

# State Taxes and Spatial Misallocation

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We study state taxes as a potential source of spatial misallocation in the U.S. We build a spatial general equilibrium framework that incorporates salient features of the U.S. state tax system, and use changes in state tax rates between 1980 and 2010 to estimate the model parameters that determine how worker and firm location respond to changes in state taxes. We find that heterogeneity in state tax rates leads to aggregate welfare losses. In terms of consumption equivalent units, harmonizing state taxes increases worker welfare by 0.6% if government spending is held constant, and by 1.2% if government spending responds endogenously. Harmonization of state taxes within Census regions achieves most of these gains. We also use our model to study the general equilibrium effects of recently implemented and proposed tax reforms.

*Key words:* State Taxes, Monopolistic Competition, Economic Geography, Misallocation

*JEL Codes:* F12, H71, H73, R12

## 1. INTRODUCTION

Regional fiscal autonomy varies considerably across countries. In some countries, such as France, Japan, and the United Kingdom, regional governments do not set tax policy. In others, such as Germany, Italy, and Spain, regional governments have varying degrees of autonomy to set tax rates, grant tax breaks, and introduce or abolish taxes. As a result, tax rates can vary considerably across regions. Over time, several countries have adjusted their reliance on regional tax policies; for example, Canada, Australia, and India have moved towards greater regional tax harmonization in recent decades. The reasoning from recent research studying dispersion in distortions—across

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firms, as in Restuccia and Rogerson (2008) and Hsieh and Klenow (2009), or across cities, as in Desmet and Rossi-Hansberg (2013)—suggests that regional tax heterogeneity may have negative aggregate effects by distorting the spatial allocation of resources. Early studies of local public finance reinforce this logic by showing that, in some cases, allocative efficiency requires equal tax payments across locations (Flatters *et al.*, 1974; Helpman and Pines, 1980).

To the best of our knowledge, however, no quantitative evidence on the general equilibrium trade-offs between centralized and decentralized tax systems exists. We develop a spatial general equilibrium model that incorporates salient features of the U.S. state tax code and quantify the aggregate effects of dispersion in tax rates across U.S. states. The U.S. is a typical example of a country with a decentralized tax structure, both in terms of the share of total tax revenue collected by regional governments and the degree of spatial dispersion in tax rates.<sup>1</sup> In our model, workers decide where to locate and how many hours to work based on each state's taxes, wage, cost of living, amenities, and availability of public goods, and firms decide where to locate, how much to produce, and where to sell based on each state's taxes, productivity, factor prices, market potential (a measure of other states' market sizes discounted by trade frictions), and provision of public goods. We use the over 350 changes in state tax rates implemented between 1980 and 2010 to estimate the model parameters that determine how workers and firms reallocate in response to changes in state taxes. Using the estimated model, we compute the general equilibrium effects on worker welfare and aggregate income of replacing the current U.S. state tax distribution with counterfactual distributions featuring varying degrees of dispersion in tax rates.

Overall, we find that tax dispersion leads to aggregate losses. In private consumption equivalent units, harmonizing state taxes increases worker welfare by 0.6% if every state's government spending is kept constant. The gains to workers increase to 1.2% when we take into account the impact that the change in taxes would have on each state's government spending. Importantly, most of these gains could be achieved by harmonizing taxes only across states located in the same U.S. Census region. We also use our model to study the general equilibrium effects of recently implemented and proposed state tax reforms, such as the limits to the State and Local Tax (SALT) deduction imposed by the 2017 tax reform. We find that eliminating SALT increases tax dispersion, results in welfare losses, and has heterogeneous effects across states depending on each state's taxes, income distribution, and composition of trading partners.

Our model embeds a canonical local public finance environment with many states, several fixed (land and structures) and mobile (workers and firms) factors of production, and state governments that use the tax revenue to finance the provision of public services which may be valued by workers or used as intermediate goods in production. We generalize this framework in several directions. First, we account for the main sources of tax revenue of U.S. state governments—sales, individual income, and corporate income taxes apportioned through firm sales and factor usage—as well as for federal taxes. Second, we allow states to have heterogeneous productivities, amenities, endowments of fixed factors, and trade frictions with other regions; specifically, we model trade costs using the standard approach in the quantitative trade literature (Eaton and Kortum, 2002; Anderson and van Wincoop, 2003). Third, we assume that firms are monopolistically competitive, as in Dixit and Stiglitz (1977) and Krugman (1980). Fourth, we allow workers' preferences and firms' productivities to have idiosyncratic components that vary across states. These four ingredients allow our model to match the observed responses of workers and firms to changes

1. According to data for the year 2011 from the OECD Fiscal Decentralization Database, the share of total tax revenue collected by U.S. states (20.9%) is very similar to that collected by regions in Germany (21.3%), Spain (23.1%), or Switzerland (24.2%). The standard deviation of the distribution of income tax rates across U.S. states (1.6 percentage points) is similar to that observed across regions in Spain (1.9 percentage points) but smaller than that observed across European Union countries (6.3 percentage points).

in taxes, and to rationalize as an equilibrium outcome of our model the distribution of economic activity and trade flows observed in any given year.

Our framework can be mapped to existing quantitative models of trade and economic geography. We leverage properties of these models to implement counterfactuals with respect to the state tax distribution, since a change to the tax distribution in our model is equivalent to a specific set of changes in amenities, productivities, bilateral trade costs, and trade imbalances in a standard trade and economic geography model such as [Redding and Rossi-Hansberg \(2017\)](#). Importantly, determining this specific set of equivalent changes in fundamentals and trade imbalances requires using the general equilibrium relationships predicted by our model to determine how much tax bases change in the counterfactual.

We rely on a simpler version of our model to establish theoretically how worker welfare and aggregate output depend on features of the U.S. state tax distribution. Eliminating dispersion in state tax rates while keeping government spending constant may have a positive or negative effect on worker welfare. As pointed out by [Wildasin \(1980\)](#), for any fixed arbitrary distribution of public spending, efficiency requires equalization across states of tax payments per worker. The reason is that efficiency requires equalization across locations of the marginal product of labour (which is equal to the wage) net of the marginal social cost of attracting a worker to a location (which is equal to consumption per capita). Absent compensating differentials (as it would be the case in [Hsieh and Klenow, 2009](#)), no dispersion in tax rates implies that tax payments are equalized. What is distinctive about a spatial environment like ours is that wages and consumption per capita vary across locations due to compensating differentials. Therefore, a change in tax rates may either increase or decrease allocative efficiency depending on its impact on the dispersion of tax payments per worker. Specifically, eliminating dispersion in tax rates increases welfare if the cross-state correlation between tax rates and fundamentals (productivity and amenities) is sufficiently large, since eliminating dispersion in tax rates reduces dispersion in tax payments per worker in this case. The impact of tax dispersion on real aggregate income is also theoretically ambiguous: eliminating tax dispersion may increase or decrease aggregate real income depending on the initial correlation between state tax rates and both state amenities and expenditure in public goods.

Four structural parameters are key for determining the impact of any change in taxes on worker welfare and aggregate output: the elasticities of worker and firm mobility with respect to after-tax real earnings and profits, respectively, and the weights that public services have in both workers' preferences and firms' productivity. To estimate these parameters, we use estimating equations derived from our model and a longitudinal dataset containing each state's number of workers and establishments, tax rates, and government revenue between 1980 and 2010. Our model generates a worker-location equation that models each state's employment share as a function of that state's after-tax real earnings and government spending, and a firm-location equation that models each state's share of establishments as a function of that state's after-tax market potential, factor prices, and government spending. We then use observed worker and firm responses to actual changes in taxes and state government spending to estimate the parameters entering these two equations. For example, small estimated partial elasticities of employment shares and firm shares with respect to government spending are rationalized in our model as a consequence of small weights of public services in worker preferences and firm productivity, respectively.

Our estimation procedure uses several approaches to instrument for each state's changes in taxes, factor prices, and government spending. We instrument for these potentially endogenous covariates using either taxes in other states or two Bartik-type instruments that exploit variation in each state's exposure to national industry shocks and national shocks that affect sources of tax revenue differentially. This latter instrument exploits the fact that if, for example, a state's tax revenue comes mostly from sales taxes, then national sales booms will generate especially high

tax revenues for that state. Regardless of instrumentation strategy, the resulting estimates always imply that workers' and firms' location decisions are more responsive to after-tax real wages or profits, respectively, than to government spending. Our baseline estimates yield a partial elasticity of state employment with respect to after-tax real wages of 1.1 and with respect to government spending of 0.2, and a partial elasticity of the share of establishments in a state with respect to after-tax market potential of 0.8 and with respect to government spending of 0.1.

The outcomes of our counterfactuals also depend on state-specific production technologies, productivities, amenities, and trade costs. These additional parameters are calibrated such that the model exactly reproduces, as an equilibrium outcome, the distribution of labour and intermediate-input income shares, wages, employment, trade flows, and trade imbalances across states observed in 2007. We find that the distributions of states' GDP and tax revenue shares in GDP implied by the estimated model are very similar to those observed in the data, even though we do not use this information to quantify the parameters of our model.

Using the estimated model, we implement a series of counterfactuals that demonstrate the importance of state tax dispersion for aggregate outcomes in the U.S. From a theoretical perspective, the question of how the distribution of state tax rates impacts the allocation of workers and firms and, through it, aggregate outcomes, is distinct from the question of how the distribution of state government spending impacts economic activity. Hence, when evaluating each counterfactual distribution of state taxes, we implement the analysis in two steps: first, holding the level of public spending of every U.S. state constant at its initial level; and, second, allowing state spending to change in response to the implied changes in tax revenue. The first step allows us to isolate the impact of the tax distribution operating through spatial efficiency. The second step allows us to take into account the impact of the tax distribution through changes in government spending.

As mentioned above, we find that dispersion in U.S. tax rates across states leads to aggregate welfare and output losses. These results are robust to alternative assumptions on how preferences for government spending vary across states. In particular, they hold both in the extreme case in which we assign zero weight to public services in workers' preferences and firms' productivity, and in the case in which we assume that the observed ratio of government spending to GDP in each state reflects its residents' preferences for public services. These results are also robust to alternative ways of measuring effective state tax rates; *e.g.* adjusting corporate tax rates for the share of establishments in a state that are C-corporations, and adjusting income, sales, and corporate taxes to account for local taxes.

We compute the aggregate implications of partial harmonizations that homogenize tax rates only across subsets of states. We find that, as taxes are harmonized across a greater number of U.S. states, the overall dispersion in tax payments per capita shrinks and, consequently, welfare gains increase. Quantitatively, however, we find that harmonizing taxes across states within the same U.S. Census region generates welfare gains that are similar to those obtained under complete harmonization. This regional harmonization result suggests that regional coordination of tax policies could achieve most of the gains from harmonization across all U.S. states.

Our quantitative results show that the gains from tax harmonization would be different if the distribution of fundamentals across U.S. states were different from that implied by the 2007 data. Consistent with our theoretical analysis, a tax harmonization that keeps government spending constant would lead to a larger increase in worker welfare if there were a higher correlation between initial state tax rates and amenities or productivity. Therefore, the answer to the question of whether a harmonized tax system that keeps government spending constant through a system of transfers is superior to an alternative tax distribution that features dispersion in tax rates across regions will depend both qualitatively and quantitatively on the specific country in question.

