, I find that increasing the Gini index by one standard deviation is associated with the state government spread increasing by 15%-20% from the mean. Migration is also a critical factor for government spreads. Using U.S. state-level data, I find that high government spreads are associated with labor outflows, consistent with findings during the European debt crisis (Alessandria et al. (2020)).

I develop a theory of sovereign default with income inequality and migration. By introducing these elements, this paper provides a framework to study defaultable government debt and progressive taxation in a context where workers are heterogeneous and can migrate. In the model, workers are heterogeneous in their labor productivity. They supply labor elastically and consume after-tax labor income. They can also migrate by paying an idiosyncratic migration cost. Thus, labor is elastic along both the intensive margin—through labor supply choices—and the extensive margin—through migration. 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 from high-income to low-income workers but reduces labor supply and increases high-income emigration, eroding the tax base and the government's ability to repay 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.

To illustrate the mechanism, I analyze a one-period version of the model with intuitive analytical solutions. Consider a government with some exogenous debt choosing a tax scheme and whether to default on its debt. The optimal tax progressivity is determined by equating the marginal cost and marginal benefit of increasing tax progressivity. The marginal cost of increasing tax progressivity is lower output and thus lower consumption. The marginal benefits of increasing tax progressivity are less disutility from working and more importantly, greater redistribution benefits. When the outstanding debt is high, the marginal cost of increasing tax progressivity 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. In other words, debt repayment forces a lower degree of tax progressivity. By defaulting on its debt, the government can avoid this force and adopt a more progressive tax.

In an economy with significant inequality, the government is more likely to default to achieve higher tax progressivity and more redistribution. With worker migration, the government also internalizes the impact of migration on its maximization problem. Migration affects the tax base and government bond price by influencing the future tax base and default risk. The emigration of high-income workers lowers the government repayment capacity and increases government spreads.

The full quantitative model provides a tool to study the interactions between the distribution of income, taxation, borrowing, and default risk, which applies to both national and sub-national governments. As an application of the model, I parametrize the full model using U.S. state-level data. An advantage of using U.S. state-level data is that the measures for income inequality, tax progressivity, and migration flows are very comparable across the states and are consistent over time. I parameterize the model to match key properties of state-level data in the U.S. from 2000 to 2019.

To quantify the role of income inequality and migration, I compare my model, *benchmark*, against two reference models. In the first reference model, *no-inequality*, I shut down inequality. The comparison of this reference model and the benchmark model highlights that inequality is a force towards higher government spreads. Inequality accounts for about one-fifth of the average government spread in the benchmark model. In the second reference model, *no-inequality-no-migration*, I further shut down labor mobility. The average spread is further reduced. The second reference model is similar to a canonical sovereign default model but with endogenous taxation.

Income inequality and its interaction with migration amplify a bad productivity shock by limiting government's capacity to adjust taxes and increasing government spreads. Following a one standard deviation negative productivity shock, the government spread increases by 0.5 percentage points (pp) in the benchmark model, while only increasing by 0.14 pp in the no-inequality model and 0.06 pp in the no-inequality-no-migration model. Facing an adverse productivity shock, a government has incentives to lower tax progressivity to encourage labor supply and reduce high-income workforce outflows. However, lower tax progressivity conflicts with government redistributive motives. This tension between redistribution and sovereign spreads was present during the recent European sovereign debt crisis. For example, the Greek government adopted rather regressive austerity measures (Matsaganis and Leventi (2014)), which raised concerns over the fiscal burden on low-income households.

To show that the model can reflect the cross-sectional variations as in the data, I vary the degree of inequality in the model to match the observed Gini for each state. I then simulate the models with different inequality levels to generate a simulated state-year panel for 50 states. Using the model-simulated panel, I run the same regression as in the data. The positive coefficients for Gini show that high income inequality is positively associated with high spreads, consistent with the empirical results. The model also generates consistent correlations related to GDP, spreads, net migration rate, and tax progressivity as in the data.

Further empirical evidence on government redistribution preferences supports the model mechanism. In the model, with a greater preference for redistribution, the government is more likely to choose more redistribution over lower spreads when facing the *redistribution–spreads* tradeoff. To test this, I use political party control of state legislatures to proxy for the redistribution preferences of state governments. The results show that the states with Democratic-controlled legislatures are more likely to have higher government spreads than those with Republican-controlled legislatures. Stronger redistributive motives among Democratic-controlled legislatures, i.e., less tolerance for income inequality, tilt the *redistribution–spreads* tradeoff towards more redistribution and thus higher spreads.

The model builds on the sovereign default models pioneered by Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), and Arellano (2008). Recent literature had paid attention to distortionary taxation with sovereign default in a closed economy setting (Pouzo and Presno (2022), Karantounias (2019)) or with no redistribution motives (Cuadra et al.

(2010)). D'Erasmo and Mendoza (2016, 2021) focus on the distributional issues of default decisions, where government default has a distributional effect because of 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 combines redistribution, endogenous taxation, and default together, and shows that defaulting on external debt is in fact redistributive because of endogenous progressive taxation.

This paper also contributes to the literature that focuses on inequality, 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 provides further evidence using cross-state data. Theoretically, the literature has improved the understanding of inequality's influence 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 et al. (2019)), and heterogeneous-agent overlapping generation models (Dovis et al. (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 particularly closely related to Ferriere (2015). We share the focus on studying the effect of inequality on sovereign default risk. There are several key differences. First, this paper uses a non-linear tax function where tax progressivity is endogenous while Ferriere (2015) focuses on exogenous tax progressivity quantitatively. The online Appendix provides the case with exogenous tax progressivity and shows that the quantitative results are consistent with Ferriere (2015). However, without endogenous tax progressivity, the government does not internalize the impact of progressivity on labor supply, migration, default risk and the cost of borrowing, thus missing a key channel of inequality affecting sovereign default risk. Second, beyond allowing for elastic labor supply as in Ferriere (2015), this paper introduces migration and investigates the extensive margin of labor distortions to progressive taxation and its impact on default risk. Migration is an empirically important driver of government spreads.

Recent literature has started to study the role of migration on government debt and default risk. Gordon and Guerron-Quintana (2019) study the role of migration in regional borrowing by focusing on municipalities. Alessandria et al. (2020) find that emigration magnified sovereign default risk in Spain, in a model with homogeneous workers. This paper is the first to consider the joint effect of inequality and migration on sovereign default risk.

This paper relates broadly to the literature that focuses on inequality and debt dynamics. Tran-Xuan (2022) shows a positive correlation between pre-tax income inequality and external debt. Azzimonti et al. (2014) show that when rising income inequality is associated with an increase in individual income risk, these higher risks result in more public debt. This paper focuses on government external debt and spreads, and allows the government to default in equilibrium.

Layout. The rest of this paper proceeds as follows. Section 1 describes empirical findings that motivate the theoretical analysis. Section 2 presents the model, defines the equilibrium, and highlights the model mechanism. Section 3 discusses the model's parametrization and quantitative findings. Section 4 concludes. The Online Appendix provides data details, model proofs, solution method, and additional empirical and quantitative results.

1 Empirical Motivation

This section documents empirical relationships between income inequality, migration flows, 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 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 do countries within the Eurozone (Ang and Longstaff (2013)). Arellano et al. (2016) document sharp increases in spreads on government debt in Europe and the U.S. states. Compared with national government spreads, state government spreads have received limited attention.

Beyond filling this gap in the literature, 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 distributional data can be affected by data choices in different countries. Thus, this section mainly focuses on results using U.S. state-level data.[2]

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[1] States are sovereigns and cannot 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.

[2] The Online Appendix provides additional results with cross-country data (Appendix A.7) and more discussions about state government finances (Appendix A.4).

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 for the severity of inequality, reflecting the extent to which the government desires to redistribute. According to the Gini index in 2019, examples for states with relatively high income inequality include New York, Connecticut, California, and Illinois, while Utah, Idaho, South Dakota, and Wisconsin have relatively low income inequality.

Individual income taxes are the major instrument by which state governments redistribute; 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, state marginal income tax rates in California ranged from 1% to 13.3% in 2019, while in North Dakota, they ranged from 1.1% to 2.9%. I use the maximum state income tax rate to measure the progressivity of a state's income tax. With higher inequality, a government tends to impose a more progressive income tax system.[3]

Migration flows. State-to-state migration flow data shows that in 2019, the top three outbound states were Illinois, California, and New Jersey. The top three inbound states were 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 (2023) find that the income-weighted rate of departure amongst top-bracket taxpayers increased by 0.8% in response to the tax hike. 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 linked to state government spreads.

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 an underlying

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[3] In Appendix A.6, using state-level panel data, I demonstrate this positive correlation by performing a regression analysis of tax progressivity on pre-tax inequality, with a vector of control variables and a time fixed effect.

security from a seller. With higher default risk, CDS spreads are correspondingly higher.[4] Advantages of using CDS spreads data are that it provides a more direct measure of a sovereign's default risk than the underlying bonds (Schwert (2017)) and it is with fixed maturity. The downsides are that CDS only exists for a subset of state issuers and did not trade prior to 2008.[5] The average yearly CDS spread ranges widely across the states: from a low of 0.41% for South Carolina to a high of 2.34% for Illinois. The CDS spreads for the states are of similar magnitude as those for European countries.

To include more states and extend the sample before 2009, I also use spreads on bonds issued by state governments to proxy for government default risk. I use municipal bond issuance yields to calculate bond spreads. For municipal bonds, the data cleaning and selection steps follow previous literature such as Novy-Marx and Rauh (2012), Schwert (2017) and Butler and Yi (2022). First, I omit observations that are most likely to contain data errors and restrict the issuers to be state governments. Second, I focus on general obligation bonds that are unsecured by any special-purpose revenue. Third, I include only bonds with fixed coupon rates to accurately calculate bond spreads. In addition, as most municipal bonds are exempt from federal and state taxes, I adjust the state bond yields by a tax-adjustment factor following Schwert (2017).

State bond spreads are calculated as the difference between the tax-adjusted yield of a state government bond and a tax-adjusted synthetic yield, constructed using the corresponding term structure together with the treasury spot rates estimated in Gürkaynak et al. (2007), following the method described in Butler and Yi (2022). More details on the data construction for state government bond spreads can be found in Appendix A.3.

Table 1 provides summary statistics for CDS spreads, government bond spreads, and the Gini index. CDS spreads span 2009 to 2017 for 19 states. Other variables span 2000 to 2019 for 50 states. The mean and standard deviation of the CDS spread data are about 0.86% and 0.63%. For bond spreads, the mean and standard deviation are 0.69% and 0.70%.

To estimate the correlation between income inequality and government default risk, I

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

[5] The spreads on five-year maturity CDS are obtained from Bloomberg. There are 19 states that have CDS data: 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. Although the sample is not comprehensive, it almost doubles the number of states used in Ang and Longstaff (2013).

Table 1: Summary statistics

Variable	Mean	Median	Std. Dev.	1st Perc.	99th Perc.	N
CDS spreads (%)	.858	.671	.634	.259	3.484	157
Bond spreads (%)	.685	.478	.701	-.465	3.268	2811
Gini index	.453	.453	.022	.402	.502	1000

Notes: This table reports summary statistics for the main variables. Units for CDS spreads and bond spreads are in percentage points. CDS spreads are five-year CDS spreads. Bond spreads are constructed by the author. Details of data cleaning and construction can be found in Appendix A.3. CDS spreads data is from 2009 to 2017 and for 19 states. The list of the 19 states can be found in footnote 5. Other data is from 2000 to 2019 and for 50 states.

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 government spreads for state j in year t. $ineq_{j,t-1}$ is income inequality for state j in year $t-1$, and it is proxied for by the state pre-tax Gini index. When calculating the Gini index, household 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, expenditure-to-output ratio, revenue-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 the state House.[6] 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 between states.

Table 2 reports the results for empirical specification (1). For the measure of government spreads, columns (1)-(3) use the average CDS spread in each year, and columns (4)-(7) use state government bond spreads at the issuance level. All regressions include year fixed effects and the standard errors are clustered at the state level.

The positive coefficients for Gini show that high pre-tax income inequality is positively associated with high spreads. The results are robust across different measures of gov-

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[6] "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 coefficients also provide information on the correlation between redistribution preference and government spreads.

ernment spreads. In terms of magnitude, increasing the Gini index by 0.1 (e.g., Utah to Connecticut) is associated with CDS spread increases of about 0.72%-0.78%. This effect is quite large. The average CDS spread in the sample is 0.86%. A one standard deviation (0.022) increase in the Gini index is associated with CDS spread increases of 0.16%-0.17%, which is about a 20% increase from the mean. For the results with bond spreads as measure, a one standard deviation increase in Gini is associated with bond spread increases of 0.09%-0.11%, which is about a 15% increase from the mean.

The results also suggest that states with Democratic-controlled legislatures are more likely to have higher spreads than those with Republican-controlled legislatures. This may reflect strong preferences for income redistribution among Democrats. Stronger redistributive motives, i.e., less 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 and higher indebtedness is associated with higher spreads. Columns (3) and (6) of Table 2 drop observations during the 2008-2009 financial crisis. Column (7) includes the last year average bond spreads as one control variable. The positive correlation between inequality and spreads is robust.

Relation between migration and government spreads. Migration is also a critical factor interacting with government spreads. Alessandria et al. (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 state-level net migration rates and government spreads. The y-axis shows the net migration rates. The x-axis shows government CDS spreads. Each dot represents a state-year observation for high-income workers or low-income workers. The figure shows that the net migration rate is negatively correlated with government spreads.

Table 3 provides summary statistics for immigration, emigration and net migration rates at the state level. The low-income workers has higher rates of both immigration and emigration, while the high-income workers has slightly higher net migration rates. Combining this with Figure 1, we can infer that although the low-income workers on average have higher migration rates, the higher-income workers are more mobile and can move more easily when the current region experiences bad shocks.