In terms of evaluating proposed tax reforms, we focus on the effects of eliminating the SALT deduction, which is one of the largest expenditures in the U.S. tax code and which was substantially reduced by the Tax Cuts and Jobs Act of 2017. Eliminating SALT would increase dispersion in tax payments, since places with high state taxes and high-income taxpayers would pay even higher taxes. Consequently, we find that eliminating SALT reduces welfare by roughly 0.6% and aggregate real GDP by approximately 0.3% if government spending is held constant, and by 0.8% and 0.4%, respectively, if government spending responds endogenously. Southeastern states experience the largest gains. The hardest hit states are those with a large share of high income people and high tax rates, especially in the Northeast. Cross-state trade linkages are also important for determining the winners and losers of the reform. For example, Mississippi enjoys the largest gains in real GDP despite having positive state income taxes, reflecting the concentration of gains in nearby states. Similarly, among states with no state income tax, Florida and Tennessee enjoy larger gains than states like Nevada, which is near states with high income tax rates.

We also use our model to study the general equilibrium impact of actual tax reforms that have taken place in the U.S. in recent years and of potential policy changes currently being discussed. Over the past thirty years, U.S. state tax rates have increased on average, and they have become more reliant on sales taxes. Overall, we find that these changes increased worker welfare and aggregate output, and that these gains are driven in part by less dispersion in tax payments per capita across states.

The rest of the article is structured as follows. Section 2 relates our work to the existing literature. Section 3 describes features of the U.S. state tax system that motivate our analysis. Section 4 introduces our model and describes its general equilibrium implications. Section 5 studies theoretically how dispersion in taxes affects welfare and aggregate output in a simplified version of our model. Section 6 presents our estimation approach, and Section 7 discusses our analysis of counterfactual changes in taxes. Section 8 concludes. We provide additional derivations and figures, and details on both our estimation approach and data sources in an Online Appendix.

## 2. RELATION TO THE LITERATURE

### 2.1. *Misallocation*

Our article contributes to the literature on the aggregate effects of misallocation. Distortions across firms are often measured as an implied wedge between an observed allocation and a model-implied undistorted allocation, as in [Hsieh and Klenow \(2009\)](#). Recent papers have adopted a similar methodology to analyse misallocation across geographic units, such as [Desmet and Rossi-Hansberg \(2013\)](#), [Brandt \*et al.\* \(2013\)](#), [Behrens \*et al.\* \(2017\)](#), and [Hsieh and Moretti \(2018\)](#).<sup>2</sup> These wedges capture distortions that may be due to multiple sources. Rather than inferring distortions from wedges, we focus on quantifying the potential misallocation caused by dispersion in state taxes that we directly observe in the data, and we use the observed variation in these taxes to estimate key model parameters. Similarly, [Albouy \(2009\)](#) studies how federal tax progressivity impacts the allocation of workers and aggregate outcomes.

2. A related literature on spatial misallocation studies rural-urban income gaps; *e.g.* [Gollin \*et al.\* \(2013\)](#) and [Lagakos and Waugh \(2013\)](#) find productivity gaps between agricultural and non-agricultural sectors which are suggestive of misallocation, and [Bryan and Morten \(2018\)](#) study whether these income gaps reflect spatial misallocation.

## 2.2. *Trade and economic geography*

Our framework shares several components with recent quantitative economic geography models, such as [Allen and Arkolakis \(2014\)](#), [Ramondo \*et al.\* \(2016\)](#), [Redding \(2015\)](#), and [Caliendo \*et al.\* \(2018\)](#). Our research question—the impact of state taxes on the U.S. economy—drives our modeling choices, estimation approach, and counterfactuals. Relative to this literature, we incorporate into our framework the main taxes imposed by U.S. states and by the federal government as well as a government sector that uses tax revenue to finance public services valued by workers and firms. Alongside workers with idiosyncratic preferences for location as in [Tabuchi and Thisse \(2002\)](#) and others, we also introduce imperfect firm mobility through firms that receive idiosyncratic productivity draws across states. A central feature of our analysis is that we perform counterfactuals with respect to policy variables that are directly observed (U.S. state tax rates) and use the observed variation in these same policies to identify the key model parameters.

*Fiscal competition.* The literature on fiscal competition, summarized among others by [Oates \(1999\)](#) and [Keen and Konrad \(2013\)](#), typically considers static and perfectly competitive economies with two or more regions and several factors of production, some of which are immobile and some of which are mobile, which may be used to produce a consumption good and a non-traded public good. These basic ingredients are included in our model. Our model generalizes this structure to a multi-region setting in which the distribution of state characteristics can be disciplined using data on the distribution of economic activity. A central question in this literature has been whether jurisdictions setting tax policies according to the equilibrium of a non-cooperative game deliver a socially efficient allocation. A recent quantitative study in the literature is [Ossa \(2018\)](#), who uses an economic geography model with home-market effects to compute the Nash equilibrium of a game where states use lump-sum taxes to finance firm subsidies. Our focus does not involve computing the equilibrium of a non-cooperative game, so it does not require taking a stand on the objective function or the information sets of policymakers, or on the process through which observed taxes are determined.<sup>3</sup>

## 2.3. *Factor mobility in response to tax changes*

We estimate elasticities of firm and worker location with respect to taxes to identify key structural parameters. Evidence on the effect of taxes on worker mobility includes [Bartik \(1991\)](#) and, more recently, [Moretti and Wilson \(2017\)](#). Estimates of worker mobility across regions include [Bound and Holzer \(2000\)](#), [Notowidigdo \(2013\)](#), and [Diamond \(2016\)](#). In terms of firm mobility, [Holmes \(1998\)](#) uses state borders to show that manufacturing activity responds to business conditions, and a large literature studies the impact of local policies on business location. Within

3. Within this literature, a body of work following [Tiebout \(1956\)](#) illustrates how heterogeneity across workers in preferences for government services can play a central role in determining the efficiency properties of tax policies set as the outcome of a non-cooperative game among jurisdictions. Quantifying these heterogeneous preferences for a large set of worker types and states is empirically challenging and, therefore, our model assumes that all workers located in the same state have the same valuation for public spending (but this valuation may vary across states). However, in our counterfactuals that hold real government spending fixed, worker location decisions do not vary depending on how workers value government services but only on how they value changes in after-tax real earnings. We show that our counterfactual results are robust to several alternative approaches to modelling the valuation that workers have for government services. Moreover, within most states, individuals with high valuations of public goods would be able to find a high public good community, and vice-versa for those with low valuations of public goods. Specifically, thirty-six states have a county that spends less than the national 25th percentile of per capita local government spending, and forty-three states have a county that spends more than the national 75th percentile of per capita local government spending.

this literature, [Suárez Serrato and Zidar \(2016\)](#) provide evidence on the impact of corporate taxes on worker and firm mobility, [Suárez Serrato and Wingender \(2016\)](#) show that local economic activity responds to public spending, and [Giroud and Rauh \(2015\)](#) show that C-corporations reduce their activity when states increase corporate tax rates.<sup>4</sup> [Online Appendix D.9](#) compares our estimates to estimates from this prior literature. While the aim of this literature is to quantify the local effects of actual policy changes, we use similar empirical specifications and variation in the data to estimate key parameters of a general equilibrium model, and then use these estimates to study how counterfactual policy changes in one state or simultaneously in many states impact aggregate outcomes in the U.S. economy.<sup>5</sup>

### 3. BACKGROUND ON THE U.S. STATE TAX SYSTEM

Our benchmark analysis focuses on three sources of state tax revenue: personal income taxes, corporate income taxes, and sales taxes. The revenue raised through these three sources accounted, respectively, for 35%, 7%, and 32% of total state tax revenue in 2007, and collectively amounted to 4% of U.S. GDP.<sup>6</sup> In this section, we describe how we model each tax, present statistics summarizing the dispersion in tax rates across states, and provide some evidence on how state taxes relate to cross-state trade flows. [Online Appendix F](#) details the sources of the data we use.

#### 3.1. *Main state taxes*

**3.1.1. Individual income tax.** States tax the individual income of their residents. In 2007, the average state income tax rate was 3.1%; the states with the highest average income tax rates were Oregon (6.0%), North Carolina (5.0%), Minnesota (4.8%), and New York (4.8%), while seven states had no income tax. State income tax rates tend to be progressive, but less so than federal income tax rates. In our analysis, we approximate the schedule of income keep tax rates in each state, defined as one minus the tax rate, through a log-linear function of income  $y$ :  $1 - t_n^y(y) = \alpha_{n,state}^y y^{-b_{n,state}^y}$ . As [Heathcote \*et al.\* \(2017\)](#) recently argue, these functional forms accurately approximate U.S. tax schedules. We compute the parameters of this tax schedule,  $(\alpha_{n,state}^y, b_{n,state}^y)$ , for each state and year using the average effective tax rate from NBER TAXSIM, which runs a fixed sample of tax returns through each state's income tax schedule every year and accounts for most features of the tax code. [Online Appendix Table A.3](#) reports the 2007 income tax schedule parameters.

4. Additionally, [Devereux and Griffith \(1998\)](#) estimate the effect of profit taxes on the location of production of U.S. multinationals, [Goolsbee and Maydew \(2000\)](#) estimate the effects of the labour apportionment of corporate income taxes on the location of manufacturing employment, [Hines \(1996\)](#) exploits foreign tax credit rules to show that investment responds to corporate tax regulations. [Chirinko and Wilson \(2008\)](#) and [Wilson \(2009\)](#) also provide evidence consistent with the view that state taxes affect the location of business activity.

5. Our article is also related to the literature that has analysed the general equilibrium effects of tax changes. [Shoven and Whalley \(1972\)](#) and [Ballard \*et al.\* \(1985\)](#) point out the importance of general equilibrium effects when analysing large changes in policy. See [Nechyba \(1996\)](#) for an early Computable General Equilibrium (CGE) model of local public goods. A large literature in macroeconomics also studies the dynamic effects of taxes in the standard growth and real business cycle model; [Mendoza and Tesar \(1998\)](#), among others, study dynamic effects of taxes in an international setting.

6. We focus on general sales taxes in our analysis. Selective sales taxes (*e.g.* alcohol sales taxes) jointly account for an extra 15% of tax revenue. The biggest remaining category is license taxes (6.2%).

**3.1.2. Corporate income tax.** States also tax businesses. The tax base and tax rate on businesses depend on the legal form of the corporation. In our baseline analysis, we treat all businesses as C-corporations—traditional corporations subject to the corporate income tax—since they account for the majority of businesses’ net income in the U.S.<sup>7</sup> In 2007, the average state corporate income tax rate was 6.6%; the states with the highest corporate tax rates were Iowa (12%), Pennsylvania (10%), and Minnesota (9.8%), while five states had no corporate tax. State tax authorities determine the share of a C-corporation’s national profits allocated to their state using apportionment rules, which aim to measure the corporation’s activity share in their state. To determine this activity share, states put different weight on three apportionment factors: the share of the corporation’s national payroll, property value, and sales. Payroll and property factors thus depend on where goods are produced and typically coincide; the sales factor depends on where goods are sold.<sup>8</sup> Apportionment through sales tends to be more prevalent: thirteen states exclusively apportion through sales, while roughly three quarters of the remaining states apply either a 50% or 33% apportionment through sales.