In summary, the empirical evidence emphasizes the role of income inequality and migration in shaping government spreads. In the next section, I present a theory of

Table 2: Regression of government spreads on inequality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	7.822*	7.194**	7.213**	4.059**	4.551**	4.829**	4.581**
	(3.791)	(3.057)	(3.156)	(1.808)	(2.090)	(1.837)	(1.801)
Political (="Split")		0.269	0.259		0.084	0.026	0.087
		(0.201)	(0.211)		(0.083)	(0.066)	(0.073)
Political (="Democratic")		0.478*	0.455*		0.136*	0.061	0.095
		(0.251)	(0.259)		(0.077)	(0.067)	(0.067)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster state	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State controls	No	Yes	Yes	No	Yes	Yes	Yes
Include 2008-2009	Yes	Yes	No	Yes	Yes	No	Yes
Spread measure	CDS	CDS	CDS	bond spread	bond spread	bond spread	bond spread
Spread frequency	year	year	year	issuance	issuance	issuance	issuance
N	157	157	147	2706	2412	2091	2250
R^2	0.338	0.473	0.453	0.130	0.143	0.148	0.172

Standard errors in parentheses

* p<.1, ** p<0.05, *** p<0.01

Notes: This table reports regression results of government spreads on inequality for the cross-state sample. All regressions include year fixed effects and the standard errors are clustered at the state level. For the measure of government spreads, column (1)-(3) use the average CDS spread in each year. Using rolling-window averages or the last daily observation in each year does not change the results. Column (4)-(7) use state government bond spreads at the issuance level. Column (3) and (6) drop observations during the 2008-2009 financial crisis. Column (7) includes the last year average bond spreads as one control variable.

Table 3: Summary statistics for migration rates

Variable	Mean	Median	Std. Dev.	1st Perc.	99th Perc.	N
Immigration rate for high-income (%)	2.463	2.294	1.088	.73	5.608	350
Immigration rate for low-income (%)	3.421	3.2	1.309	1.354	7.458	350
Emigration rate for high-income (%)	2.402	2.275	.867	.909	5.242	350
Emigration rate for low-income (%)	3.426	3.159	1.304	1.514	8.706	350
Net migration rate for high-income (%)	.061	-.094	.764	-1.634	2.527	350
Net migration rate for low-income (%)	-.005	-.033	.572	-2.017	1.53	350

Notes: This table reports summary statistics for migration rates by income. Immigration rates are calculated as number of immigrants entering the state in year t divided by the average population in year t and $t-1$. Emigration rates are calculated as number of emigrants leaving the state in year t divided by the average population in year t and $t-1$. Net migration rates are immigration rates minus emigration rates. High-income is defined as individuals whose income is higher than the median. Low-income is defined as income lower than the median. Data is from 2013 to 2019 and for 50 states. Notes that data from 1990 to 2011 does not provide information by income groups. Data source: Internal Revenue Service (IRS) Migration Dataset.

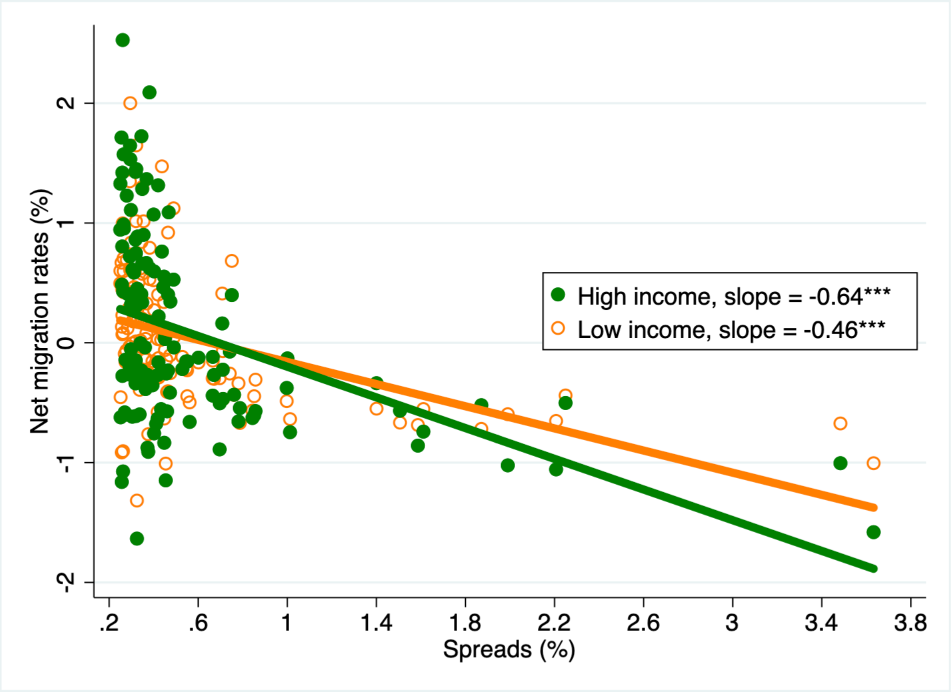

Figure 1: Government spreads and migration

Notes: This figure plots net migration rates and government CDS spreads using U.S. state-level data. Each dot represents a state-year observation for high-income workers or low-income workers. High-income is defined as income higher than the median. Low-income is defined as income lower than the median. Net migration rates are immigration rates minus emigration rates. The negative relationships remain robust when winsorizing data at 1% or 5% levels. Additional figures are provided in Appendix A.5.

inequality, migration, and sovereign default risk.

2 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 workers are heterogeneous in labor productivity z_i, which is a once-and-for-all productivity draw. The government imposes non-linear taxation, issues state-uncontingent bonds, and can default on them. If the government defaults, the economy suffers from an aggregate productivity loss and is temporarily excluded from the credit market. The main departure from the canonical sovereign default model is the introduction of endogenous labor supply and a progressive income tax that aims to reduce income inequality. The endogenous labor supply comes from both labor supply choices and migration decisions.

2.1 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.

Each period, a worker makes a discrete choice to stay or emigrate. The worker migration setup closely follows Alessandria et al. (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.[7] Rather than one constant parameter value, this reflects that the mean and volatility of migration costs for high-income and low-income workers are different.

To allow the model to better capture the data, there is also an exogenous inflow of workers every period. The immigration rate for worker with labor productivity z depends on the aggregate productivity A in a reduced form: $m(A) = \bar{m}(z)e^{(A/\bar{A}-1)}$ where $\bar{A}$ is the average aggregate productivity and $\bar{m}(z)$ is a parameter that depends on labor productivity. This is a reduced-form way to capture the cyclicality of immigration flows and is similar to the approach of Neumeyer and Perri (2005) in modelling risk premiums on international borrowing. With positive $\bar{m}(z)$, a rise in worker inflow occurs during good times. The extent of inflow varies among workers with different income levels, which is captured by $\bar{m}(z)$. Quantitatively, I calibrate $\bar{m}(z)$ to match immigration rates by income.

Let Φ denote the distribution of workers. It is endogenous and time-variant due to the emigration decisions of workers as well as the exogenous inflow of workers.

2.2 Government

The government is benevolent and maximizes a 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.

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

$$T(y) = y - \lambda y^{1-\tau}, \tag{3}$$

where y is labor income and T is net tax revenue at income level y. 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

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

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 after-tax labor income is $\lambda y^{1-\tau}$. 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 $\tau > 0$, $\frac{T'(y)}{T(y)/y} > 1$, the tax system is progressive. A 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. The HSV tax function provides a parsimonious way to capture tax progressivity.

The government can issue state-uncontingent bonds to creditors and can default on them. The creditors recognize that the government may default and set the government bond price to break even in expectation. 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. When government defaults, there is an exogenous cost that reduces aggregate productivity: $A^d = f(A) < A$. The government regains the ability to borrow with probability θ. When forming tax, debt, and default policies, the government will internalize the labor supply and migration decisions of the heterogeneous workers.

2.3 Recursive formulation

Each period the economy starts with a level of government debt B, an aggregate productivity 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 $S = (B, A, \Phi, aut)$. 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). I omit the time subscript t and use x' to denote a 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 the idiosyncratic shocks for migration cost δ and labor productivity z for each worker are observed. Given the aggregate state $S = (B, A, \Phi, aut)$ and idiosyncratic state (z, δ), workers decide whether to emigrate. After the migration decision (and the exogenous inflow of workers), 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 government choices, the staying workers choose labor supply ℓ and consume c. Figure 2 provides a diagram of the model timing.

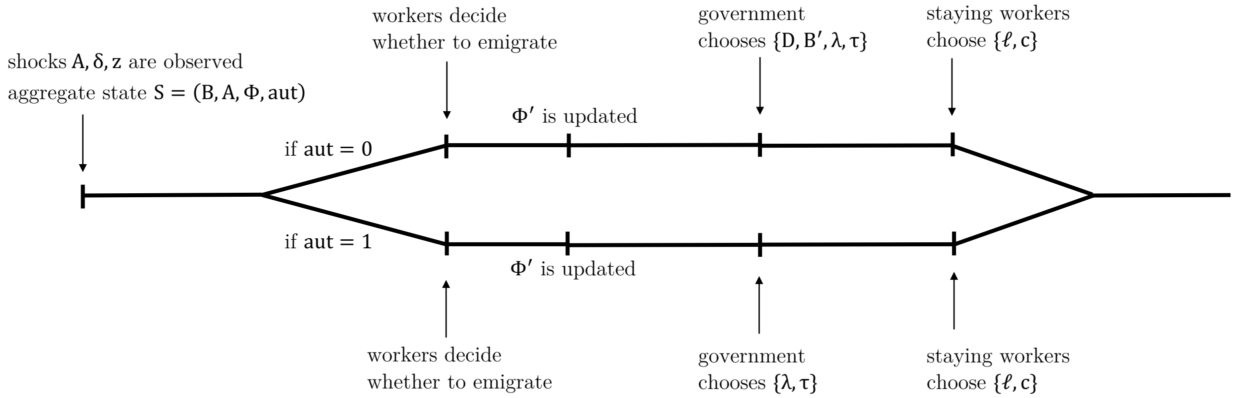

Figure 2: Timing

2.3.1 Worker choices

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 their original location, W^m is the value of emigrating, and δ is the idiosyncratic migration cost. The worker who stays chooses labor supply and consumption to maximize utility. Since the labor productivity z is a once-and-for-all draw, the next period labor productivity $z' = z$. Thus, the staying value $W^s(S, z)$ can be written as:

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

subject to:

$$(1 + \tau_c)c = \lambda y^{1-\tau}, \quad y = wz\ell, \tag{6}$$

$$\lambda = H_\lambda(S), \quad \tau = H_\tau(S), \quad \Phi' = H_\Phi(S),$$

where τ_c is the exogenous sales tax rate[8] and $y = wz\ell$ is pre-tax labor income in which w is the wage rate, z is labor productivity, and ℓ is labor supply. $\lambda y^{1-\tau}$ is the after-tax income. As indicated by the tax/transfer function (3), λ and τ are chosen by the government.

A worker will choose to stay if and only if $W^s(S,z) \geq W^m - \delta$. Let $M(S,z,\delta) = 1$ denote migration (to any other place). As δ follows an exponential distribution, the probability of a worker not emigrating is then given by:

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

2.3.2 Taxation, borrowing, and default

After workers make migration choices, the distribution of workers becomes $\Phi' = H_\Phi(S)$. Then government makes choices. The government is aware that its decisions over taxation, borrowing, and default affect labor supply in the current period and migration decisions in 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. Let $D(B, A, \Phi') = 1$ denote default.

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:

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

subject to the government budget constraint and worker distribution implied by the worker optimal decision rules:

$$B = \int_{\Phi'} T(y_i) di + q(B', A, \Phi')B', \tag{10}$$

$$c_i = \frac{\lambda}{(1+\tau_c)} y_i^{1-\tau},$$

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[8] Including sales tax allows the model to closely match the data because sales tax revenue constitutes a large fraction of state government revenues. In the model, (6) is equivalent to $c \leq \frac{\lambda}{(1+\tau_c)} y^{1-\tau}$, thus the government doesn't distinguish between λ and τ_c. Here I assume τ_c is exogenously given and government chooses λ and τ. In this setting, λ incorporates variations in τ_c.

$$\Phi'' = H_{\Phi'},$$

where $\int_{\Phi'} T(y_i)di = \int_{\Phi'}(y_i - \frac{\lambda}{1+\tau_c} y_i^{1-\tau})di$ is the total tax revenue collected from all staying workers. $q(B', A, \Phi')$ is the bond price, which compensates lenders for the government's future default risk. The budget constraint (10) shows that there are two main purposes for taxation here: to redistribute income and 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:

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

subject to the government budget constraint and worker distribution implied by the workers' optimal decision rules:

$$0 = \int_{\Phi'} T(y_i^d)di, \tag{12}$$

$$c_i^d = \frac{\lambda}{(1+\tau_c)}(y_i^d)^{1-\tau},$$

$$\Phi'' = H_{\Phi'},$$

where $u(c_i^d, \ell_i^d)$ is the utility of worker i when the economy is in financial autarky. With probability θ, the government comes back to the financial market and the future worker distribution is denoted as $\Phi''_{aut=0}$. With probability $1-\theta$, the government is still in financial autarky and the future worker distribution is denoted as $\Phi''_{aut=1}$. When the government defaults, it cannot borrow and does not service its debt. Thus, the only purpose for taxation is to redistribute income, as shown in the budget constraint (12).

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 its bonds. Thus, in equilibrium, the break-even condition implies that the bond price schedule $q(B', A, \Phi')$ satisfies:

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

As in standard sovereign default literature, the bond price depends on the 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, $sp = 1/q(B', A, \Phi') - (1+r)$.

2.3.3 Recursive equilibrium

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

1. Taking as given the government policies, a worker's choices for migration $M(S, z, \delta)$, consumption $c(S, z)$, and labor supply $\ell(S, z)$, along with their value functions $W(S, z, \delta)$ and $W^S(S, z)$, solve the worker's problem (4).
2. Taking as given the worker's choices, the government's choices for borrowing $B'(B, A, \Phi')$, the tax system $\{\tau(B, A, \Phi'), \lambda(B, A, \Phi')\}$, and default $D(B, A, \Phi')$, along with its value functions $V(B, A, \Phi')$, $V^c(B, A, \Phi')$, and $V^d(A, \Phi')$, satisfy the government's budget constraint and solve the government's problem (8).
3. The government bond price schedule (13) reflects the government's default probability and satisfies the external lenders' break-even condition.
4. The wage rate satisfies the following marginal condition: $w(S) = AL(S)/L(S) = A$, where $L(S) = \int_{\Phi} z_i \ell_i(S, z_i) di$.
5. Consistency. The forecasting functions $H_{\lambda}(S)$ and $H_{\tau}(S)$ are consistent with the actual law of motion implied by the optimal decision rules for the government. The future distribution of workers $H_{\Phi}(S)$ is consistent with the actual law of motion implied by the optimal decision rules for the workers.