**3.1.3. Sales tax.** Sales taxes are usually paid by the consumer upon final sale, and states typically do not levy sales taxes on firms for purchases of intermediate inputs or goods that they will resell. In 2007, the average statutory general sales tax rate was 4.9%; the states with the highest sales tax rates were California (7.25%), Mississippi (7%), New Jersey (7%), Maryland (7%), and Tennessee (7%), while five states had no sales taxes.

### 3.2. Stylized facts on state taxes

Figure 1a–c show that tax rates and tax revenue vary considerably across states. Figure 1a shows the 2007 distribution of sales, income, corporate, and sales-apportioned corporate tax rates.<sup>9</sup> Corporate tax rates are the most dispersed; the 90–10 percentiles of the distributions of general sales, average personal income, and corporate income tax rates are 6.8%–1.5%, 4.6%–0%, and 9.2%–1.0%, respectively. For each type of tax, there are at least five states with 0% rates.

These differences in tax structures across states are associated with differences in the total tax revenue collected. Figure 1b shows the distribution of tax revenue as a share of state GDP by type of tax. The share of the sum of income, general sales, and corporate tax revenue in GDP varies across states between 1.1% and 6.5%. Local (sub-state) governments also tax residents. State taxes amount to roughly 65% of state and local tax revenue combined.<sup>10</sup> Figure 1c plots our

7. C-corporations are incorporated and officially registered business entities whose owners enjoy limited liability. The other main type of business entities are private “pass-through” businesses, which are taxed at the owner rather than the entity level, *i.e.* the income that these private businesses earn passes through to the owners, who pay personal income taxes on their share of the firm’s income. C-corporations accounted for 66% of total business receipts in 2007 (PERAB, 2010). In robustness checks, we also explore how our results change when we adjust state corporate tax rates for the fraction of C-corporations revenue in each state’s total business revenue.

8. For example, a single-plant firm  $j$  located in state  $i$  with sales share  $s_{ni}^j$  in each state  $n$  pays a corporate tax rate of  $\bar{t}^j = t_{\text{fed}}^{\text{corp}} + t_i^j + \sum_n s_{ni}^j t_n^x$ , where  $t_{\text{fed}}^{\text{corp}}$  is the federal tax rate,  $t_n^x = \theta_n^x t_n^{\text{corp}}$  is the corporate tax apportioned through sales in state  $n$  (where  $t_n^{\text{corp}}$  is the corporate tax rate of state  $n$  and  $\theta_n^x$  is its sales apportionment), and  $t_i^j = (1 - \theta_i^x) t_i^{\text{corp}}$  is the corporate tax apportioned through property and payroll in state  $i$ .

9. The sales-apportioned corporate tax rate is the product of the sales apportionment factor and the corporate rate; *i.e.*  $t_n^x = \theta_n^x t_n^{\text{corp}}$  (see footnote 8). Table A.2 in Online Appendix F.2 shows the state tax rates in 2007 in all fifty states. Appendix Table A.1 shows the federal income, corporate, and payroll tax rates in 2007.

10. Heterogeneity in tax rates across states is also present when both state and local taxes are taken into account. Figure A.1 in Online Appendix A reproduces Figure 1a using the sum of state and local tax rates. It shows that cross-state differences in tax rates increase when local tax rates are taken into account. Local governments rely mostly on property



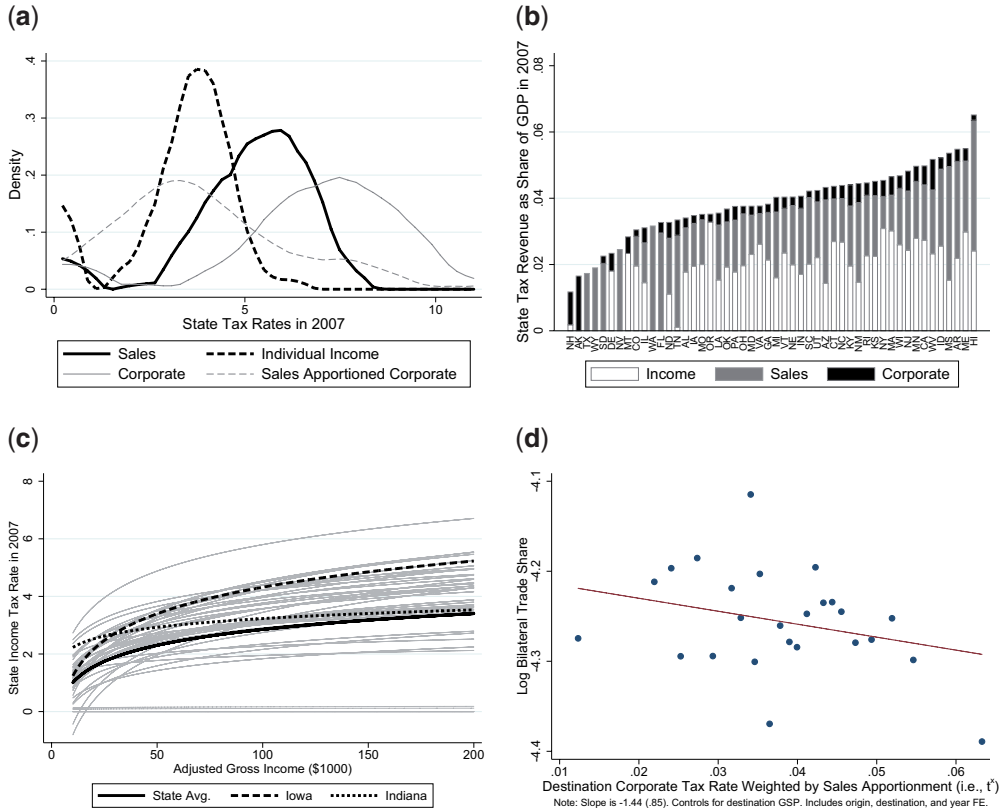


FIGURE 1

Stylized facts on state taxes. (a) Distribution of tax rates across states; (b) tax revenue as share of GDP across states; (c) state tax rate progressivity; (d) trade shares and tax rates

Notes: (a) Shows the density of tax rates across states in 2007. Specifically, sales ( $t_n^c$ ) and corporate income ( $t_n^{corp}$ ) tax rates are statutory, while individual income tax rates ( $t_n^y$ ) are estimated using NBER’s tax simulator TAXSIM. For each state, we compute average state tax liabilities and divide them by average Adjusted Gross Income (AGI) in that state. Finally, we compute sales apportioned corporate income tax rates ( $t_n^x$ ) by multiplying  $t_n^{corp}$  by sales apportionment weights. (b) Shows state government tax revenue as a share of state GDP. Individual income, corporate income, and general sales tax revenues are drawn from Census Government Finances. (c) Shows how average state income tax rates in 2007 vary with taxpayer AGI for each state. For each level of AGI, we compute each state’s tax rate as  $t_{n,state}^y = 1 - a_{n,state}^y - b_{n,state}^y$ . Progressivity is heterogeneous across states. For instance, the effective tax rate in Indiana is higher than Iowa for AGI below \$30K, while the opposite is true for AGI above \$30K. (d) Shows the OLS estimate of the coefficient from a regression of intra-U.S. trade flows on state corporate tax rates. Specifically, we compute bilateral trade shares as  $s_{in} = \frac{x_{in}}{\sum_i x_{in}}$ , where  $x_{in}$  denotes sales from state  $n$  to state  $i$ , and sales-apportioned corporate tax rates ( $t_i^x$ ) in destination states. The panel includes information on bilateral trade flows among the forty-eight contiguous states for the years 1993, 1997, 2002, 2007, and 2012. Each observation is an origin-destination-year triplet. We account for origin state, destination state, and year fixed effects. Observations are weighted by destination state population. Online Appendix Table A.4 provides further evidence on the relationship between state bilateral trade shares and trade-dispersion costs.

estimated individual income tax schedules for all states in 2007. Some states like Indiana have flatter average tax rates as a function of income, whereas others like Iowa have substantially more progressive tax rates. Finally, Figure 1d shows that inter-state exports are lower to destinations with high sales-apportioned corporate taxes (see Table A.4 in [Online Appendix A](#) for additional evidence), after controlling for state and year fixed effects.

### 3.3. State tax revenue and government spending

Besides taxes, transfers from the federal government are a major source of revenue for U.S. state governments. On average across states, these transfers amounted to roughly 3.3% of their GDP in 2007. Once these federal government transfers are taken into account, state governments typically have balanced budgets ([Poterba, 1994](#)). Federal transfers therefore allow state spending to exceed state tax revenue. The actual process determining these transfers is complex. However, empirically, for the period 1980–2010, the size of the total direct expenditures of each state is well approximated by a state-specific multiplier of that state’s tax revenue. Letting  $R_{nt}$  be state  $n$ ’s tax revenue and  $E_{nt}^G = (1 + \psi_n)R_{nt}$  be state  $n$ ’s direct expenditures in year  $t$ , of which  $\psi_n R_{nt}$  is the part financed through federal transfers, the estimates of the regression

$$\ln E_{nt}^G = \ln(1 + \psi_n) + \ln R_{nt} + \varepsilon_{nt} \quad (1)$$

yield an  $R^2$  of 0.97.<sup>11</sup> We adopt this relationship when modeling federal transfers in our quantitative model.

## 4. ECONOMIC GEOGRAPHY MODEL WITH STATE TAXES AND PUBLIC GOODS

We model a closed economy with  $N$  states indexed by  $n$  or  $i$ . A mass of workers, normalized to be of measure one, receives idiosyncratic preference shocks, which impact how they sort across states. After the location decision has been made, each worker receives a productivity draw and chooses how many hours to work. In our baseline model, a fixed mass of firms, also normalized to be of measure one, sorts across states according, in part, to idiosyncratic productivity draws. For robustness, we also examine an alternative model in which firms freely enter each location subject to entry costs. We let  $L_n$  and  $M_n$  be the measure of workers and firms that locate in state  $n$ .

Each state  $n$  has an endowment  $H_n$  of fixed factors of production (land and structures), an amenity level  $u_n$ , and a productivity level  $z_n$ . There is an iceberg cost  $\tau_{ni} \geq 1$  of shipping from state  $i$  to state  $n$  (if one unit is shipped from  $i$  to  $n$ ,  $1/\tau_{ni}$  units arrive). Firms are single-plant and sell differentiated products. They use the fixed factor, workers, and intermediate inputs to produce output. Workers only receive labour income, which they spend in the state where they live. Firms and fixed factors are owned by immobile capital owners exogenously distributed across states.

State governments collect personal income taxes  $t_n^y(y)$  that depend on individual income  $y$ , sales taxes  $t_n^c$ , and corporate income taxes apportioned through sales,  $t_n^x$ , and through payroll and property,  $t_n^l$ . Each state uses the tax revenue to finance the provision of public services, which

taxes. State tax revenue make up roughly 92%, 87%, and 79% of consolidated state and local revenue from income, corporate, and sales taxes, respectively, but only 3% of consolidated property tax revenue.

11. We measure the variable  $E_{nt}^G$  using “state direct expenditures” from the Census of Governments. The main direct-expenditure items include: education, public welfare, hospitals, highways, police, correction, natural resources, parks and recreation, government administration, and utility expenditure. Panel (a) of [Online Appendix Figure A.2](#) illustrates the close relationship between  $E_{nt}^G$  and  $R_{nt}$  in 2007.

enter as shifters of both that state’s amenity and productivity. The sensitivity of a state’s amenity to public services may vary across states.

The federal government collects personal income taxes  $t_{fed}^y(y)$ , payroll taxes  $t_{fed}^w$ , and corporate taxes  $t_{fed}^{corp}$ . Federal taxes are used to finance federal transfers to state governments as well as federal public goods that benefit any worker independently of their location (*e.g.* national defense).

#### 4.1. Workers

A continuum of workers  $l \in [0, 1]$  decides in which state to work and consume. Each worker  $l$  observes a vector  $\{\epsilon_n^l\}_{n=1}^N$  of idiosyncratic state-specific preferences and decides the state of residence. Then, the worker discovers her own productivity level  $z_n^l$  in that state. This productivity draw captures heterogeneity in job opportunities and gives rise to a non-degenerate income distribution within each state. After observing her productivity in state  $n$ , each worker  $l$  chooses her number of working hours,  $h_n^l$ . The total income of a worker  $l$  in state  $n$  is thus  $w_n h_n^l z_n^l$ , where  $w_n$  is the wage per efficiency unit and  $h_n^l z_n^l$  are the efficiency units that worker  $l$  supplies in that state.

Workers have preferences over amenities, public goods, and final consumption goods, and experience disutility from working.<sup>12</sup> The direct utility of a worker who lives in state  $n$ , consumes  $c_n$  units of the private good, and works  $h_n$  hours is  $\epsilon_n^l U_n(c_n, h_n)$ , where

$$U_n(c, h) = u_n g_n^{\alpha_{W,n}} c^{1-\alpha_{W,n}} d_n(h). \tag{2}$$

The amenity level  $u_n$  captures both natural characteristics, like the weather, and the rate at which the government transforms total real spending into services valued by workers; this rate includes the fraction of the state budget used to finance public services valued by workers. It may also capture utility from a national public good provided by the federal government. The parameter  $\alpha_{W,n}$  captures the weight of state-provided services in preferences. This weight may vary across states, reflecting complementarities between state-specific features such as the weather or natural amenities and government services. In turn, real government spending enjoyed by each worker in state  $n$ ,  $g_n$ , equals total real government spending,  $G_n$ , normalized by a function of the total number of workers living in state  $n$ ,  $L_n^{\chi_W}$ :

$$g_n = \frac{G_n}{L_n^{\chi_W}}. \tag{3}$$

The parameter  $\chi_W$  captures the degree to which public goods are rival, and ranges from  $\chi_W = 0$  (non-rival) to  $\chi_W = 1$  (rival). Workers also face disutility from effort, captured by the term  $d_n(h)$ . This disutility function is allowed to vary by state in order to give the model enough flexibility to match cross-state differences in the per-worker number of hours worked. The indirect utility of a worker  $l$  living in state  $n$  is  $\epsilon_n^l v_n$ , where

$$v_n \equiv \mathbb{E}_n \left[ \max_h U_n(c_n(w_n h z), h) \right] \tag{4}$$

12. The framework could be generalized to allow for direct consumption of the fixed factor by workers in the form of housing. Furthermore, housing supply could be allowed to be elastic. While adding these elements would be straightforward, measuring state-specific property taxes or housing supply elasticities would be less so because they vary considerably across cities within states, as documented by Saiz (2010).

is the expected value over the possible realizations of the individual productivity shock  $z$  in state  $n$ , and where  $c_n(y)$  is the quantity of final goods consumed by an individual with income  $y$  in state  $n$ . We refer to  $v_n$  as the “appeal” of state  $n$ .

From the consumer’s budget constraint, and letting  $P_n$  be the price of the final good in state  $n$ , the final good consumption of an individual with income  $y$  living in state  $n$  is

$$c_n(y) = \frac{1 - T_n(y)}{P_n} y, \quad (5)$$

where the real keep-tax rate is

$$1 - T_n(y) \equiv \frac{(1 - t_{fed}^y(y))(1 - t_n^y(y))}{1 + t_n^c}. \quad (6)$$

This formulation takes into account that state income taxes can be deducted from federal taxes.

The idiosyncratic taste draw  $\epsilon_n^l$  is assumed to be independent and identically distributed across individuals  $l$  and states  $n$ . Hence, the fraction of workers located in state  $n$  is  $L_n = \Pr[n = \arg \max_{n'} v_{n'} \epsilon_n^l]$ . Assuming that the idiosyncratic taste draws follow a Fréchet distribution,  $\Pr(\epsilon_n^l < x) = \exp(-x^{-\varepsilon_W})$  with  $\varepsilon_W > 1$ , then

$$L_n = \left(\frac{v_n}{v}\right)^{\varepsilon_W}, \quad (7)$$

where

$$v \equiv \left(\sum_n v_n^{\varepsilon_W}\right)^{1/\varepsilon_W}. \quad (8)$$

The ex-ante expected utility of a worker over the distribution of taste draws  $\{\epsilon_n^l\}_{n=1}^N$  is proportional to  $v$ . A larger value of  $\varepsilon_W$  implies that idiosyncratic taste draws are less dispersed across states; as a result, locations become closer substitutes and an increase in the relative appeal of a location (an increase in  $v_n/v$ ) leads to a larger response in the fraction of workers who choose to locate there.

We make additional functional-form assumptions to reach a closed-form solution for  $v_n$ . First, we assume log-linear keep-tax schedules at the state and federal levels:  $1 - t_n^y(y) = a_{n,\text{state}}^y y^{-b_{n,\text{state}}^y}$  and  $1 - t_{fed}^y(y) = a_{fed}^y y^{-b_{fed}^y}$ . These schedules are progressive (regressive) when the coefficients  $b_{n,\text{state}}^y$  and  $b_{fed}^y$  adopt positive (negative) values. Together with (6), these forms imply

$$1 - T_n(y) = \frac{a_n^y y^{-b_n^y}}{1 + t_n^c}, \quad (9)$$

where

$$a_n^y \equiv a_{fed}^y (a_{n,\text{state}}^y)^{1-b_{fed}^y}, \quad (10)$$

$$b_n^y \equiv b_{n,\text{state}}^y + b_{fed}^y - b_{n,\text{state}}^y b_{fed}^y. \quad (11)$$

Second, we assume disutility from hours worked of the form

$$d_n(h) = \exp\left(-\alpha_{h,n} \frac{h^{1+1/\eta}}{1+1/\eta}\right). \quad (12)$$

Together with (4), this functional form implies that utility is separable between consumption and leisure and, thus, all workers in a state  $n$  work the same number of hours:

$$h_n = \left( \frac{1 - \alpha_{W,n}}{\alpha_{h,n}} (1 - b_n^y) \right)^{\frac{1}{1+1/\eta}}. \quad (13)$$

Finally, we assume that productivity draws across workers located in state  $n$  follow a Pareto distribution with scale and shape parameters  $(z_{L,n}, \zeta_n)$ :

$$\Pr \left[ z_n^l \leq Z \right] = 1 - \left( \frac{Z}{z_{L,n}} \right)^{-\zeta_n}. \quad (14)$$

This assumption leads to the empirically consistent prediction of a fat-tailed income distribution. The expressions (9)–(14) imply the following solution for the common component of utility defined in (4):

$$v_n = \frac{\zeta_n}{\zeta_n - (1 - b_n^y)(1 - \alpha_{W,n})} u_n g_n^{\alpha_{W,n}} \left( \frac{a_n^y}{(1 + t_n^c) P_n} \left( w_n z_{L,n} (h_n e^{-1})^{\frac{1}{1+1/\eta}} \right)^{1 - b_n^y} \right)^{1 - \alpha_{W,n}}. \quad (15)$$

Equation (15) captures several forces determining workers' location. The first term reflects wage heterogeneity within the state. Wage heterogeneity vanishes as  $\zeta_n \rightarrow \infty$ , in which case the individual productivity distribution converges to a mass point at  $z_{L,n}$ . The average returns to locating in state  $n$  are also a function of the common component of amenities, public spending per capita, after-tax wages, and hours worked.

From the definitions of  $L_n$  and  $v_n$  in (7) and (15), the partial elasticity of the share of workers who locate in state  $n$  with respect to the nominal wage per efficiency unit is  $\varepsilon_W (1 - b_n^y)(1 - \alpha_{W,n})$  while  $\varepsilon_W \alpha_{W,n}$  is the partial elasticity with respect to real government services per worker,  $g_n$ . We will rely on these relationships to estimate  $\varepsilon_W$  and  $\{\alpha_{W,n}\}_{n=1}^N$  in Section 6.2.

#### 4.2. Capital owners

Immobile capital owners located in state  $n$  own a fraction  $\omega_n$  of a portfolio that includes the profits of all firms in the economy and the payments to all fixed factors. In our model, a larger ownership rate relative to other states results in larger trade imbalances. Therefore, we will calibrate the ownership shares  $\omega_n$  to match the observed trade imbalances across states.<sup>13</sup> Capital owners spend their income locally, pay sales taxes on consumption, and pay the highest marginal rate for both federal and state income taxes (Cooper *et al.*, 2016). We do not need to specify the number of capital owners or their utility function at any stage of our analysis.

#### 4.3. Final good

In each state, a competitive sector assembles a final good from differentiated varieties through a constant elasticity of substitution aggregator with elasticity  $\sigma$ ,

$$Q_n = \left( \sum_i \int_{j \in J_i} (q_{ni}^j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}, \quad (16)$$

13. Two alternative modeling approaches would be to assume that all workers own equal shares of the national portfolio, or that the returns of that portfolio are spent outside of the model. Under these approaches, the model would lead to empirically inconsistent predictions for trade imbalances across states.

where  $J_i$  denotes the set of varieties produced in state  $i$  and  $q_{ni}^j$  is the quantity of variety  $j$  produced in state  $i$  which is used for production of the final good in state  $n$ . Letting  $p_{ni}^j$  be the price of this variety in state  $n$ , the cost of producing one unit of the final good in state  $n$  (and also its price before sales taxes) is

$$P_n = \left( \sum_i \int_{j \in J_i} (p_{ni}^j)^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}}. \quad (17)$$

The final good  $Q_n$  is non-traded and can be used by consumers (workers and capital-owners) for aggregate consumption of workers and capital owners ( $C_n^L$  and  $C_n^K$ ), by firms as an intermediate input in production ( $I_n$ ), and by state governments ( $G_n$ ) and the federal government ( $G_n^{fed}$ ) as an input for the supply of public services:

$$Q_n = C_n^L + C_n^K + I_n + G_n + G_n^{fed}. \quad (18)$$

#### 4.4. Firms

In our baseline model, we assume that there exists a fixed mass of firms which must decide in which state to locate.<sup>14</sup> Assuming that these firms heterogeneous in terms of their productivity across locations, this approach enables us to use data on firms' location choices to estimate a parameter determining the elasticity of the number of firms located in a state with respect to its taxes. In this approach, taxes do not affect the mass of firms in the economy. To account for this possible effect of taxes, we also explore the implications of an alternative model that features free entry of firms with homogeneous productivity to each location, as in [Krugman \(1991\)](#) and [Helpman \(1998\)](#). We describe the main implications of this alternative model at the end of this section.