2.4 Model mechanism

To further explain the tradeoff between redistribution and default that the government faces in the model, we can consider a simplified version of the model with one period. This simplified model allows for intuitive analytical solutions that illustrate the underlying mechanism.

Assume the government has some exogenous debt stock B_0. The government chooses the income tax system and whether to default on its debt B_0. Given the government tax system, the workers choose labor supply and consumption. There is no migration choice in this simplified one-period model.[9]

There are two types of workers with equal unit masses. Let $z_L = \bar{z} - \sigma_z$ denote labor productivity for workers of type L, and $z_H = \bar{z} + \sigma_z$ denote labor productivity for workers of type H, where $0 < \sigma_z < \bar{z}$. Thus, σ_z measures labor productivity heterogeneity without changing average labor productivity in this simplified model. A higher σ_z generates higher income inequality.

Assume workers have utility function $u(c, \ell) = \log c - \frac{\ell^{1+\gamma}}{1+\gamma}$. With logarithmic utility, I can obtain closed-form solutions for optimal labor choices and use the solutions to establish important properties relating tax progressivity and default risk.[10] There is no sales tax in this simple model. The optimal labor and consumption choices for workers are:

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

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

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.[11] 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:

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

subject to the budget constraint:

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

where $T_L = w z_L \ell_L - \lambda (w z_L \ell_L)^{1-\tau}$ and $T_H = w z_H \ell_H - \lambda (w z_H \ell_H)^{1-\tau}$ are the taxes (trans-

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[9] Appendix B.2 analyzes the effect of migration by analyzing the intertemporal Euler equation for the government.

[10] Appendix B.4 derives the optimal labor supply choices under constant relative risk aversion (CRRA) utility and shows that the main results stay unchanged.

[11] With 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.

fers, 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 social welfare. The superscript d denotes the variables in the case of government default. The defaulting value is given by:

$$V^d(A) = \max_{\tau^d, \lambda^d}\{0.5u(c_L^d, \ell_L^d) + 0.5u(c_H^d, \ell_H^d)\} \tag{19}$$

subject to the budget constraint:

$$T_L^d + T_H^d = 0. \tag{20}$$

The budget constraint (20) shows that without debt repayment, 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 functional form for utility, 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 total consumption. High tax progressivity discourages labor supply and thus decreases total output and consumption. Thus, the first term of (21) is *decreasing* in τ.[12] The second term $\frac{1-\tau}{1+\gamma}$ shows the disutility from working. Higher tax progressivity discourages labor supply and thus generates less disutility from working. The second term, including the negative sign, is therefore *increasing* in τ. The first two terms show the tradeoff between consumption and leisure: high tax progressivity τ discourages labor supply and lowers consumption, but reduces disutility from working.

With redistribution incentives, high tax progressivity τ brings extra benefits shown as

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

the third term in (21). When $\tau = 1$, which implies $\alpha \equiv (z_L^{1-\tau})/(z_L^{1-\tau} + z_H^{1-\tau}) = 1/2$, the value of the third term in (21) is the largest. The optimal tax progressivty τ^* is determined by equating the marginal cost and the marginal benefit of increasing τ.

Incentives to default. Similarly 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 degree of tax progressivity: higher tax progressivity distorts labor supply and lowers consumption, but reduces disutility from working and increases welfare from redistribution. Comparing the repayment value (21) and defaulting value (22), the marginal cost of high τ on consumption is increasing with debt repayment B_0, while the marginal benefits of high τ are the same under both 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 productivity A is reduced to A^d. The left-hand side of (23) remains unchanged, and the right-hand side of (23) decreases 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 therefore forces a lower degree of tax progressivity. To repay the debt, the government has to encourage labor supply to finance 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 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.

Debt and tax progressivity. As shown in (23), 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 repay, it adopts a less progressive tax.[13]

Effect of inequality. The level of inequality is the key determinant of optimal government policies. 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 high 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, higher inequality results in higher optimal tax progressivity. Further, the default set is larger under higher inequality, the proof for which is in the Online Appendix.

2.5 Transformed problem

The government's problem is not stationary with permanent changes in population. Here I rewrite the model to obtain a stationary model in per-capita terms. Denote the total population before migration choices as N. Then $b = B/N$ is per-capita government bonds. Similarly, all other 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 $s = (b, A, f, aut)$.

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[13] 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. There, government spending is 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 et al. (2017)).

The value of a worker is given by $W(s,z,\delta) = \max\{W^s(s,z),\ W^m - \delta\}$. After migration, the population of z_i workers becomes N_i' $(i = L, H)$. Denote the growth rate of the population with z_i as $g_i(s) = N_i'/N_i = (1+m_i)e^{-\zeta(z_i)(W^m - W^s(s,z_i))}$. The second equals sign comes from assuming an immigration rate m_i and drawing the emigration cost from an exponential distribution.

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 rates of the populations of types z_L and z_H.

The fraction of z_L workers after migration choices is:

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

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

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

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

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

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 z_L workers 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:

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

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 the future fraction of workers with z_L when the government returns 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.

2.6 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. This is because of two reasons. First, it is a common assumption in the sovereign default literature. Instead of worker borrowing, the government borrows and then returns all proceeds to the workers. An alternative setting is that workers can also invest, borrow, and default. In this case, if the government imposes taxes or subsidies on domestic investment and capital flows due to pecuniary externalities, the allocations in this alternative setting are the same as when assuming that only the government can borrow. The second reason is model tractability. When including worker assets as an extra individual state variable and the distribution of worker assets as an extra aggregate state variable, the numerical solution is substantially more involved. However, it is useful to emphasize that a modification with worker wealth would not alter the main results—because the government also has incentives to reduce wealth inequality with progressive taxation. For literature that allows for households' borrowing and savings, see Roldán (2022), Bianchi et al. (2022), among others.

The model features external government debt. In the state government case, this means that the government borrows externally. Although there is no good source for the exact holders of state government debt, we can infer from examining historical defaults. For example, when the state of Arkansas defaulted in 1933, most creditors were from other states.[14] An extension of this model would involve the government issuing both internal and external debt. With internal debt, wealthier workers are likely to hold a significant portion of the government's debt. Consequently, if the government defaults, it defaults on all its debt, impacting wealthier workers more severely. The distributional effect of a default on internal government debt has been emphasized in D'Erasmo and Mendoza (2016, 2021). By combining the effects of both external and internal debt, the redistribution effect from default could be intensified.

3 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 and welfare. I also study the effects of income inequality and migration on government spreads during bad times by analyzing the impulse response functions. Next, I show that the model can replicate the key correlations found in the data. Finally, I perform sensitivity analysis.

3.1 Parameterization and moments

The model is calibrated at an annual frequency. Aggregate productivity A follows a first-order autoregressive process: $\log(A_t) = \rho_A \log(A_{t-1}) + \varepsilon_t$, where ε_t follows a normal distribution with mean zero and a standard deviation σ_A. 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 worker equally ($\omega_i = 0.5$) in the social welfare function.[15] There are two types $\{L, H\}$ of workers. Type-L workers have labor productivity z_L and type-H workers have labor productivity z_H. Let $z_L = \bar{z} - \sigma_z$ and $z_H = \bar{z} + \sigma_z$, where $0 < \sigma_z < \bar{z}$. Thus, σ_z measures labor productivity heterogeneity without changing the average labor productivity level $\bar{z}$ in this economy. The workers have utility function $u(c, \ell) = \log c - \frac{\ell^{1+\gamma}}{1+\gamma}$.

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[14] 65% of all debt (95 of 146 million) was held by creditors from New England and the Middle Atlantic states, with the rest held by creditors from the Midwest and the South.

[15] Section 3.5 explores the results in an alternative setting by letting the Pareto weights be $\omega_i = z_i^\eta / (\sum_I z_i^\eta)$. $\eta = 0$ indicates equal weights in the social welfare function.

I parameterize the model to match key properties of state-level data in the U.S. from 2000 to 2019. Table 4 reports the parameter values. There are two groups of parameters. The first group of parameters are assigned, and those in the second group are chosen to jointly match relevant empirical moments. The first group includes $\{r, \gamma, \theta, \rho_A, \tau_c, \bar{z}\}$. The risk-free rate r is set to be 1.78%, which is the average Federal Funds Effective Rate. For Frisch elasticity, following Heathcote et al. (2017), I set $\gamma = 2$. The return parameter θ is 0.25 following Gelos et al. (2011).[16] The persistence of the productivity process ρ_A is set to be 0.9. The sales tax rate τ_c is 5.06%, which is the average state sales tax rate during 2000-2019. The average labor productivity level $\bar{z}$ is normalized to 0.5.

The second group includes nine parameters $\{\sigma_A, \beta, d_1, d_2, \sigma_z, \zeta_L, \zeta_H, \bar{m}_L, \bar{m}_H\}$. I choose these parameters to jointly target the empirical moments reported in Table 5. Even though the parameters are chosen jointly, I can give a heuristic description of how the sample moments included in the estimation inform specific parameters. The volatility of productivity shocks σ_A mainly affects the volatility of GDP and spreads. The discount factor β and the two parameters in the productivity loss function, d_1 and d_2, mostly affect the average debt-to-GDP ratio, the average spread, and the volatility of spread. The Gini index informs the labor productivity gap σ_z. Emigration rates for the low-income and the high-income are informative about the parameters in the migration cost distribution $\{\zeta_L, \zeta_H\}$ and the immigration rates pin down the exogenous inflow parameters $\{\bar{m}_L, \bar{m}_H\}$.

3.2 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 workers decide their own 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 less redistribution.

The degree to which inequality affects government default risk (and thus government spreads) depends on the magnitude of labor distortions. The *intensive* margin of labor distortion depends on the Frisch elasticity. With a more elastic labor supply, the ability to increase tax progressivity diminishes, leading to a larger effect of inequality on government

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[16] State government default also triggers financial exclusions. For example, after Arkansas defaulted in 1933, large financial centers remained closed to Arkansas for some time. 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.

Table 4: Parameters

Parameter	Description	Value	Target/Source
Assigned Parameters			
r	Risk-free interest rate	1.78%	Average Federal Funds Rate
γ	Frisch elasticity $(1/\gamma)$	2	Heathcote et al. (2017)
θ	Reentry probability	0.25	Conventional value
ρ_A	Productivity persistence	0.90	Conventional value
τ_c	Sales tax rate	5.06%	Average sales tax rate
$\bar{z}$	Average labor productivity	0.5	Normalization
Parameters from Moment Matching			
σ_A	Std. of aggregate productivity shocks	0.012	Std. Dev. of GDP
β	Discount factor	0.9	Average debt-to-GDP
d_1	Default loss	-0.35	Average spread
d_2	Default loss	0.417	Std. Dev. of spread
σ_z	Labor heterogeneity	0.457	Gini index
ζ_L	Migration cost distribution, low-income	0.0021	Emigration rate for low-income
ζ_H	Migration cost distribution, high-income	0.0028	Emigration rate for high-income
$\bar{m}_L$	Exogenous inflow, low-income	0.033	Immigration rate for low-income
$\bar{m}_H$	Exogenous inflow, high-income	0.0246	Immigration rate for high-income

Table 5: Model fit

	Data	Model
Std. Dev. of GDP	0.024	0.024
Average spread (%)	0.858	0.808
Std. Dev. of spread (%)	0.634	1.142
Average debt-to-GDP	0.156	0.155
Average Gini index	0.453	0.453
Average emigration rate of low-income (%)	3.426	3.467
Average emigration rate of high-income (%)	2.402	2.375
Average immigration rate of low-income (%)	3.421	3.311
Average immigration rate of high-income (%)	2.463	2.468

Notes: This table reports the moments that are used to estimate the parameters listed in the bottom panel of Table 4. GDP in the table refers to (logged) per-capita GDP. Government spread, debt-to-GDP, Gini index, emigration rates, and immigration rates are in levels. The GDP loss during default in the model is 8.1%. Although we lack this data at the state level because the most recent state government default occurred in Arkansas in 1933. However, the decline in output that the model generated is consistent with the literature. For example, Mendoza and Yue (2012) find that Argentina's GDP decreased by around 13% during the 2002 default.

spreads. The *extensive* margin of labor distortion depends on labor mobility. The impact of inequality on government default risk is lower if people are unlikely to move even when facing 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 in labor productivity and thus also pre-tax labor income (denoted as *no-inequality*). To explore the role of migration, I further shut down the labor mobility channel to generate a reference model with no inequality and no labor mobility (denoted as *no-inequality-no-migration*).

In the no-inequality model, labor productivity is the same for all 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, except for those employed to generate scenarios with no inequality or no migration. Appendix B.6 reports the parameter values for the reference models. For each model, I simulate 3000 paths for 500 periods, then drop the first 100 periods to eliminate the influence of the initial guesses. I then take average of government spreads across the paths conditional on the government not defaulting.

Table 6 compares the moments generated in the benchmark model and the reference models. In the benchmark, the average government spread is 0.808%, while in the no-inequality model, the average spread is 0.641%. The comparison highlights that inequality is a force towards higher government spreads. Inequality accounts for about 20% ($(0.808 - 0.641)/0.808$) of the average government spread in the benchmark model. When we further shut down migration (Column "no-inequality-no-migration"), the average spread is reduced to 0.181%. The volatility of spreads is also lower in the reference models. With higher government spreads, the benchmark model generates a lower average debt-to-GDP ratio compared with the reference models.