**4.4.1. Production technologies.** Each firm  $j \in [0, 1]$  produces a differentiated variety and is endowed with state-specific productivities  $\{z_i^j\}_{i=1}^N$ . To produce quantity  $q_i^j$  in region  $i$ , firm  $j$  combines its own productivity in that location  $z_i^j$ , a fixed factor  $h^j$ , efficiency units of labour  $l^j$ , and intermediate inputs  $i^j$ , through a Cobb–Douglas technology:

$$q_i^j = z_i^j \left[ \frac{1}{\gamma} \left( \frac{h^j}{\beta} \right)^\beta \left( \frac{l^j}{1-\beta} \right)^{1-\beta} \right]^\gamma \left( \frac{i^j}{1-\gamma} \right)^{1-\gamma}, \quad (19)$$

where  $\gamma$  is the value-added share in production and  $1-\beta$  is the labour share in value added. The fixed factor acts as a source of congestion: the higher the number of firms and workers located in a given state, the higher the relative price of this fixed factor.

**4.4.2. Profit maximization given firm location.** Each firm decides in which state to produce and how much to sell in every state. Firms are monopolistically competitive. Consider a firm  $j$  located in state  $i$  whose productivity is  $z$ . Its profits are

$$\pi_i(z) = \max_{\{q_{ni}^j\}} \left( 1 - \bar{\tau}_i^j \right) \left( \sum_{n=1}^N x_{ni}^j - \frac{c_i}{z} \sum_{n=1}^N \tau_{ni} q_{ni}^j \right), \quad (20)$$

14. This modelling approach is similar to [Martin and Rogers \(1995\)](#). See also Chapter 3 of [Baldwin et al. \(2005\)](#).

where  $\bar{r}_i^j$  is the corporate tax rate of firm  $j$  if it were to locate in state  $i$ ,  $x_{ni}^j = P_n Q_n^{\frac{1}{\sigma}} (q_{ni}^j)^{1-\frac{1}{\sigma}}$  are its sales to state  $n$ , and

$$c_i = \left( \left( (1 + t_{fed}^w) w_i \right)^{1-\beta} r_i^\beta \right)^\gamma P_i^{1-\gamma} \tag{21}$$

is the the minimum unit cost of a bundle of factors and intermediate inputs, where  $w_i$  is the wage per efficiency unit,  $r_i$  stands for the cost of a unit of land and structures in state  $i$  and  $t_{fed}^w$  are federal payroll taxes. This definition of  $c_i$  accounts for the fact that, unlike consumers, firms do not face sales taxes when purchasing the final good to use it as an intermediate.

All firms face corporate taxes apportioned through sales, payroll, and land and structures. A firm  $j$  located in state  $i$  whose share of sales to state  $n$  is  $s_{ni}^j$  pays a share  $s_{ni}^j t_n^x$  of its pre-tax national profits in corporate taxes to state  $n$ . Firms located in  $i$  also pay a fraction  $t_i^l$  of its pre-tax national profits in corporate taxes to state  $i$ , and a rate  $t_{fed}^{corp}$  in federal corporate income taxes. As a result, the overall corporate tax rate of firm  $j$  is:

$$\bar{r}_i^j = t_{fed}^{corp} + t_i^l + \sum_{n=1}^N t_n^x s_{ni}^j. \tag{22}$$

Due to the sales apportionment of corporate taxes, the decision of how much to sell in each state is not separable across states. When a firm increases the fraction of its sales to state  $n$  (*i.e.* when  $s_{ni}^j$  increases), the average tax rate on the firm’s national profits changes depending on the sales-apportioned corporate tax in state  $n$ ,  $t_n^x$ . Firms thus trade off the marginal pre-tax benefit of exporting more to a given state against the potential marginal cost of increasing the corporate tax rate on all its profits.

**4.4.3. Pricing distortion through corporate taxes.** Despite the non-separability of the sales decision across markets, the solution to the firm optimization problem in (20) retains convenient aggregation properties inherited from the standard CES maximization problem with constant marginal production costs in [Krugman \(1980\)](#) or [Melitz \(2003\)](#). We describe these properties here and refer to [Online Appendix B.1](#) for details. Specifically, all firms located in a state  $i$  choose the same sales shares across destinations irrespective of their productivity; *i.e.*  $s_{ni}^j = s_{ni}$  for all firms  $j$  located in  $i$ . From (22), this property leads to a common corporate tax rate across firms,  $\bar{r}_i^j = \bar{r}_i$ . Additionally, firms set identical, constant markups over marginal costs, but these markups vary bilaterally depending on corporate taxes. The price set in  $n$  by a firm with productivity  $z$  located in state  $i$  is:

$$p_{ni}(z) = \tau_{ni} \frac{\sigma}{\sigma - \tilde{r}_{ni}} \frac{\sigma}{\sigma - 1} \frac{c_i}{z}, \tag{23}$$

where

$$\tilde{r}_{ni} \equiv \frac{t_n^x - \sum_{n'} t_{n'}^x s_{n'i}}{1 - \bar{r}_i}. \tag{24}$$

The term  $\tilde{r}_{ni}$  is a pricing distortion due to heterogeneity across states in the sales-apportioned corporate tax rates. This distortion increases with the sales tax in the importing state,  $t_n^x$ , implying that prices will be higher in states with higher sales-apportioned corporate taxes.<sup>15</sup> If sales-apportioned corporate tax rates were common across all states ( $t_n^x = t^x$  for all  $n$ , and, thus  $\tilde{r}_{in} = 0$

15. This relationship is consistent with the stylized fact shown in [Figure 1d](#) and the regressions in [Online Appendix A.2](#).

for all  $i$  and  $n$ ), firms' prices would be as predicted in the standard CES framework; *i.e.* the markup over marginal cost would equal  $\sigma/(\sigma - 1)$ .

**4.4.4. Firm location choice.** We assume that firm-level productivity  $z_i^j$  can be decomposed into a term  $z_i^0$  common to all firms located in  $i$  and a firm- and state-specific component  $\epsilon_i^j$ , *i.e.*  $z_i^j = z_i^0 \epsilon_i^j$ . The common component of productivity is assumed to be:

$$z_i^0 = \left( \frac{G_i}{M_i^{\chi_F}} \right)^{\alpha_F} z_i^{1-\alpha_F}. \quad (25)$$

This common component has an endogenous part that depends on the amount of public spending and an exogenous part,  $z_i$ . The endogenous part equals total real government spending,  $G_i$ , divided by a function of the number of firms located in state  $i$ ,  $M_i^{\chi_F}$ , where the parameter  $\chi_F$  captures rivalry among the mass of firms  $M_i$  in the access to public goods. The exogenous part captures natural characteristics that impact productivity, like natural resource availability, the rate at which the government transforms real spending into services valued by firms, and the share of public goods provided by state governments that increase the productivity of the firms located in their states. Firm  $j$  decides to locate in state  $i$  if  $i = \operatorname{argmax}_i \pi_i(z_i^j)$ . The idiosyncratic component of productivity,  $\epsilon_i^j$ , is independent and identically distributed across firms and states and is drawn from a Fréchet distribution,  $\Pr(\epsilon_i^j < x) = \exp(-x^{-\varepsilon_F})$ . As a result, the profits of firm  $j$  when it locates in state  $i$ ,  $\pi_i(z_i^j) = \pi_i(z_i^0)(\epsilon_i^j)^{\sigma-1}$ , are also Fréchet-distributed with shape parameter  $\varepsilon_F/(\sigma - 1) > 1$ . The fraction of firms located in state  $i$  is thus

$$M_i = \left( \frac{\pi_i(z_i^0)}{\bar{\pi}} \right)^{\frac{\varepsilon_F}{\sigma-1}}, \quad (26)$$

where  $\pi_i(z)$  is defined in (20) and  $\bar{\pi}$  is proportional to the expected profits before drawing the idiosyncratic productivity shocks  $\{\epsilon_i^j\}_{i=1}^N$ . Equation (26) indicates that the fraction of firms located in  $n$  depends on the common component of profits in  $n$ ,  $\pi_i(z_i^0)$ , relative to that in other locations. A larger value of  $\varepsilon_F/(\sigma - 1)$  implies that the idiosyncratic productivity draws are less dispersed across states; as a result, states become closer substitutes and an increase in the relative profitability of a state leads to a larger response in the fraction of firms that choose to locate in it.

**4.4.5. Equilibrium state productivity distribution and aggregation.** As firms choose where to locate based on their state-specific productivity draws, the productivity distribution in each state is endogenous. State-level outcomes can be formulated as a function of a single moment  $\tilde{z}_i$  of the productivity distribution in each state  $i$ .<sup>16</sup>

$$\tilde{z}_i = z_i^0 M_i^{-\frac{1}{\varepsilon_F}}. \quad (27)$$

The productivity of the representative state- $i$  firm,  $\tilde{z}_i$ , is larger than the unconditional average of the distribution of productivity draws (*i.e.*  $\tilde{z}_i > z_i^0$ ), reflecting selection. This equation describes

16. By definition,  $\tilde{z}_i = (\int_{j \in I_i} (z_i^j)^{\sigma-1} dj)^{\frac{1}{\sigma-1}}$ . To reach (27), we use the equality  $\pi(\tilde{z}_i) = \bar{\pi}$  (implied by the Fréchet assumption on the distribution of productivity draws), equation (26), and the relationship  $\pi_i(z_i^0)/\pi_n(\tilde{z}_i) = (z_i^0/\tilde{z}_i)^{\sigma-1}$ .



one of the congestion forces in the model: as firms are heterogeneous and self-select based on productivity, a higher number of firms locating in a state  $i$  is associated with lower average productivity in that state.

Aggregate outcomes in state  $i$  can be constructed as if all of the  $M_i$  firms located there had the (endogenous) productivity level  $\tilde{z}_i$ . [Online Appendix B.2](#) presents the expressions for the state-level outcomes needed to compute the general equilibrium of the model.

**4.4.6. Alternative model with free entry of firms.** For robustness, we also perform counterfactuals under the alternative assumption of free entry in each state  $i$  of firms with a common productivity level  $z_i^0$  defined in (25). Conditional on entering state  $i$ , firms solve the problem (20) for  $z = z_i^0$ , leading also to (22) to (24). To enter state  $i$ , firms must pay a cost equal to  $f_{E,i}$  units of the cost-minimizing bundle of factors and inputs  $c_i$  in (21). In this alternative model, the zero-profit condition  $\pi_i(z_i^0) = c_i f_{E,i}$  determines the number of firms in each state  $i$ . [Online Appendix B.2](#) presents the expressions for the state-level outcomes needed to compute the general equilibrium of the model under this free entry assumption. As in the baseline model, the number of firms in each state turns out to also be proportional to aggregate sales in the state.<sup>17</sup>

#### 4.5. State governments

State governments use state tax revenue  $R_n$  and transfers from the federal government  $T_n^{fed \rightarrow st}$  to finance spending in public services,  $P_n G_n$ . The budget constraint of state  $n$  is thus

$$P_n G_n = R_n + T_n^{fed \rightarrow st}, \tag{28}$$

where the tax revenue collected by the state is

$$R_n = R_n^{corp} + R_n^y + R_n^c, \tag{29}$$

and where  $R_n^{corp}$ ,  $R_n^c$ , and  $R_n^y$  denote government revenue from corporate, sales, and income taxes, respectively. These expressions are defined in (A.15) to (A.17) in [Online Appendix B.2](#).