To further illustrate the impact of inequality and migration on default risk, Figure 3 plots the welfare gain (in terms of current consumption) from default for the benchmark model, the no-inequality model, and the no-inequality-no-migration model. Panel (a) plots the welfare gain from default as a function of aggregate productivity. With lower productivity, the welfare gain from default is larger, leading to a higher default risk. Comparing the benchmark model and the reference models, the welfare gain from default is the largest in the benchmark model and the smallest in the no-inequality-no-migration model at each productivity level. Panel (b) plots the welfare gain from default as a function of the debt

Table 6: Moments comparison

	Data	Benchmark	No-inequality	No-inequality-no-migration
Std. Dev. of GDP	0.024	0.024	0.024	0.024
Average spread (%)	0.858	0.808	0.641	0.181
Std. Dev. of spread (%)	0.634	1.142	0.789	0.121
Average debt-to-GDP	0.156	0.155	0.162	0.231
Average Gini index	0.453	0.453	0	0
Average emigration rate of low-income (%)	3.426	3.467	2.218	0
Average emigration rate of high-income (%)	2.402	2.375	2.870	0
Average immigration rate of low-income (%)	3.421	3.311	3.313	0
Average immigration rate of high-income (%)	2.463	2.468	2.469	0

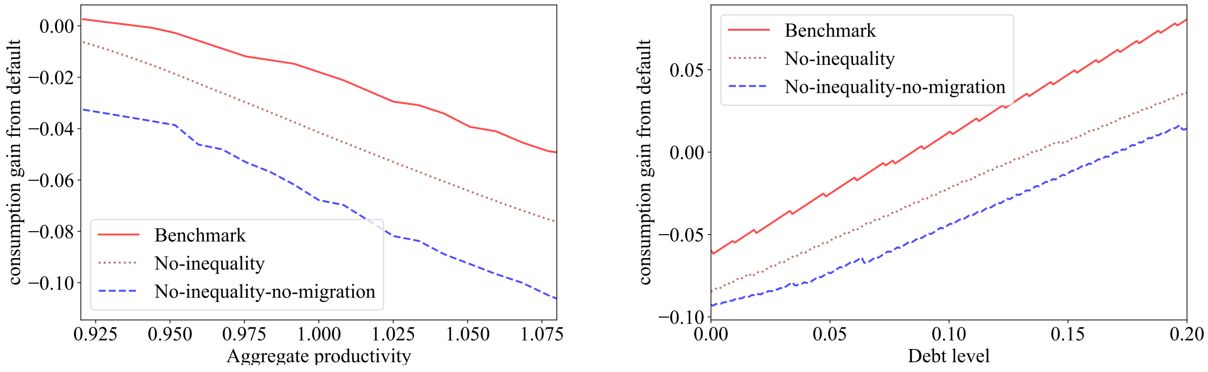
Notes: This table compares the moments generated in the benchmark model and reference models. GDP in the table refers to (logged) per-capita GDP. Government spread, debt-to-GDP, Gini index, emigration rates, and immigration rates are in levels. Column "No-inequality" corresponds to the reference model that shuts down inequality compared with the benchmark model. Column "No-inequality-no-migration" refers to the reference model that further shuts down migration.

level. The higher the level of debt, the greater the benefit from default and the greater the risk of default. Comparing across models, again, the welfare gain from default in the benchmark model is the largest at any given level of debt.

3.3 Impulse response functions

To explore the effects of income inequality and migration on government spreads during recessions, I now analyze the impulse response functions (IRFs) of key variables to a negative productivity shock. I simulate 30,000 paths for the model for 500 periods. From periods 1 to 400, the aggregate productivity shock A follows its underlying Markov chain. In period 401, there is a one standard deviation negative productivity shock. From period 401 on, the productivity shocks follow again its underlying Markov process. The impulse responses plot the averages, across the 30,000 paths, of the variables.

Figure 4 plots the IRFs for the benchmark model, no-inequality model, and no-inequality-no-migration model from period 400 to 410 (period 0 to 10 in the figure). Panel (a)-(h) plot the government spread, tax progressivity, debt-to-GDP ratio, trade-balance-to-GDP ratio, emigration rate of the high income, emigration rate of the low income, labor supply and output. The red solid lines are for the benchmark model, brown dotted lines are for the no-inequality model, and the blue dashed lines are for the no-inequality-no-migration



(a) (b)

Figure 3: Consumption gain from default

Notes: This figure plots the welfare gain (in terms of current consumption) from default as a function of aggregate productivity (Panel (a)) and as a function of debt level (Panel (b)). Other state variables are fixed at the median level in the benchmark model. The red solid lines plot for the benchmark model, the brown dotted lines plot for the no-inequality reference model, and the blue dashed lines plot for the no-inequality-no-migration reference model.

model. For Panels (a) to (f), which are ratios or potentially take negative values, I normalize each series by its value in period 0, i.e., the value for period 1 is the value in period 1 minus the value in period 0. For Panels (g) and (h), the lines plot for the percentage change from period 0.

After a one standard deviation negative productivity shock, the government spread goes up in all models (Panel (a)). Lower productivity increases the probability that the government will default. The spreads rise to compensate for the heightened default risk. Without inequality and migration (blue dashed line), the spread increases by 0.06 percentage points (pp). In the benchmark model, the spread increases by 0.5pp, more than that in the no-inequality model or no-inequality-no-migration model. This is because in the benchmark model, the government cannot decrease tax progressivity as in the other cases, as shown in Panel (b). In the benchmark model, the tax progressivity τ only decreases by 0.002 because the government considers the redistribution benefit from progressivity.

After the productivity shock, debt-to-GDP rises a little bit on impact due to the decrease in GDP and then falls (Panel (c)). In the benchmark model, the debt-to-GDP ratio decreases by about 3pp (from 15pp in period 1 to 12pp in period 2), more than that in the no-inequality-no-migration model where debt-to-GDP decreases by 2pp (from 23pp to 21pp). For the trade balance, there are two opposing forces. On the one hand, the increase in the spread drives capital out of the economy, increasing the trade balance. On the other hand, an increase in equilibrium default probabilities reduces the trade balance. The smaller net increases in the trade balance in the benchmark model and the no-inequality model are because of a larger increase in equilibrium default probabilities.

Panel (e) and (f) show that the emigration rates go up after the negative shock. By construction, there are no changes in the no-inequality-no-migration model. Comparing (e) and (f), the increase of emigration rate of high-income workers (0.035%) is larger than that of low-income workers (0.025%). This shows that although the average emigration rate of the low-income is higher in the steady state (recall the summary statistics in Table 3), the higher-income workers are more mobile and can move more easily when the current region experiences bad shocks.

By pushing down tax progressivity, the government stimulates labor supply as shown in Panel (g). In the benchmark model, government decreases tax progressivity by less, thus encouraging labor supply by less, compared with the other two cases.[17] Without being able to push down tax progressivity to simulate labor supply in period 1, the decline of GDP per capita in the benchmark model is 0.24% larger than in the no-inequality model and 1.17% larger than in the no-inequality-no-migration model.

3.4 Cross-sectional Analysis

To show that the model can reflect the cross-sectional variations as in the data, I vary the degree of inequality in the model to generate the observed Gini for each state. For each state, I calculate the average Gini index from 2000 to 2019. Appendix A.2 lists the Gini index for each state.

I adjust the parameter σ_z to match Gini for each state. I then simulate the models with different inequality levels to generate a simulated state-year panel for 50 states. I keep the data for 20 years, which is consistent with the empirical part. Using this model-simulated panel data, I study the relationship between government spreads and income inequality. Specifically, I regress spreads on inequality, controlling for output and debt-to-output ratio, as well as time fixed effect, as in the empirical part.

Table 7 reports the regression coefficients using the model-simulated data. Column (1)

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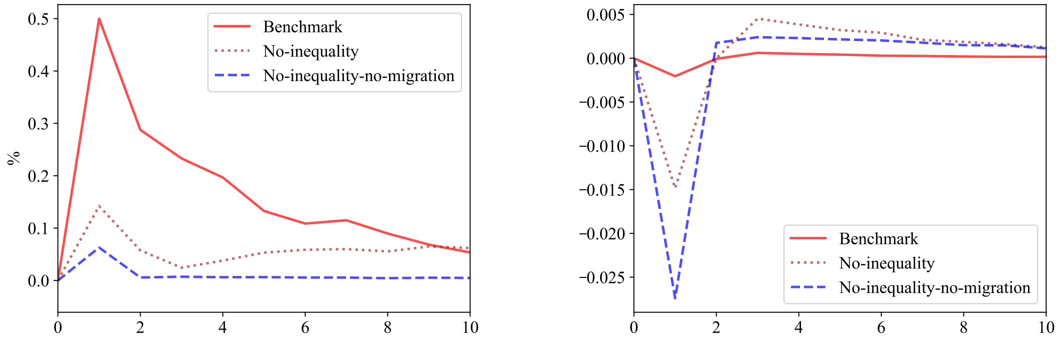
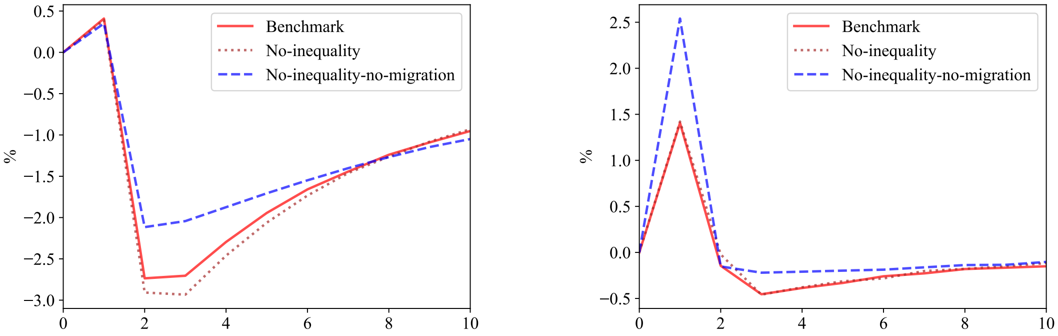
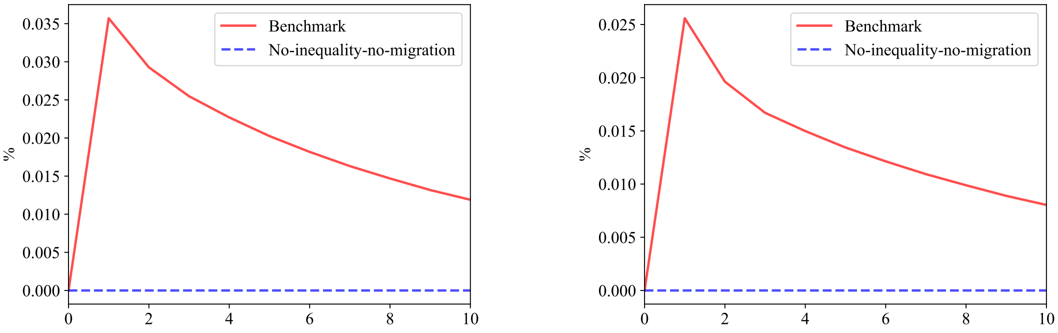
[17] Note that under logarithmic utility, the optimal labor choices are affected only by tax progressivity as shown in Eq. (14). Aggregate productivity does not affect optimal labor choice. Using a more general CRRA utility functional form would fix the countercyclical labor supply here by allowing labor supply to depend on the aggregate productivity and the average tax level. Appendix B.4 derives the optimal labor supply choices using a CRRA utility function.



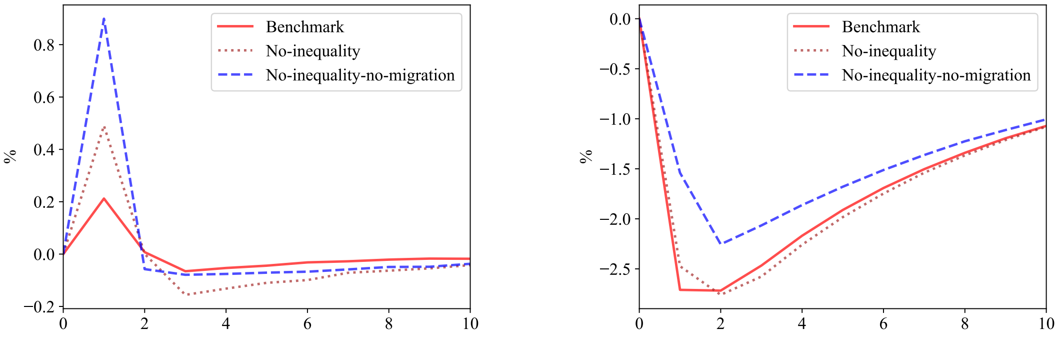
(a) Spread (b) Tax progressivity



(c) Debt-to-GDP (d) Trade-balance-to-GDP



(e) Emigration rate of the high-income (f) Emigration rate of the low-income



(g) Labor (h) GDP per capita

Figure 4: IRFs to a one standard deviation decrease in productivity

Notes: Impulse response functions to a one standard deviation decrease in aggregate productivity A. The impulse responses plot the average across the 30,000 simulations.

shows the result when not controlling for output and debt-to-output ratio. The positive coefficients for Gini show that high income inequality is positively associated with high spreads, consistent with the empirical results. When controlling for output and debt-to-output ratio, results shown in Column (2), the positive relationship is still significant and even stronger. The results are robust to using lagged output and debt-to-GDP, longer time periods, sample excluding default periods, etc. The regression coefficients of the model are not too far from those found in the data (4.059 to 7.822, depending on the measure of spreads and the specification, see Table 2). This shows that the model can reflect the cross-sectional variations as in the data. Note that the goal here is not the exactly match the regression coefficients, but to show that the model is able to generate the relationship as in the data in cross-sectional sense.

Table 7: Regression Results using Model-Simulated Data

	(1)	(2)
Gini	2.720***	13.787***
	(0.296)	(1.289)
Year FE	Yes	Yes
State controls	No	Yes
N	1000	1000
R^2	0.081	0.397

Notes: This table reports regression results of government spreads on inequality using the model-simulated 50 states panel data. Column (1) shows the result when not controlling for output and debt-to-output ratio. Column (2) shows the result when adding output and debt-to-output ratio as state controls. Output is in log terms. Government spreads, Gini, and debt-to-output ratio are in levels. Standard errors in parentheses. Significance level: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Using the model-simulated panel data, I calculate the correlations for the key variables in the model and compare them with those in the data, and the results are presented in Table 8. The correlations suggest that the model performs reasonably well in capturing the relationships between the variables in the data. For instance, government spread is negatively correlated with GDP in both the data (-0.694) and the model (-0.311). The net migration rate is positively correlated with GDP and negatively correlated with spread in both the data and the model, although the model predicts a stronger correlation. Furthermore, the positive correlation between spread and tax progressivity in the data (0.204) is also reflected in the model (0.291).

Table 8: Correlations: data and model

	Data	Model
Corr (GDP, Spread)	-0.694	-0.311
Corr (GDP, Net migration rate)	0.141	0.794
Corr (Spread, Net migration rate)	-0.27	-0.426
Corr (Spread, Progressivity)	0.204	0.291

Notes: This table reports the correlations for the data and the model. GDP in the table refers to (logged) per-capita GDP. Spread, net migration rate, and progressivity are in levels.

3.5 Sensitivity

Redistribution preference. Empirical evidence shows that governments with stronger preferences for redistribution are more likely to have higher spreads. Here I 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 $\omega_i = z_i^\eta / (\sum_{i \in I} z_i^\eta)$, where $\eta = 0$ corresponds to equal weights in the social welfare function as in the benchmark model.

Table 9 compares the statistics of model moments under different Pareto weights. With higher η, the government assigns larger weights to high-income workers and imposes a less progressive tax (lower τ). A less progressive tax encourages labor supply and reduces the emigration rate of high-income workers. The emigration rate of low-income workers increases. With higher labor supply and less emigration of high-income workers, total output is larger. With a larger tax base, the government spread declines and the debt-to-GDP ratio increases.

Table 9: Experiments with Pareto weights

	tax progressivity τ	labor supply	emigration rate (high-income)	emigration rate (low-income)	spread	debt-to-GDP
$\eta = 0$	0.666	0.684	2.375%	3.467%	0.808%	0.155
$\eta = 0.1$	0.616	0.719	2.213%	3.597%	0.649%	0.161
$\eta = 0.5$	0.337	0.867	1.640%	4.528%	0.269%	0.189

Notes: This table reports the results with different Pareto weights. $\eta = 0$ is the benchmark model. A higher η reflects a larger weight on high-income workers and thus a weaker government redistribution preference. The numbers in the table are the averages from model simulations.

Frisch elasticity. The elasticity of labor supply determines the response of labor supply to changes in taxation and determines the degree of distortions that taxation introduces. The value of this elasticity, however, is well known to be controversial. On one hand, researchers who look at micro data typically estimate relatively small labor supply elasticities, while on the other hand, researchers who use representative agent models to study aggregate outcomes typically employ parameterizations that imply relatively large aggregate labor supply elasticities. Table 10 reports averages of key variables from 3,000 simulations with alternative values for the Frisch elasticity. With a higher Frisch elasticity (lower γ), the equilibrium tax progressivity is lower because the labor distortion cost of increasing tax progressivity is higher. Although lower tax progressivity encourages labor supply, the force of a higher Frisch elasticity dominates, leading to lower equilibrium labor supply. With a higher Frisch elasticity, the government spread is higher and the associated debt-to-GDP is lower.

Table 10: Experiments with alternative Frisch elasticity $(1/\gamma)$

	tax progressivity τ	labor supply	spread	debt-to-GDP
$\gamma = 2$	0.666	0.684	0.808%	0.155
$\gamma = 1$	0.608	0.616	1.417%	0.142
$\gamma = 0.5$	0.561	0.567	1.620%	0.129

Notes: This table reports the results with different Frisch elasticities. $\gamma = 2$ is the benchmark model. A smaller γ corresponds to a larger Frisch elasticity. The numbers in the table are the averages from model simulations.

In the benchmark model, I set the Frisch elasticity to be 0.5 ($\gamma = 2$) following Heathcote et al. (2017). With a higher Frisch elasticity, a progressive tax brings more distortion, thus magnifying the key mechanism in this paper. Therefore, the magnitude of inequality on default risk derived in the previous sections can be viewed as the lower bound.

4 Conclusion

Income inequality affects fiscal policies dealing with taxation, government borrowing, 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 taxation, debt, and income inequality.

With high inequality and strong preferences for redistribution, the government imposes progressive taxation, which distorts labor supply decisions and increases emigration of high-income workers, 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 explains one-fifth of the average U.S. state government spread.

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 effects for domestic agents. By introducing heterogeneous workers and endogenous taxation, this paper provides a framework to study inequality and a rich set of fiscal policies, including taxation, government borrowing, and default.

Additional fruitful research could carry on this line of work. For example, the framework could be used to evaluate the welfare consequences of austerity during a debt crisis. The proponents of austerity argue that by reducing government transfers, a country would have more 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 increases inequality. An interesting future step would be to address these two views with the model framework.

Finally, the connection between the sovereign debt crises 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 of the financial and fiscal links between sovereign debt crises and the labor market.

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ONLINE APPENDIX TO "INEQUALITY, TAXATION, AND SOVEREIGN DEFAULT RISK"

BY MINJIE DENG

A Data and Additional Empirical Results

A.1 Data Sources

State government CDS spreads: Bloomberg.
Municipal bond yields: Global Public Finance database.
State Gini index: U.S. Census Bureau and American Community Survey.
State party control: National Conference of State Legislatures.
State total output: U.S. Bureau of Economic Analysis.
State government debt: U.S. Census State Finances Dataset.
State-to-state migration: Internal Revenue Service Migration Dataset.
State government tax revenue: U.S. Census Bureau, "State and Local Government Finance".
State government expenditures: U.S. Census Bureau, "State and Local Government Finance".
Maximum state income tax rate: NBER's calculations using TAXSIM model.
State unemployment rate: Local Area Unemployment Statistics.
State real personal income: Bureau of Economic Analysis.
State price parities: Bureau of Economic Analysis.
Country government bond spreads: OECD Database.
Country Gini index: World Income Inequality Database (WIID4).
Country income shares by quintile groups: World Income Inequality Database (WIID4).
Country debt-to-GDP ratio: central government debt as the percentage of GDP, IMF.

A.2 State Gini Index

Table A.1 reports the average Gini index for each state from year 2000 to 2019.

Table A.1: State Gini Index

State	Gini	State	Gini	State	Gini
Alabama	0.472	Louisiana	0.482	Ohio	0.452
Alaska	0.412	Maine	0.44	Oklahoma	0.458
Arizona	0.456	Maryland	0.444	Oregon	0.45
Arkansas	0.46	Massachusetts	0.472	Pennsylvania	0.46
California	0.475	Michigan	0.452	Rhode Island	0.459
Colorado	0.45	Minnesota	0.436	South Carolina	0.463
Connecticut	0.485	Mississippi	0.472	South Dakota	0.439
Delaware	0.439	Missouri	0.451	Tennessee	0.468
Florida	0.474	Montana	0.443	Texas	0.473
Georgia	0.468	Nebraska	0.435	Utah	0.414
Hawaii	0.433	Nevada	0.446	Vermont	0.434
Idaho	0.431	New Hampshire	0.425	Virginia	0.458
Illinois	0.469	New Jersey	0.466	Washington	0.446
Indiana	0.437	New Mexico	0.467	West Virginia	0.457
Iowa	0.429	New York	0.501	Wisconsin	0.43
Kansas	0.446	North Carolina	0.465	Wyoming	0.425
Kentucky	0.465	North Dakota	0.444		

Notes: This table reports the average Gini index for each state from year 2000 to 2019. Data source: U.S. Census Bureau and American Community Survey.

A.3 Construction of State Government Bond Spreads

The data on municipal bond issuance comes from the Global Public Finance database of the Securities Data Company (SDC). The dataset contains rich information on various characteristics of newly issued bonds at the state and local levels, including issuer information, amount issued, years to maturity, coupon, prices and yields, and credit ratings, among others.

As most municipal bonds are exempt from federal and state taxes, state bond yields are adjusted by a tax-adjustment factor $\tau_{s,t}$ specified as $1 - \tau_{s,t} = (1 - \tau_{s,t}^{fed})(1 - \tau_{s,t}^{state})$, where $\tau_{s,t}^{fed}$ and $\tau_{s,t}^{state}$ denote the top federal and maximum state income tax rates, following Schwert (2017).

State bond spreads are calculated as the difference in yields between a municipal bond and a synthetic treasury bond with equivalent coupon and maturity date. First, for each municipal bond, solve for the theoretical price on a synthetic treasury bond with the same maturity date and coupon rate by calculating the present value of its coupon payments and face value using the U.S. Treasury yield curve.

$$P_N^T = \sum_{n=1}^{N} \frac{C/2}{(1 + r_n^T/2)^n} + \frac{100}{\left(1 + r_N^T/2\right)^N}$$

where r_n^T is the set of treasury spot rates estimated in Gürkaynak et al. (2007). Second, calculate the yield-to-maturity of the synthetic Treasury bond using this price, the coupon payments, and the face value. Last, take the difference between the municipal bond yield and the synthetic Treasury bond yield to generate a bond spread. This procedure is similar to the yield spread calculation in Longstaff et al. (2005) and Ang et al. (2014), among others.

A.4 Institutional Details for State Government Finances

Balanced budget requirements. Balanced budget requirements typically only apply to state operating budgets. Bond finance for capital projects generally does not fall within any constraints of a balanced budget requirement. Less attention (if any) is given to the question of whether a state's entire budget is in balance.[18] The details of balanced budget requirements vary across states, and political cultures reinforce the requirements.

State debt limits. States structure their debt limits very differently. For authorized debt, some states have quite a strict limit, for example, Georgia restricts debt to less than 3.5% of personal income and less than $1200 in debt per capita as specified in their Debt Management Plan.[19] Some states have less restrictive debt limits. For example, the policy to limit authorized debt for Illinois is that a three-fifths vote of the legislature is required to increase the state debt limit. Out of 50 states, seven states do not have any debt limits (including authorized debt and debt service): Arkansas, California, Montana, New Hampshire, New Mexico, Oklahoma, and Oregon.

State tax and expenditure limits. Tax and expenditure limits (TELs) restrict the growth of government revenues or spending by either capping them at fixed-dollar amounts or limiting their growth rate to match increases in population, inflation, personal income, or

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[18] National Conference of State Legislatures Fiscal Brief, `https://docs.house.gov/meetings/JU/JU00/20170727/106327/HHRG-115-JU00-20170727-SD002.pdf`

[19] The Debt Management Plan is adopted by the Georgia State Financing and Investment Commission annually and sets target planning ratios for current and future debt for a five-year projection cycle.

some combination of those factors. Most states do not have a revenue limit.[20] About half of the states do not have a spending limit.[21]

State government expenditures over time. State governments spent about $2.15 trillion on general government expenditures in fiscal year 2019. State government general expenditures fall into one of these categories: education, public welfare, health and hospitals, highways, police protection, fire protection, corrections, natural resources, parks and recreation, housing and community development, sewerage and solid waste, and interest on general debt. Figure A.1 plots the state general expenditures by functional category from 1977 to 2019. Public welfare constitutes a large and growing portion of state spending.

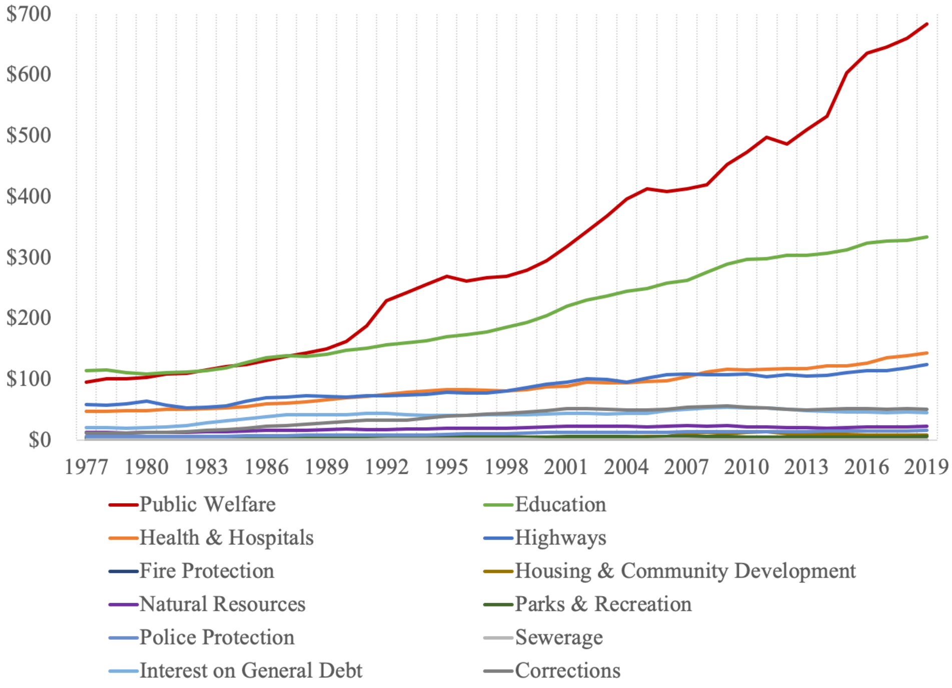

Figure A.1: State Government General Expenditures, by Function

Notes: This figure plots state government general expenditures (billions of dollars, real, 2019 dollars) decomposed by function from 1977 to 2019. Data source: US Census Bureau's Census of Governments and its associated annual survey. Compiled by the Urban-Brookings Tax Policy Center. Washington, DC. Website: https://state-local-finance-data.taxpolicycenter.org

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[20] Only four states (Colorado, Florida, Michigan, Missouri) have a revenue limit. For Florida, for instance, its revenue is limited to the average growth rate in state personal income for the previous five years. Source: National Association of State Budget Officers, "Budget Processes in the States," Spring 2015.

[21] States with no limits on spending: Alabama, Arkansas, Florida, Georgia, Illinois, Kansas, Kentucky, Maryland, Massachusetts, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Mexico, New York, North Dakota, Pennsylvania, South Dakota, Vermont, Virginia, West Virginia, Wisconsin, Wyoming. Source: National Association of State Budget Officers, "Budget Processes in the States," Spring 2015.

A.5 Government Spreads and Migration: Additional Figures

Figure A.2 and A.3 plot state-level net migration rates and government spreads winsorized at 1% and 5% level, respectively. The results remain robust: net migration rate is negatively correlated with government spreads.