Consistent with the empirical evidence in Section 3.3, we assume that transfers from the federal government to state governments are proportional to the tax revenue collected by these state governments, where the constant of proportionality  $\psi_n$  may vary by state:  $T_n^{fed \rightarrow st} = \psi_n R_n$ . Combined with (28), this relationship implies that  $P_n G_n = (1 + \psi_n) R_n$ . While the distribution of federal transfer rules  $\{\psi_n\}_{n=1}^N$  impacts all model outcomes in levels, they do not have any impact on the counterfactual results we report in Section 7.

#### 4.6. Federal government

The federal government uses income and corporate taxes to finance transfers to state governments and to purchase the final good produced in each state,  $G_n^{fed}$ , which it employs as an input in the production of a national public good. Our analysis assumes that public services from the federal government are valued in the same way across locations.

17. Under free entry, the number of firms in state  $i$  is  $M_i = (1 - \bar{t}_i) X_i / (\sigma c_i f_{E,i})$ . Under a fixed mass of ex-ante heterogeneous firms,  $M_i = (1 - \bar{t}_i) X_i / (\sigma \bar{\pi})$ . The free-entry model has thus an additional parameter per state, the entry cost  $f_{E,i}$ , which can be calibrated to exactly match the observed number of firms per state. However, as illustrated in Section 6.4, the distribution of firms across states is well approximated by our baseline model.

#### 4.7. General equilibrium

A general equilibrium of this economy consists of distributions of workers and firms  $\{L_n, M_n\}_{n=1}^N$ , aggregate quantities  $\{Q_n, C_n^L, C_n^K, I_n, G_n, G_n^{fed}\}_{n=1}^N$ , wages per efficiency unit and cost of fixed factors  $\{w_n, r_n\}_{n=1}^N$ , and final good prices  $\{P_n\}_{n=1}^N$  such that: (1) final good producers optimize, setting their prices according to (17); (2) workers make consumption, work hours and location decisions optimally, as described in Section 4.1; (3) budget constraints of capital owners hold; (4) firms make production, sales, and location decisions optimally, as described in Section 4.4; (5) government budget constraints hold, as described in Section 4.5; (6) final good markets clear in every location, *i.e.* (18) holds for all  $n$ ; (7) the labour market clears in every state, *i.e.* labour supply (7) equals labour demand (given by (A.7) in Online Appendix B.2) for all  $n$ ; (8) the land market clears in every state, *i.e.* (A.8) in Online Appendix B.2 holds; and (9) the national labour market clears, *i.e.*,  $\sum_n L_n = 1$ .

#### 4.8. Adjusted fundamentals and implementation of counterfactuals

According to our model, taxes in any state may affect outcomes in every state. However, as shown in Online Appendix B.3, state tax rates  $\{t_n^c, t_n^y(\cdot), t_n^x, t_n^l\}_{n=1}^N$  only impact state outcomes through their effect on a set of *adjusted fundamentals*,  $\{\tau_{in}^A\}_{i=1}^N, z_n^A, u_n^A\}_{n=1}^N$ ,

$$z_n^A = \left( \frac{1 - \bar{t}_n}{\sigma - 1} \right)^{\frac{1}{\sigma-1} - \left( \frac{1}{\varepsilon_F} + \alpha_F \chi_F \right)} G_n^{\alpha_F} z_n^{1-\alpha_F}, \quad (30)$$

$$\tau_{in}^A = \frac{\sigma}{\sigma - \bar{t}_{in}} \tau_{in}, \quad (31)$$

$$u_n^A = \left( \frac{1 - T_n(z_n^L w_n)}{1 + t_n^c} \right)^{1-\alpha_{W,n}} G_n^{\alpha_{W,n}} u_n, \quad (32)$$

and on the set of relative trade imbalances  $\{P_n Q_n / X_n\}_{n=1}^N$  (*i.e.* the ratio between state expenditures and sales). Adjusted fundamentals  $(z_n^A, \tau_{in}^A, u_n^A)$  become identical to state fundamentals (productivity  $z_n$ , amenity  $u_n$ , and trade costs  $\tau_{in}$ ) if we assume away preferences for government spending ( $\alpha_F = \alpha_{W,n} = 0$ ) and set all tax rates to zero.

In our model, the distribution of outcomes across states depends on the distributions of adjusted fundamentals and relative trade imbalances similarly to how it depends on the state fundamentals and relative trade imbalances in standard economic geography models such as Allen *et al.* (2014) or Redding (2015). Therefore, the effect of a counterfactual change in the tax distribution predicted by our model is identical to the effect of a specific set of changes in amenities, productivities, trade costs, and trade imbalances in a standard economic-geography model. Importantly, the mapping from taxes to adjusted fundamentals and relative trade imbalances depends on the specific features of the tax system that we incorporate in our framework. Thus, to compute our model-predicted impact of counterfactual changes in the tax distribution, we simultaneously use a mapping from changes in fundamentals to changes in outcomes that is standard in existing economic-geography models, as well as a mapping from changes in taxes to changes in adjusted fundamentals that is specific to our environment. The first mapping is presented in (A.35) to (A.42) in Online Appendix B.5, and the second one in (A.43) to (A.46).

#### 4.9. Agglomeration and congestion forces

Our model features agglomeration forces that push workers and firms to locate in the same state, as well as congestion forces that push them to spread across different states. Specifically, our model features agglomeration through standard home market effects. Because of trade costs, workers (who consume final goods) and firms (which purchase intermediate inputs) have an incentive to locate near or in states with low price indices and large markets; in turn, the price index of a state decreases with the number of firms located in that state, and its market size increases with the number of workers located in it. Our model also features agglomeration through public service provision as long as public goods are not fully rival (*i.e.* as long as either  $\chi_F$  or  $\chi_W$  are less than one). States with a larger number of firms and workers have higher tax revenue and public spending and, thus, higher utility per worker (see (4)) and firm productivity (see (25)).

At the same time, our baseline model features congestion through immobile factors in production, leading to a higher marginal production cost in a state as employment increases in that state (see (A.18) in [Online Appendix B.2](#)); through selection of heterogeneous firms, leading to a lower average firm productivity in a state as the number of firms increases (see (27)); and through the presence of immobile capital owners, who spend their income where they are located.<sup>18</sup>

### 5. IMPACT OF TAX DISPERSION IN SIMPLE THEORETICAL FRAMEWORKS

In this section, we discuss theoretically how changes in the dispersion in state tax rates holding government spending constant in every state impacts two aggregate outcomes: the welfare of the representative U.S. worker, as defined in (8), and the aggregate real income of all factors. We defer to Section 7 for a discussion of the additional effects caused by the changes in government spending implied by the changes in taxes.

We consider a special case of the model presented in Section 4. We assume away trade frictions, workers' intensive margin of labour supply, and heterogeneity in firms and workers, and impose that the public good is non-rival. We also assume that state sales and income taxes are the only taxes in the economy. This simplified version retains the ingredients of existing frameworks in the macro and local public finance literatures, including key spatial economics forces such as location-specific amenities and local congestion through fixed factors of production. We provide here an intuitive discussion of the predictions of this simplified model followed by formal propositions, and relegate the proofs to [Online Appendix C](#). As we shall see in Section 7, the intuitions derived in this simpler model hold up in the full quantitative model.

To gain intuition, suppose momentarily that, in addition to the restrictions from the previous paragraph, there were no differences in public spending per capita or amenities across states ( $g_n = g$  and  $u_n = u$  for all  $n$ ). In this case, the production side of the model would be the same as in standard models of labour allocation across firms, such as [Hsieh and Klenow \(2009\)](#), where the aggregate production function of each location can be interpreted as a firm. Spatial efficiency,

18. When there is no dispersion in sales-apportioned corporate taxes across states ( $t_n^x = t^x$  for all  $n$ ), no cross-ownership of assets across states, and same preferences for government spending across states ( $\alpha_{W,n} = \alpha_W$  for all  $n$ ), our baseline model fits in the class of models studied by [Allen et al. \(2014\)](#). Conditions (A.33) and (A.34) in [Online Appendix B.4](#) show the restrictions to our model parameters implied by the relevant uniqueness condition included in that paper. Our baseline estimates satisfy these restrictions. While we do not derive an analogous uniqueness condition for the general version of our model, we have found no evidence of multiple equilibria in the system of equations we employ to compute the counterfactual predictions discussed in Section 7. Specifically, when numerically computing these counterfactual predictions, we experiment with multiple different starting values of our algorithm and always find the same results, suggesting that the system of equations we employ to compute such predictions indeed has a unique solution.

defined as any allocation on the utility frontier that takes into account the utility of workers and capital owners, would then be attained by maximizing total output through equalization of the marginal products of labour across locations,  $MPL_n = MPL_{n'}$  for all  $n$  and  $n'$ .

In this context, dispersion in tax rates would create dispersion in marginal products, which is inefficient. To see why, note that in any spatial equilibrium workers must be indifferent about where to locate, leading to the same consumption per worker everywhere. That is, denoting as  $c_n^L$  the consumption of a worker in state  $n$ , any spatial equilibrium with homogeneous workers would require  $c_n^L = c_{n'}^L$  for any two states  $n$  and  $n'$ . In a world without trade costs, uniform per-capita consumption across states would imply that after-tax wages would be equal across any two states; *i.e.*,  $(1 - T_n)w_n = (1 - T_{n'})w_{n'}$ . Since wages equal marginal products, spatial dispersion in sales or income tax rates entering in  $T_n$  would result in spatial dispersion in the marginal product of labour, and in a spatial equilibrium that is inefficient.

Consider now the more relevant case in which public spending per capita and amenities differ across states. Given any distribution of these variables, spatial efficiency is no longer attained by maximizing total output. Instead, it requires the equalization of  $MPL_n - c_n^L$  across locations. To see why, note that reallocating a worker from one location to another entails an output gain (equal to the difference in the marginal product of labour across those two locations) as well as a cost in terms of final goods consumed (equal to the difference in the per capita consumption  $c_n^L$  of those two locations). In any spatial equilibrium of this more general model, consumption per worker  $c_n^L$  will vary across locations to compensate for the differences in public spending per capita and amenities. Because  $MPL_n = w_n$ , this means that  $w_n - c_n^L$ , the tax payment per worker, must be equalized across locations for efficiency. This point was established by [Flatters \*et al.\* \(1974\)](#), [Wildasin \(1980\)](#), and [Helpman and Pines \(1980\)](#). Note that, as a result, efficiency now requires dispersion in the marginal product of labour across locations.