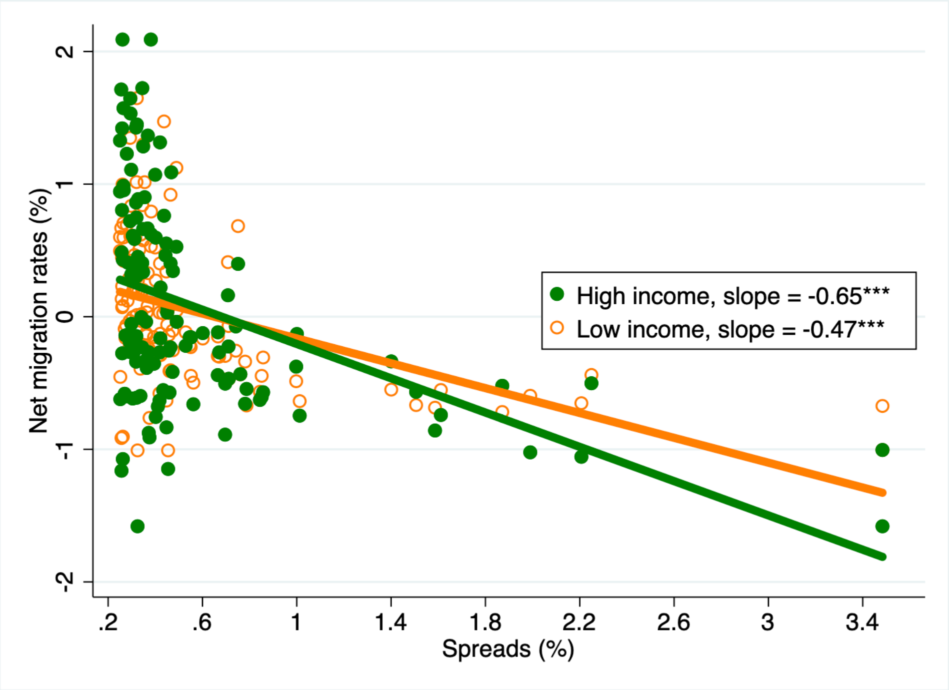

Figure A.2: Government spreads and migration: winsorize at 1%

A.6 Additional State-level Results

A novel mechanism in this paper that generates the positive correlation between spreads and income inequality is endogenous tax progressivity. Here I use state-level data to test the following two model predictions. First, with higher inequality, a government tends to impose a more progressive income tax system; second, more progressive taxation is associated with higher government spreads.

The empirical specification that explores the relationship between tax progressivity and income inequality is as follows:

$$prog_{jt} = \beta_0 + \beta_1 ineq_{j,t-1} + \Gamma' Z_{j,t-1} + \alpha_t + \epsilon_{jt}, \qquad \text{(A.1)}$$

where $prog_{jt}$ is income tax progressivity in state j in year t, which is proxied for by the

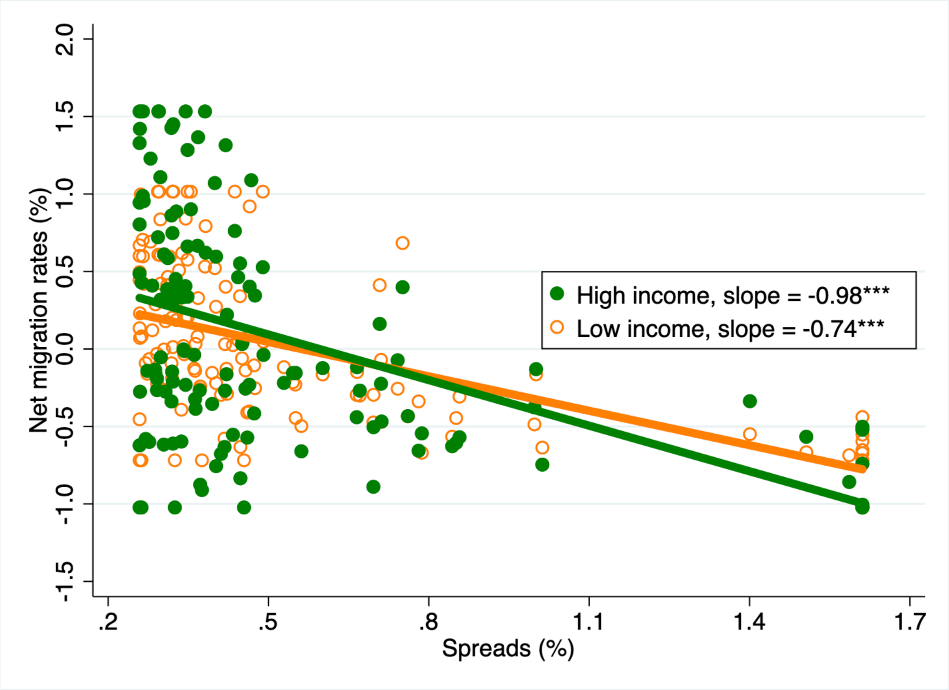

Figure A.3: Government spreads and migration: winsorize at 5%

maximum state income tax rate; $ineq_{j,t-1}$ is pre-tax income inequality proxied for by the Gini index for state j in year $t-1$; and $Z_{j,t-1}$ is a vector of control variables, including state total output, the debt-to-output ratio, and political party control of state legislatures. α_t is a time fixed effect. Data covers 49 states from 2006 to 2017.[22] Coefficient β_1 captures the correlation between income inequality and tax progressivity.

Table A.2 reports the result for regression (A.1), showing that a more unequal state tends to impose a more progressive income tax system. Also, the states with Democratic-controlled or split legislatures are more likely to impose a more progressive tax than those with Republican-controlled legislatures.

To explore the correlation between government bond spreads and tax progressivity, I use the following empirical specification:

$$spread_{jt} = \beta_0 + \beta_1 prog_{j,t-1} + \Gamma' Z_{j,t-1} + \alpha_t + \epsilon_{jt}, \tag{A.2}$$

where $spread_{jt}$ is the average CDS spread for state j in year t. Table A.3 shows the regression results. A more progressive tax is associated with higher government bond spreads. Since CDS spreads data is available for 19 states, the number of observations is smaller than for

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[22] Nebraska does not have partisan composition (political party control of state legislatures) data since it is a non-partisan unicameral legislature. Thus, after merging the variables, the panel covers 49 states.

Table A.2: Regression of tax progressivity on inequality

	(1)	(2)
Gini	26.78***	16.38*
	(7.64)	(8.33)
Political (="Split")		1.55***
		(0.47)
Political (="Democratic")		3.10***
		(0.36)
Year FE	Yes	Yes
Controls	Yes	Yes
N	408	392
R^2	0.05	0.20

Standard errors in parentheses
* p<.1, ** p<0.05, *** p<0.01

regression (A.1).

Table A.3: Regression of spreads on tax progressivity

	(1)	(2)
Progressivity	0.03**	0.02**
	(0.01)	(0.01)
Political (="Split")		0.33**
		(0.16)
Political (="Democratic")		0.29**
		(0.11)
Year FE	Yes	Yes
Controls	Yes	Yes
N	109	109
R^2	0.55	0.58

Standard errors in parentheses
* p<.1, ** p<0.05, *** p<0.01

A.7 Cross-country Empirical Evidence

To explore the correlation between government spreads and income inequality across countries, I use the following empirical specification:

$$spread_{jt} = \beta_0 + \beta_1 ineq_{j,t-1} + \Gamma' Z_{j,t-1} + \alpha_t + \epsilon_{jt}, \tag{A.3}$$

where $spread_{jt}$ is the government bond spread of country j in period t. Spread here is defined as the 10-year government bond interest rate of country j in period t minus that of the U.S. for the same period; $ineq_{j,t-1}$ is income inequality for country j in period $t-1$. Here I use two measures for income inequality: the pre-tax Gini index and the gap between the income shares of the top 20% and the bottom 20%. $Z_{j,t-1}$ includes real per-capita GDP and debt-to-GDP ratio as controls. α_t is the time fixed effect. The panel covers 1960-2017 and contains 35 countries.[23]

Table A.4 shows the results of specification (A.3). Columns (1) and (2) use the Gini index as the measure of income inequality, and columns (3) and (4) use the gap between the income shares of the top 20% and the bottom 20% to measure inequality. The results show that high inequality is associated with high government default risk. Increasing the Gini index by 0.1 (e.g., Sweden to Portugal) is associated with government bond spread increases of about 0.5%.

Table A.4: Regression of government spreads on inequality (cross-country)

	(1)	(2)	(3)	(4)
Gini	12.29***	4.96***		
	(1.32)	(1.59)		
top-bottom-gap			11.96***	4.84***
			(1.34)	(1.53)
Year FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
N	688	540	604	486
R^2	0.30	0.48	0.31	0.47

Standard errors in parentheses

* p<.1, ** p<0.05, *** p<0.01

Note: This table reports regression results for the cross-country sample. Columns (1) and (2) report the results when using the Gini index as measure for inequality; columns (3) and (4) instead use the gap between the income shares of the top 20% and the bottom 20%.

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[23] Countries in the sample: Australia, Austria, Belgium, Canada, Switzerland, Chile, Colombia, Costa Rica, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hungary, India, Ireland, Iceland, Israel, Italy, Japan, Korea, Lithuania, Luxembourg, Latvia, Mexico, Netherlands, Norway, New Zealand, Poland, Portugal, Slovenia, Sweden, and South Africa.

B Theoretical Appendix

B.1 Model Proofs

Here I prove some results in Section 2.4 including 1) the monotonicity of each term in (21) with respect to tax progressivity τ; and 2) that the default set is larger with higher inequality. I also show the equivalence of the transformed problem (in Section 2.5) and the original problem.

Monotonicity of each term in (21). Taking derivatives for each term in the government repayment value (21) with respect to τ generates:

(i)

$$\frac{\partial \log(Y - B_0)}{\partial \tau} = -\frac{A\bar{z}\frac{1}{1+\gamma}(1-\tau)^{\frac{1}{1+\gamma}-1}}{A\bar{z}(1-\tau)^{\frac{1}{1+\gamma}} - B_0} < 0$$

(ii)

$$\frac{\partial \frac{1-\tau}{1+\gamma}}{\partial \tau} = -\frac{1}{1+\gamma} < 0$$

(iii)

$$\frac{\partial \frac{1}{2}\log[\alpha(1-\alpha)]}{\partial \tau} = \frac{1}{2}\frac{(z_H^{1-\tau} - z_L^{1-\tau})(\ln z_H - \ln z_L)}{z_L^{1-\tau} + z_H^{1-\tau}} > 0$$

Thus, in the repayment value function, total consumption is decreasing in τ, disutility from working is decreasing in τ, and redistribution is increasing in τ.

Default set is larger under higher inequality. The government's productivity threshold $\bar{A}$ that satisfies $V^d(A) = V^c(B_0, A)$ is given by:

$$\bar{A} = \frac{B_0}{\bar{z}(\ell - \Theta \ell^d)}$$

where

$$\Theta = \exp\left(-\frac{1}{2}\log\frac{\alpha(1-\alpha)}{\alpha^d(1-\alpha^d)} - \frac{\tau - \tau^d}{1+\gamma}\right),$$

and

$$\alpha \equiv \frac{(\bar{z}-\sigma_z)^{1-\tau}}{(\bar{z}-\sigma_z)^{1-\tau} + (\bar{z}+\sigma_z)^{1-\tau}},$$

$$\alpha^d \equiv \frac{(\bar{z}-\sigma_z)^{1-\tau^d}}{(\bar{z}-\sigma_z)^{1-\tau^d}+(\bar{z}+\sigma_z)^{1-\tau^d}}.$$

Lemma 1. *Θ is increasing in σ_z.*

Since Θ is increasing in σ_z, we have $\frac{\partial \bar{A}}{\partial \sigma_z} > 0$. That is, higher inequality (a higher value for σ_z) would lead to a higher productivity threshold $\bar{A}$, and thus a larger default set. Alternatively, one can write down the borrowing threshold and show that a higher σ_z leads to a lower borrowing threshold $\bar{B}_0$.

Proof of Lemma 1:

Take the derivative of Θ with respect to σ_z:

$$\frac{\partial \Theta}{\partial \sigma_z} = \Theta \frac{\partial \left[-\frac{1}{2}\log \frac{\alpha(1-\alpha)}{\alpha^d(1-\alpha^d)}\right]}{\partial \sigma_z},$$

where

$$\frac{\alpha(1-\alpha)}{\alpha^d(1-\alpha^d)} = \left[(\bar{z}-\sigma_z)(\bar{z}+\sigma_z)\right]^{\tau^d-\tau}\left[\frac{(\bar{z}-\sigma_z)^{1-\tau^d}+(\bar{z}+\sigma_z)^{1-\tau^d}}{(\bar{z}-\sigma_z)^{1-\tau}+(\bar{z}+\sigma_z)^{1-\tau}}\right]^2,$$

then

$$\frac{\partial \Theta}{\partial \sigma_z} = \frac{\Theta\,\bar{z}}{\ln(10)(\bar{z}-\sigma_z)(\bar{z}+\sigma_z)}\left[(1-\tau)\frac{(\bar{z}+\sigma_z)^{1-\tau}-(\bar{z}-\sigma_z)^{1-\tau}}{(\bar{z}+\sigma_z)^{1-\tau}+(\bar{z}-\sigma_z)^{1-\tau}} - (1-\tau^d)\frac{(\bar{z}+\sigma_z)^{1-\tau^d}-(\bar{z}-\sigma_z)^{1-\tau^d}}{(\bar{z}+\sigma_z)^{1-\tau^d}+(\bar{z}-\sigma_z)^{1-\tau^d}}\right]$$

Since $f(\tau) = (1-\tau)\frac{(\bar{z}+\sigma_z)^{1-\tau}-(\bar{z}-\sigma_z)^{1-\tau}}{(\bar{z}+\sigma_z)^{1-\tau}+(\bar{z}-\sigma_z)^{1-\tau}}$ is decreasing in τ and $\tau^d > \tau$, we have:

$$\frac{\partial \Theta}{\partial \sigma_z} = \frac{\Theta\,\bar{z}}{\ln(10)(\bar{z}-\sigma_z)(\bar{z}+\sigma_z)}\left[(1-\tau)\frac{(\bar{z}+\sigma_z)^{1-\tau}-(\bar{z}-\sigma_z)^{1-\tau}}{(\bar{z}+\sigma_z)^{1-\tau}+(\bar{z}-\sigma_z)^{1-\tau}} - (1-\tau^d)\frac{(\bar{z}+\sigma_z)^{1-\tau^d}-(\bar{z}-\sigma_z)^{1-\tau^d}}{(\bar{z}+\sigma_z)^{1-\tau^d}+(\bar{z}-\sigma_z)^{1-\tau^d}}\right] > 0.$$

Equivalence of the transformed problem and the original problem. The following relations hold:

$$W^s(S,z) = W^s(s,z),$$

$$W(S,z,\delta) = W(s,z,\delta),$$

$$g_i(S) = g_i(s) = N_i'/N_i = (1+m_i)e^{-\zeta(z_i)(W^m - W^s(s,z_i))}\ (i = L, H),$$

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

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

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

$$\frac{V(B,A,\Phi')}{N} = v(b,A,f'),$$

$$\frac{V^c(B,A,\Phi')}{N} = v^c(b,A,f'),$$

$$\frac{V^d(A,\Phi')}{N} = v^d(A,f').$$

In the original problem, the government chooses whether to repay or default:

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

Divide both sides of the default decision by N:

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

which implies

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

Thus the default decisions satisfy

$$D(B,A,\Phi') = d(b,A,f').$$

Let the default decision be $d(b,A,f') = 1$ if $v^c(b,A,f') < v^d(A,f')$. Thus, for the bond price, we have:

$$\begin{aligned} q(B',A,\Phi') &= \frac{1 - Pr[D(B',A',\Phi'')]}{1+r} \\ &= \frac{1 - Pr[d(b',A',f'')]}{1+r} \\ &= q(b',A,f'). \end{aligned}$$

Now I derive the repayment value in the transformed problem. The repayment value function in the original problem is:

$$V^c(B,A,\Phi') = \max_{B',\tau,\lambda}\{u(c_L,\ell_L)N'_L\omega_L + u(c_H,\ell_H)N'_H\omega_H + \beta\mathbb{E}V(B',A',\Phi'')\}.$$

Divide both sides by N:

$$\begin{aligned}\frac{V^c(B,A,\Phi')}{N} &= \max_{B',\tau,\lambda}\{u(c_L,\ell_L)\frac{N_L'}{N_L}\frac{N_L}{N}\omega_L + u(c_H,\ell_H)\frac{N_H'}{N_H}\frac{N_H}{N}\omega_H + \beta\frac{N'}{N}\frac{1}{N'}\mathbb{E}V(B',A',\Phi'')\} \\ &= \max_{B',\tau,\lambda}\{u(c_L,\ell_L)g_L f\omega_L + u(c_H,\ell_H)g_H(1-f)\omega_H \\ &+ \beta(fg_L+(1-f)g_H)\frac{1}{N'}\mathbb{E}V(B',A',\Phi'')\},\end{aligned}$$

which gives

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

The budget constraint in the original problem is:

$$B \le T + qB'.$$

Divide both sides by N:

$$\frac{B}{N} \le \frac{N_L'}{N_L}\frac{N_L}{N}(y_L-c_L) + \frac{N_H'}{N_H}\frac{N_H}{N}(y_H-c_H) + q\frac{B'}{N'}\frac{N'}{N},$$

which gives

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

The derivation of the defaulting value function in the transformed problem follows similar steps. The defaulting value function in the original problem is:

$$V^d(A,\Phi') = \max_{\tau,\lambda}\{u(c_L^d,\ell_L^d)N_L'\omega_L + u(c_H^d,\ell_H^d)N_H'\omega_H + \beta[\theta\mathbb{E}V(0,A',\Phi''_{aut=0}) + (1-\theta)\mathbb{E}V^d(A',\Phi''_{aut=1})]\}$$

Divide both sides by N:

$$\begin{aligned}\frac{V^d(A,\Phi')}{N} &= \max_{\tau,\lambda}\{u(c_L^d,\ell_L^d)\frac{N_L'}{N_L}\frac{N_L}{N}\omega_L + u(c_H^d,\ell_H^d)\frac{N_H'}{N_H}\frac{N_H}{N}\omega_H \\ &+ \beta[\theta\frac{N'}{N}\frac{1}{N'}\mathbb{E}V(0,A',\Phi''_{aut=0}) + (1-\theta)\frac{N'}{N}\frac{1}{N'}\mathbb{E}V^d(A',\Phi''_{aut=1})]\} \\ &= \max_{\tau,\lambda}\{u(c_L^d,\ell_L^d)g_L f\omega_L + u(c_H^d,\ell_H^d)g_H(1-f)\omega_H \\ &+ \beta[\theta\mathbb{E}v(0,A',f''_{aut=0}) + (1-\theta)\mathbb{E}v^d(A',f''_{aut=1})][fg_L+(1-f)g_H]\}\end{aligned}$$

which gives

$$v^d(A,f') = \max_{\tau,\lambda}\{g_L\, f\, u(c_L^d,\ell_L^d)\omega_L + g_H\,(1-f)\,u(c_H^d,\ell_H^d)\omega_H \\ + \beta\,[g_L\, f + g_H\,(1-f)]\,[\theta\mathbb{E}v(0,A',f''_{aut=0}) + (1-\theta)\mathbb{E}v^d(A',f''_{aut=1})]\}.$$

The budget constraint under default in the original problem is:

$$0 \leq T.$$

Divide both sides by N:

$$0 \leq \frac{N'_L}{N_L}\frac{N_L}{N}(y_L - c_L) + \frac{N'_H}{N_H}\frac{N_H}{N}(y_H - c_H),$$

which gives

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

B.2 Model mechanism: effect of migration

The simplified one-period model in Section 2.4 offers clear analytical solutions that help to demonstrate the central model mechanism through explicit representations of the repayment value V^c and default value V^d. However, it cannot be used to analyze the impact of migration. Here, we turn our attention to the infinite horizon model to investigate the effects of migration.

Recall the government chooses $\{B',\tau,\lambda\}$ to maximize its value:

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

subject to the government budget constraint and worker distribution implied by the worker optimal decision rules:

$$B = \int_{\Phi'} T(y_i)di + q(B',A,\Phi')B',$$

$$c_i = \frac{\lambda}{(1+\tau_c)}y_i^{1-\tau},$$

$$\Phi'' = H_{\Phi'}.$$

The worker distribution Φ' enters into the government's problem in three ways. First, it affects the government's value function, as shown in the first term in the value function. Second, it affects the tax base, shown as the first term in the right-hand side of the government budget constraint. Third, it affects the government bond price $q(B', A, \Phi')$ by affecting future default risk. The emigration of workers, especially high-income workers, lowers the government's future repayment capacity and suppresses the bond price. The government also internalizes the impact of its choices on Φ'', which is the next-period worker distribution.

To illustrate the intertemporal trade-off faced by the government, here I assume differentiability of the bond price and the value function with respect to B'. Note that I do not rely on the optimality conditions to solve the equilibrium numerically. The next equation represents the intertemporal Euler equation for the government:

$$[q(B', A, \Phi') + \frac{\partial q(B', A, \Phi')}{\partial B'} B'] \int_{\Phi'} u'(c_i, \ell_i)\omega_i di = \beta \mathbb{E} \int_{\Phi''} [u(c_i', \ell_i')\omega_i \frac{\partial \Phi''}{\partial B'} + u'(c_i', \ell_i')\omega_i] di \tag{B.4}$$

The left-hand side of equation (B.4) represents the current marginal benefit from issuing bonds. The government collects $[q(B', A, \Phi') + \frac{\partial q(B', A, \Phi')}{\partial B'} B']$ additional units of the consumption good when it issues an extra bond, and the second term shows that it is costly to lower the current bond price. A lower bond price reduces the proceeds the government obtains from issuing bonds. To measure the welfare impact of issuing additional bonds, the marginal change in current consumption is weighted by the current consumption valuation $\int_{\Phi'} u'(c_i, \ell_i)\omega_i di$. The right-hand side of equation (B.4) represents the cost of transferring more debt to the future.

B.3 Decision rules

Here I plot the optimal decision rules for the government to visualize how optimal tax progressivity and borrowing depend on key variables. Figure B.4 plots the decision rules when government chooses to repay the debt. Panel (a) and (b) plot the optimal tax progressivity τ as a function of aggregate productivity A and debt level B. Panel (c) and (d) plot the optimal next period debt B' as a function of aggregate productivity A and debt level B. The red solid lines plot correspondingly for the benchmark model and the black dash-dotted lines for the no-migration model. In the no-migration model, the worker distribution Φ is time-invariant. The parameter values for each model follow the parameterization in Section 3.

Optimal tax progressivity is increasing in aggregate productivity (Panel (a)). Intuitively, in good times, the government chooses to impose a more progressive tax to redistribute. When government has a large debt to repay, it adopts a less progressive tax (Panel (b)). As illustrated in Section 2.4, with high outstanding debt, the marginal cost of increasing tax progressivity is high, leading to a less progressive tax in equilibrium. As is commonly found in sovereign default literature, with higher productivity (Panel (c)) or higher current debt (Panel (d)), next period debt is higher.

To isolate the impact of worker migration on the optimal government policies, we can compare the decision rules in the benchmark model and those in the no-migration reference model. With everything else equal, the optimal tax progressivity and next period debt level are higher in the no-migration reference model than in the benchmark model. This is because government internalizes the impact of its policies on worker migration. If workers are not allowed to emigrate (as for the black dash-dotted line), the government would impose a more progressive tax (Panel (a) and (b)) and borrow more (Panel (c) and (d)) to redistribute income.

B.4 CRRA utility

I derive the optimal labor supply choices using a constant relative risk aversion (CRRA) utility function and show that the main results stay unchanged. Assume the utility of worker i is given by:

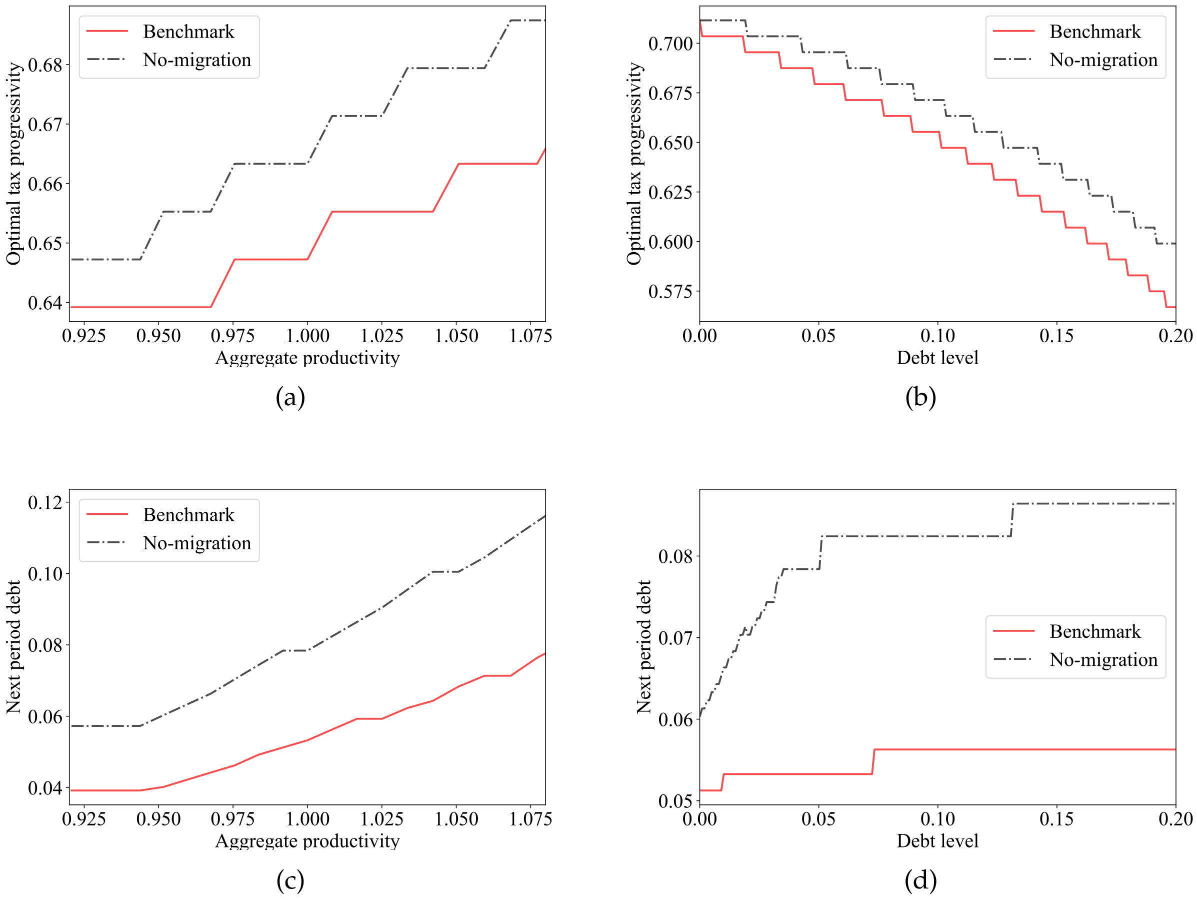
$$u(c_i, \ell_i) = \frac{c_i^{1-\sigma}}{1-\sigma} - \frac{\ell_i^{1+\gamma}}{1+\gamma},$$

where σ is the parameter for risk aversion ($\sigma = 1$ gives logarithmic utility). The optimal choice of labor supply for worker i satisfies:

$$\ell_i^{\sigma-\tau\sigma+\tau+\gamma} = (1-\tau)\lambda^{1-\sigma}(wz_i)^{1-\sigma+\tau\sigma-\tau}.$$

To illustrate, I calculate the optimal labor supply and λ under the following set of parameters: $A = 1$, $z_L = 0.3$, $z_H = 0.7$, and $\sigma = 2$. Then I calculate and plot the social welfare functions under different values of τ. The optimal solutions that maximize the value function are characterized by three unknowns ℓ_L, ℓ_H, and λ and three nonlinear equations:

$$\ell_L^{\sigma-\tau\sigma+\tau+\gamma} - (1-\tau)\lambda^{1-\sigma}(wz_L)^{1-\sigma+\tau\sigma-\tau} = 0,$$



(a) (b)

(c) (d)

Figure B.4: Decision rules

Notes: Decision rules when government chooses to repay the debt. Panel (a) and (b) plot the optimal tax progressivity τ as a function of aggregate productivity and debt level. Panel (c) and (d) plot for the optimal next period debt B' as a function of aggregate productivity and debt level. The red solid lines plot correspondingly for the benchmark model and the black dash-dotted lines for the no-migration model. In the no-migration model, the worker distribution Φ is time-invariant. The parameter values for each model follow the parameterization in Section 3.

$$\ell_H^{\sigma-\tau\sigma+\tau+\gamma} - (1-\tau)\lambda^{1-\sigma}(wz_H)^{1-\sigma+\tau\sigma-\tau} = 0,$$

$$\lambda - \frac{wz_L\ell_L + wz_H\ell_H - B_0}{(wz_L\ell_L)^{1-\tau} + (wz_H\ell_H)^{1-\tau}} = 0.$$

With $\{\ell_L^*, \ell_H^*, \lambda^*\}$, it is easy to solve for output, tax revenue, and consumption. Given consumption and labor choices, I calculate and plot social welfare under different scenarios.