We summarize these results in the following proposition.

**Proposition 1** Consider a tax structure with only sales and income taxes. Assume no trade costs ( $\tau_{in} = 1$  for all  $i, n$ ), perfect substitutability across varieties ( $\sigma \rightarrow \infty$ ), homogeneous firms ( $\varepsilon_F \rightarrow \infty$ ), homogeneous workers with constant labour supply ( $\varepsilon_W \rightarrow \infty$ ,  $\zeta_n \rightarrow \infty$  and  $h_n$  constant), and non-rival public goods ( $\chi_W = 0$ ). Then:

- (i) ([Hsieh and Klenow, 2009](#)) In the absence of compensating differentials ( $g_n$  and  $u_n$  constant across locations), no dispersion in state wages,  $w_n$ , is necessary for efficiency. This requirement implies that no dispersion in tax rates  $T_n$  across states is necessary for efficiency.
- (ii) ([Flatters \*et al.\*, 1974](#); [Wildasin, 1980](#); [Helpman and Pines, 1980](#)) In the presence of compensating differentials ( $g_n$  and  $u_n$  may vary across locations), no dispersion in state wages minus personal consumption expenditures,  $w_n - c_n^L$ , is necessary for efficiency. This requirement implies that no dispersion in the per capita tax payments  $T_n w_n$  across states is necessary for efficiency.

The first part of this proposition is a special case of the second one. In the absence of compensating differentials, we have that  $(1 - T_n)w_n = (1 - T_{n'})w_{n'}$  for all states  $n$  and  $n'$ . Therefore, the condition of tax payment equalization established in the second part of the proposition implies tax rate equalization. As pointed out by [Wildasin \(1980\)](#), this reasoning holds for any arbitrary distribution of public service provision, including the efficient one, and regardless of whether that distribution is determined within the model to satisfy a government budget constraint or exogenously given. Under more general conditions than those assumed in the proposition, some dispersion in per capita tax payments may be required for efficiency. However,

in assessing the implications of the full quantitative model, we shall see that the intuition provided by the second part of Proposition 1 is consistent with the results: the gains from changes in tax rates given a distribution of spending in public services are larger in counterfactuals in which the reduction in the dispersion in tax payments per capita is larger.

Proposition 1 implies that, given a distribution of spending in public services, an elimination of dispersion in tax rates will increase the efficiency of the allocation if it reduces the dispersion of the tax payments per capita,  $T_n w_n$ . The next proposition formalizes that the impact of dispersion in tax rates on dispersion in tax payments per capita depends on the relationship between state tax rates and fundamentals in the initial allocation.

**Proposition 2** In addition to the restrictions from Proposition 1, assume no cross-state dispersion in preferences for government spending ( $\alpha_{W,n} = \alpha_W$  for all  $n$ ). Then, eliminating the dispersion in the real keep-tax rates (i.e. setting  $T_n = T$  for all  $n$ ), while keeping constant both its mean and the government spending in every state:

- (i) increases worker welfare if  $corr(Z_n^{\frac{1}{\beta}}, (1 - T_n)^{\frac{1}{\beta}})$  is low enough, and decreases worker welfare if  $corr(Z_n^{\frac{1}{\beta}}, (1 - T_n)^{\frac{1}{\beta}})$  is large enough, where  $Z_n = (z_n^0 / \gamma)^{1/\gamma} H_n^\beta (u_n G_n^{\alpha_W})^{\frac{1}{1-\alpha_W}}$ ; and
- (ii) may increase or decrease the aggregate real income depending on the joint distribution of  $T_n$ ,  $u_n$ , and  $G_n$ .

The first part of the proposition reflects that, when the correlation between  $T_n$  and fundamentals is sufficiently large (in the sense that  $corr(Z_n^{\frac{1}{\beta}}, (1 - T_n)^{\frac{1}{\beta}})$  is low enough), so is the correlation between taxes and wages, leading to high dispersion in tax payments per capita in the initial allocation.<sup>19</sup> In this case, eliminating dispersion in  $T_n$  increases welfare through less dispersion in tax payments per capita. To understand the second part of Proposition 2, bear in mind that aggregate real income is maximized when marginal products of labour are equalized across regions. Therefore, eliminating dispersion in worker keep tax rates will increase or decrease aggregate real income depending on whether this change in the tax system reduces or increases cross-state dispersion in the marginal product of labour. It is straightforward to construct examples in which an elimination of tax dispersion reduces output; for example, this result may happen in cases with an initially negative correlation between keep tax rates and amenities.<sup>20</sup> However, as implied by the first part of Proposition 1, an elimination of tax dispersion will necessarily increase aggregate output if there is no dispersion in compensating differentials ( $u_n = u$  for all  $n$  and either  $G_n = G$  for all  $n$  or  $\alpha_W = 0$ ).

An important implication of Proposition 2 is that the model described in Section 4 includes forces pushing aggregate outcomes in opposite directions in response to a reduction in the dispersion in income and sales taxes. Furthermore, the relative strength of these opposing forces and thus the resulting impact of such a counterfactual change in taxes depends on the value of parameters such as the amenities and productivities of each state.

19. In the proof of Proposition 2 in [Online Appendix C](#), we provide a more general correlation condition that does not impose restrictions on  $\varepsilon_W$  and  $\chi_W$ .

20. For example, let  $A_n \equiv u_n G_n^{\alpha_W}$  and  $B_n = (1 - T_n)^{1-\alpha_W}$ . Consider a case with two states,  $n = 1, 2$  and two levels of keep tax rates,  $B_1 = 1/A_1$  and  $B_2 = 1/A_2$ . In this case, output is maximized because marginal products of labour are equalized across both states in equilibrium ( $v^{1/(1-\alpha_W)} = MPL_n$  for  $n = 1, 2$ ). Therefore, in this example, eliminating tax dispersion increases dispersion in marginal products, reducing output.

## 6. DATA AND ESTIMATION

This section describes how we quantify the model parameters. Section 6.1 discusses the calibration of the production function, preference parameters, state fundamentals, and ownership of capital by state. Section 6.2 discusses the estimation of the elasticities of employment and firm mobility with respect to state taxes, and the estimation of the weights of public goods on workers' preferences and firms' productivity. Section 6.3 describes how these parameter estimates collectively determine the location of workers and firms. Section 6.4 shows that the estimated model matches features of data not used in our parametrization. [Online Appendix F](#) describes the data sources that we use.

6.1. *Calibrated parameters*

**6.1.1. Production technologies, preference parameters, and the distribution of efficiency units.** The value-added share  $\gamma$  and share of labour in value added  $1-\beta$  are calibrated from KLEMS Data for the U.S. We use 2007 data to compute  $1-\gamma=0.45$  as the ratio of expenditure in intermediate inputs to gross output, and  $1-\beta=0.62$  as the ratio of labour compensation to gross value added. In our model, the elasticity of substitution across varieties  $\sigma$  impacts the partial elasticity of import shares with respect to bilateral trade costs. A common practice in the international trade literature is to identify this elasticity from variation in tariffs across countries. No tariff applies to the exchange of goods between U.S. states, complicating the estimation of  $\sigma$  in our context. Therefore, we set its value to 4, which is a central value in the range of estimates used in the international trade literature; see [Head and Mayer \(2014\)](#). We set the disutility of effort  $\eta=2.84$  following [Chetty \*et al.\* \(2011\)](#). Finally, the parameters  $(z_{L,n}, \zeta_n)$  that characterize the distribution of efficiency units within each state are chosen to match the distribution of hourly wages across individuals within each state, as described in [Online Appendix D.2.1](#).

**6.1.2. Fundamentals.** The system of equations (A.35)–(A.46) that characterizes the general equilibrium impact of changes in taxes, described in [Online Appendix B.5](#), is a function of all fundamentals across states (endowments of land and structures  $H_n$ , productivities  $z_n$ , parameters  $\zeta_n$  and  $z_{L,n}$  of the skill distributions, amenities  $u_n$ , disutility from labour  $\alpha_{h,n}$ , trade costs  $\tau_{in}$ , and, in the version of the model with free entry of firms, entry costs  $f_{E,n}$ ). According to this system, these fundamentals affect the equilibrium of the economy through the joint distribution of expenditures, sales revenue, and employment shares across states. This property of the system of equilibrium conditions allows us to compute the effect of counterfactual changes in these fundamentals without having to separately determine the value of each different fundamental.<sup>21</sup> Specifically, one only needs to set the composite of the fundamentals  $A_{in}$  defined in (A.29) to be consistent with the observed expenditure shares through (A.27).<sup>22</sup>

**6.1.3. Ownership rates.** Equation (A.23) in [Online Appendix B.2](#) shows that the set of ownership rates  $\{\omega_n\}_{n=1}^N$  are uniquely identified as a function of observables, technology

21. This feature of our model is shared by the trade and economic geography models discussed in the Introduction. [Dekle \*et al.\* \(2008\)](#) show how to undertake counterfactuals with respect to trade costs without having to identify all fundamentals separately.

22. [Online Appendix Table A.5](#) shows that the model-predicted relation between the composite of the fundamentals  $A_{in}$  and proxies of both trade costs between states  $i$  and  $n$  and amenities in each of these two states are consistent with the data.

parameters in state  $n$ , and the parameter  $\sigma$ . The parametrized model exactly matches the distribution of trade imbalances across states in 2007. We measure these trade imbalances as the ratio of aggregate expenditures to sales.

## 6.2. Estimated elasticities

In this section, we describe how we estimate the parameters governing the dispersion of workers' idiosyncratic preferences for each state,  $\varepsilon_W$ , the share of public goods in worker preferences,  $\{\alpha_{W,n}\}_{n=1}^N$ , the dispersion of firms' idiosyncratic productivities in each state,  $\varepsilon_F$ , and the share of public goods in firms' productivity,  $\alpha_F$ . [Online Appendix D.9](#) shows that our baseline estimates are in line with the previous literature, which relies on alternative identifying assumptions.