Figure B.5 plots social welfare as a function of tax progressivity τ. The blue dashed line plots for the scenario with $z_L = 0.5$ and $z_H = 0.5$ (no inequality). The comparison between the solid line with inequality and the dashed line without inequality shows that inequality increases the degree of optimal tax progressivity. When the government chooses to default, it can achieve a larger τ^*, as shown in Figure B.6. These results are consistent with the predictions for logarithmic utility.

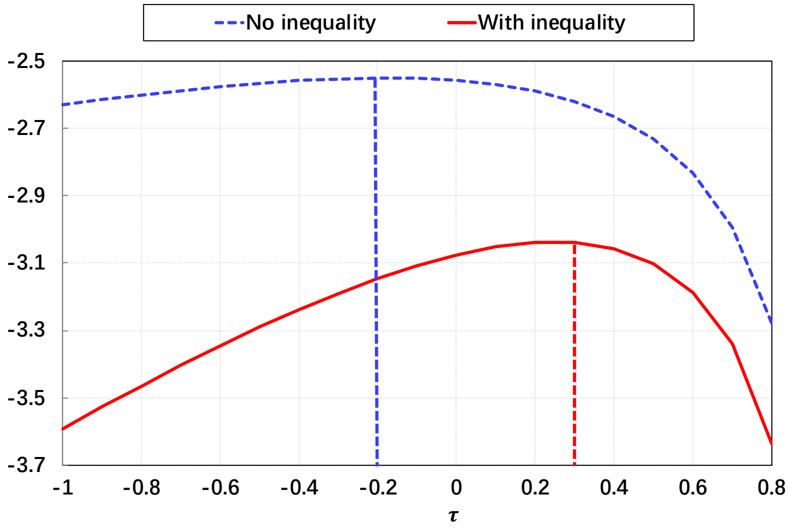


Figure B.5: CRRA utility: inequality and optimal tax progressivity

Notes: This figure plots social welfare as a function of tax progressivity under the parameterization $A = 1$, $\sigma = 2$ and $B_0 = 0.2$. The blue dashed line (no inequality) plots for the scenario with $z_L = 0.5$ and $z_H = 0.5$. The red solid line plots for the case with inequality where $z_L = 0.3$ and $z_H = 0.7$. The comparison of the two lines shows that inequality increases the degree of optimal tax progressivity.

Recall that with logarithmic utility, tax progressivity τ discourages labor. Figure B.7 shows this is still the case with CRRA utility. The yellow dashed line plots total effective labor. Total effective labor is decreasing in tax progressivity τ, and thus the total output is decreasing in tax progressivity τ.

Figure B.8 plots tax revenues collected from different workers and relative consumption as a function of τ. With a more progressive tax, low-income workers pay less tax, high-

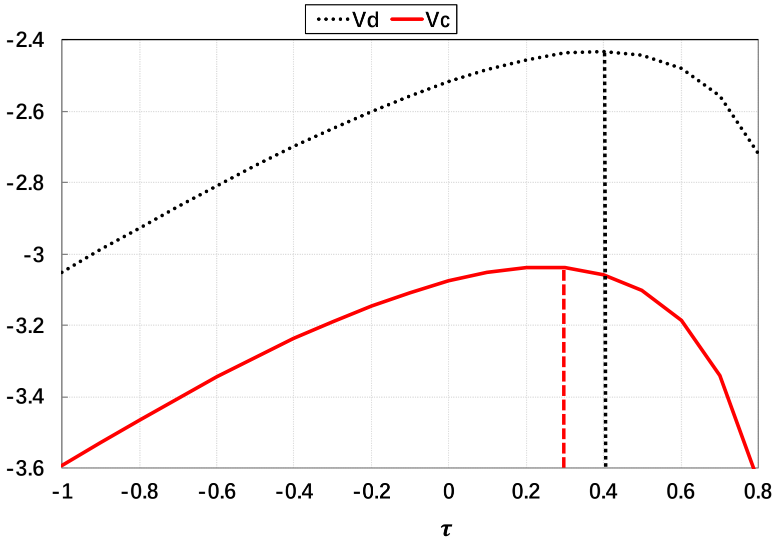


Figure B.6: CRRA utility: default and optimal tax progressivity

Notes: This figure plots social welfare as a function of tax progressivity under the parameterization $A = 1$, $\sigma = 2$, $B_0 = 0.2$, $z_L = 0.3$ and $z_H = 0.7$. The red solid line plots the repayment value and the black dotted plots the defaulting value. The comparison of the two lines shows that when government chooses to default, it can achieve a larger degree of optimal tax progressivity.

income workers pay more tax, and the relative consumption of low-income workers to that of high-income workers increases.

B.5 Exogenous tax progressivity

This section solves for several economies with exogenous tax rules capturing different tax progressivities and reports the key moments in Table B.5. The moments in the table are the averages from 3,000 model simulations. The parameterization follows Benchmark model parameter values. Table B.5 shows that a more progressive tax (higher τ) distorts labor supply, increases emigration of high-income workers, and reduces emigration of the low-income workers. With a more progressive tax, the government has lower spreads, which is consistent with the quantitative results in Ferriere (2015) where tax progressivity is exogenous. Without endogenous tax progressivity, the government does not internalize the impact of progressivity on labor supply, migration, default risk and the cost of borrowing.

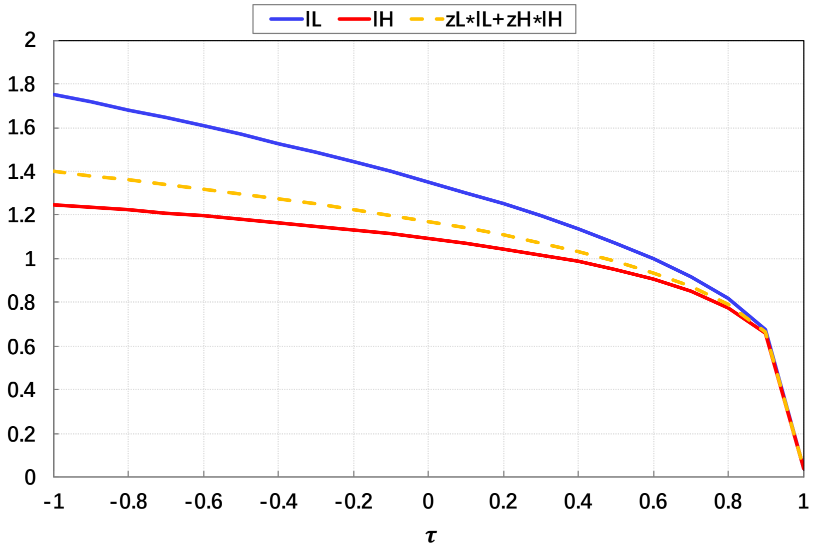


Figure B.7: CRRA utility: labor supply and tax progressivity

Notes: This figure plots labor supply as a function of tax progressivity under the parameterization $A = 1$, $\sigma = 2$, $B_0 = 0.2$, $z_L = 0.3$ and $z_H = 0.7$. The yellow dashed line plots total effective labor. Labor supply is decreasing in tax progressivity τ. It shows that tax progressivity τ discourages labor with CRRA utility, similar to the case with logarithmic utility.

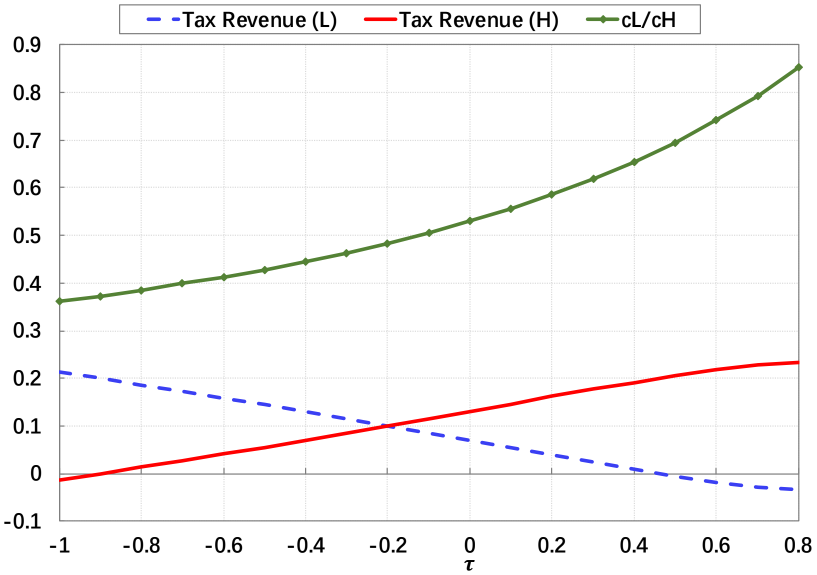


Figure B.8: CRRA utility: tax revenue, relative consumption, and tax progressivity

Notes: This figure plots tax revenues collected from different workers and relative consumption as a function of tax progressivity under the parameterization $A = 1, \sigma = 2, B_0 = 0.2, z_L = 0.3$ and $z_H = 0.7$. With a more progressive tax, low-income workers pay less tax, high-income workers pay more tax, and the relative consumption of low-income workers to that of high-income workers increases.

Table B.5: Exogenous tax progressivity τ

Exogenous τ	labor supply	emigration rate (high-income)	emigration rate (low-income)	spread	debt-to-GDP
$\tau = 0.1$	0.965	1.419%	5.458%	1.239%	0.131
$\tau = 0.3$	0.888	1.578%	4.698%	1.226%	0.145
$\tau = 0.5$	0.794	1.883%	3.987%	0.737%	0.155

Notes: This table reports the results with exogenous tax progressivity. Higher τ reflects a more progressive tax. The numbers in the table are the averages from 3,000 model simulations. The parameterization follows Benchmark model parameter values.

B.6 Parameters for the reference models

In section 3.2, I compare the benchmark model with two reference models: no-inequality model and no-inequality-no-migration model. Both reference models share the same parameter values as the benchmark, except the following parameters shown in Table B.6.

Table B.6: Parameters changed from benchmark

	Benchmark	No-inequality	No-inequality-no-migration
Labor heterogeneity σ_z	0.457	0	0
Migration cost distribution, low-income ζ_L	0.0021	0.0021	-
Migration cost distribution, low-income ζ_H	0.0028	0.0028	-
Exogenous inflow, low-income $\bar{m}_L$	0.033	0.033	0
Exogenous inflow, high-income $\bar{m}_H$	0.0246	0.0246	0

B.7 Solution method

I solve the government and worker problems using value function iteration. The AR(1) process for the aggregate productivity shock A is discretized using 21 equally spaced grid points with Tauchen's method. The government makes a borrowing decision b' and tax progressivity choice τ if not in default, but makes only a tax progressivity choice τ if in default (λ will be determined by the government budget constraint). For government debt, I use a grid with 200 equally spaced points on $b \in [0, 0.2]$. For tax progressivity, I use a grid with 200 equally spaced points on $\tau \in [-0.8, 0.8]$. For the fraction of low-income workers f, I use a grid with 11 equally spaced points on $f \in [0, 1]$. Given optimal government policies, workers determine whether to migrate or not. The staying workers choose labor supply and consumption to maximize lifetime utility. Given the workers' choices, the government updates the repayment value and default value and decides whether to default. For each iteration, I update the value of the government and the value of each type of worker. The code stops running when the value function of the government and the value function for each type of worker converge. The tolerance level for the government is 1e-4. The tolerance level for the each type of worker is 1e-3.

Here is a more detailed description of the algorithm:

1. Create grids and discretize Markov process for the productivity shock A. Create grids for government bonds b, tax progressivity τ, and fraction of low-income workers f.
2. Guess an initial value function of government $v_0(b, A, f)$ and a bond price function $q_0(b, A, f)$; guess the initial value functions for workers $W_0(b, A, f, aut, z)$.
3. Update the repayment value $v^c(b, A, f)$ and the default value $v^d(A, f)$.
4. Compare $v^c(b, A, f)$ and $v^d(A, f)$, and update the defaulting rule, price function, and the value function of the government $v(b, A, f)$.
5. Compute the optimal policy of the government with and without access to credit. With access to the financial market, the optimal policies consists of borrowing $b'(b, A, f)$ and taxation $\tau(b, A, f), \lambda(b, A, f)$; without access to the financial market, the optimal policy consists of taxation $\{\tau(A, f), \lambda(A, f)\}$.
6. Given government policies, update the staying value for workers $W^s(b, A, f, aut, z)$.
7. Update workers' value $W(b, A, f, aut, z)$.
8. Check the distance $dist_g$ between the updated value function of the government and the one from the last iteration, and the distance $dist_i$ between the updated value function of worker i and the one from last iteration. If any of these distances are larger than the given tolerance levels, then go back to 3. Otherwise, stop.