### 6.2.1. Estimation of workers' location preferences and value of public goods.

Combining the definition of the state appeal in (4), the labour supply equation in (7), the expression for hours worked in (13), and the government budget constraint in (28), we obtain the following expression for the share of workers living in state  $n$ :

$$\ln L_{nt} = a_{0,n} \ln \tilde{y}_{nt} + a_{1,n} \ln \tilde{R}_{nt} + a_{2,n} \ln A_{nt} + \psi_t^L + \xi_n^L + v_{nt}^L, \quad (33)$$

where the coefficients  $a_{0,n} \equiv \varepsilon_W(1 - \alpha_{W,n}) / (1 + \chi_W \varepsilon_W \alpha_{W,n})$ ,  $a_{1,n} \equiv \varepsilon_W \alpha_{W,n} / (1 + \chi_W \varepsilon_W \alpha_{W,n})$  and  $a_{2,n} \equiv \varepsilon_W / (1 + \chi_W \varepsilon_W \alpha_{W,n})$  are functions of structural parameters. The variables  $\tilde{y}_{nt}$  and  $\tilde{R}_{nt}$  are measures of after-tax real labour earnings and real government spending, respectively, and  $A_{nt}$  is a measure of within-state wage dispersion. Specifically:

$$\tilde{y}_{nt} \equiv \frac{a_{nt}^y}{1 + t_{nt}^c} \frac{(h_{nt} z_n^L w_{nt})^{1 - b_{nt}^y}}{P_{nt}}, \quad (34)$$

$$\tilde{R}_{nt} \equiv \frac{R_{nt}}{P_{nt}}, \quad (35)$$

$$A_{nt} \equiv \frac{\zeta_n}{\zeta_n - (1 - b_{nt}^y)(1 - \alpha_{W,n})}. \quad (36)$$

Finally, the term  $\psi_t^L + \xi_n^L + v_{nt}^L \equiv (\varepsilon_W / (1 + \chi_W \varepsilon_W \alpha_{W,n})) \ln u_{nt} / v_t$  accounts for year and state fixed effects and deviations from these state and year fixed effects in states' amenities,  $u_{nt}$ . To construct the covariates in (34)–(36), we measure state-specific after-tax labour earnings combining hours and earnings data from the March Current Population Survey (CPS), information on sales tax rates from the Book of States and on income tax rates from NBER's TAXSIM, and regional price index data from the Bureau of Labor Statistics (BLS). We construct a measure of real government spending as the sum of sales, individual income, and corporate income tax revenue reported in the U.S. Census of Governments divided by the corresponding regional price index. The wage dispersion term  $A_{nt}$  depends on the wage distribution parameter  $\zeta_n$ , income tax schedule parameter  $b_{nt}^y$  (from NBER's TAXSIM), and the structural parameter  $\alpha_{W,n}$ . We provide in [Online Appendix F.3](#) detailed descriptions of how we construct each of these covariates.

The structural parameters  $\{\alpha_{W,n}\}_{n=1}^N$  enter (33) through  $\{(a_{0,n}, a_{1,n})\}_{n=1}^N$  and  $\{A_{nt}\}_{n=1}^N$ . In practice, as shown in [Online Appendix Table A.8](#), the terms  $\{A_{nt}\}_{n=1}^N$  have minimal effect on the estimates. Therefore, intuitively, we can think of the parameter  $\alpha_{W,n}$  as being identified by the vector  $(a_{0,n}, a_{1,n})$ ; *i.e.*,  $\alpha_{W,n} = a_{1,n} / (a_{0,n} + a_{1,n})$ . The parameters  $\varepsilon_W$  and  $\chi_W$  are however not separately identified from the coefficients in (33) alone. We thus present estimates of the parameter  $\varepsilon_W$  conditional on different values of  $\chi_W$ .

*Endogeneity.* If state amenities  $\{u_{nt}\}_{n=1,t=1}^{N,T}$  are not fully captured by the year  $\{\psi_t^L\}_{t=1}^T$  and state  $\{\xi_n^L\}_{n=1}^N$  fixed effects, our model predicts that the state-year specific error term in (33),  $v_{nt}^L$ , will be correlated with the regressors  $\tilde{y}_{nt}$  and  $\tilde{R}_{nt}$ . The key source of this correlation is the impact that amenities have on the location of workers. If, for example, there is a positive amenity shock in California, then workers will move to this state. This outward shift of the labour supply curve would lower wages, thus causing a reduction in the after-tax labour earnings in California. Thus, following a positive amenity shock, we would observe an increase in the number of workers in California. *Ceteris paribus*, this inflow of workers would generate a decrease in wages and, as a result, after-tax labour earnings. This negative correlation between amenity improvements and after-tax labour earnings would tend to generate a downward bias in Ordinary Least Squares (OLS) estimates of the parameters  $\{a_{0,n}\}_{n=1}^N$ . Similarly, our model predicts that an amenity-induced increase in the number of workers in a state raises tax revenue in this state, therefore increasing government service provision and generating a positive correlation between amenity improvements in a state and the state's real government spending. This positive correlation would tend to generate an upward bias in the OLS estimates of  $\{a_{1,n}\}_{n=1}^N$ . Since our estimates of the parameters capturing workers' preferences for government services in state  $n$ ,  $\alpha_{W,n}$ , are decreasing in our estimates of the reduced-form parameter  $a_{0,n}$  and increasing in our estimates of  $a_{1,n}$ , OLS estimates of  $a_{W,n}$  will tend to be biased upwards. To obtain consistent estimates of  $\{a_{W,n}\}_{n=1}^N$ , we rely on two different sets of instruments: (1) a vector of "external" state tax rates  $\mathbf{Z}_{nt}^T$ ; and (2) a vector of Bartik-type instruments  $\mathbf{Z}_{nt}^B$ .

*Instruments.* For each state  $n$ , the instrument vector  $\mathbf{Z}_{nt}^T$  is a weighted-average of tax rates in states other than  $n$ . Specifically,  $\mathbf{Z}_{nt}^T \equiv (t_{nt}^{*c}, t_{nt}^{*y}, t_{nt}^{*x})$  is a vector of inverse-distance weighted averages of sales (indexed as  $c$ ), income ( $y$ ), and sales-apportioned corporate ( $x$ ) tax rates in every state other than  $n$ :

$$t_{nt}^{*z} \equiv \sum_{i \neq n} d_{ni} t_{it}^z, \quad \text{with} \quad d_{ni} = \frac{\ln(\text{dist}_{ni})^{-1}}{\sum_{i' \neq n} \ln(\text{dist}_{ni'})^{-1}} \quad \text{for} \quad z = c, y, x. \quad (37)$$

These instruments will be relevant as long as they affect after-tax earnings and tax revenues in state  $n$ . Our model is consistent with the relevance of the instrument vector  $\mathbf{Z}_{nt}^T$ : it predicts that, for example, an income tax increase in Oregon would cause some workers to move to other states, affecting the after-tax equilibrium earnings and total tax earnings in the states to which they move. Conversely, our model does not take a stand on the political process that determines states' tax rates and, thus, is silent about the validity of the instrument vector  $\mathbf{Z}_{nt}^T$ . However, all variables in vector  $\mathbf{Z}_{nt}^T$  are valid instruments if changes in taxes in nearby states are not correlated with state  $n$ 's residual amenity level  $v_{nt}^L$ .

Our second instrument vector  $\mathbf{Z}_{nt}^B \equiv (\text{BtkP}_{nt}, \text{BtkTR}_{nt})$  includes two Bartik (1991)-type instruments:

$$\begin{aligned} \text{BtkP}_{nt} &= \sum_k \frac{L_{kn,1974}}{L_{n,1974}} \frac{\text{PAY}_{kt} - \text{PAY}_{k,t-10}}{\text{PAY}_{k,t-10}}, \\ \text{BtkTR}_{nt} &= \sum_{\tau \in \{c,y,x\}} \frac{REV_{\tau,n,1974}}{REV_{n,1974}} \frac{REV_{\tau,t} - REV_{\tau,t-10}}{REV_{\tau,t-10}}, \end{aligned} \quad (38)$$

where  $k$  indexes one-digit SIC industries,  $\text{PAY}$  denotes real annual payroll,  $\tau$  indexes different types of taxes (*i.e.*, personal income taxes, corporate income taxes, and sales taxes), and  $REV$



denotes tax revenue. The instrument  $\text{BtkP}_{nt}$  uses variation in each state's exposure to national industry shocks.<sup>23</sup> For example, if a state  $n$  is very dependent on a particular industry  $k$  (*i.e.*  $L_{kn,1974}/L_{n,1974}$  is high) and this industry experiences relative growth at the national level, then after-tax real earnings in state  $n$  are likely to grow. The instrument  $\text{BtkTR}_{nt}$  uses variation in each state's exposure to revenue-source national shocks. Suppose a state relies mostly on sales taxes for tax revenue (*i.e.*  $REV_{\text{sales},n,1974}/REV_{n,1974}$  is relatively high), then national sales booms (*i.e.*  $(REV_{\tau,t} - REV_{\tau,t-10})/REV_{\tau,t-10}$  is relatively high for  $\tau = \text{sales}$ ) will cause especially high tax revenues for that state and, consequently, a growth in government spending. Empirically, initial revenue-share weighted national tax revenue shocks are good predictors of state tax revenue changes.<sup>24</sup>

We use data on  $\tilde{y}_{nt}$ ,  $\tilde{R}_{nt}$ , and  $A_{nt}$ , a fixed value of  $\chi_W$ , and a vector of instruments  $\mathbf{Z}_{nt}^L$  (where  $\mathbf{Z}_{nt}^L$  may equal either  $\mathbf{Z}_{nt}^T$  or  $\mathbf{Z}_{nt}^B$  or both) to identify the parameters  $\varepsilon_W$  and  $\{\alpha_{W,n}\}_{n=1}^N$  using the following moment conditions:

$$\mathbb{E}[v_{nt}^L * (\mathbf{Z}_{nt}^L, \boldsymbol{\xi}^L, \boldsymbol{\psi}^L)'] = 0, \tag{39}$$

where  $v_{nt}^L$  is the residual from (33). This orthogonality restriction assumes that the state-year specific amenity shocks,  $v_{nt}^L$ , are mean independent of the vector of instruments  $\mathbf{Z}_{nt}^L$ , conditional on  $\boldsymbol{\xi}^L$ , which denotes a complete set of state dummies, and  $\boldsymbol{\psi}^L$ , which denotes a complete set of year dummies. Given the unconditional moment conditions in (39), we use the optimal two-step Generalized Method of Moments (GMM) estimator (Hansen, 1982) to estimate the parameters of interest. We report the resulting estimates in Table 1.

*Estimates of worker preferences.* Our estimates exploit several approaches to deal with the potential variability in  $\alpha_{W,n}$  across states.

First, we impose the assumption that  $\alpha_{W,n} = \alpha_W$  for every state  $n$ . Conditional on imposing that public goods enjoyed by workers are rival (*i.e.*  $\chi_W = 1$ ), our estimates of  $\varepsilon_W$  and  $\alpha_W$  using external taxes as instruments,  $\mathbf{Z}_{nt}^L = \mathbf{Z}_{nt}^T$ , equal 2.1 and 0.23, with standard errors 0.8 and 0.07, respectively. The results using the Bartik-style instruments,  $\mathbf{Z}_{nt}^L = \mathbf{Z}_{nt}^B$ , are similar. Combining both vectors of instruments,  $\mathbf{Z}_{nt}^L = (\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B)$ , we obtain estimates of  $\varepsilon_W$  and  $\alpha_W$  equal to 1.73 and 0.16. We use this last set of estimates as our baseline specification.

Second, we allow for workers' preferences for public goods to vary by state and use the observed ratio of tax revenue to GDP in each state to calibrate the corresponding parameter  $\alpha_{W,n}$ . Specifically, we assume that  $\alpha_{W,n} = R_n/GDP_n$ , where  $R_n/GDP_n$  denotes the average ratio of tax revenue to GDP during the sample period. This approach yields estimates of  $\alpha_{W,n}$  between 0.01 and 0.06. Conditional on these calibrated values of the parameter vector  $\{\alpha_{W,n}\}_{n=1}^N$  and  $\chi_W = 1$ , the resulting estimate of  $\varepsilon_W$  is 1.48 (0.33).

Third, rows five and six present estimates of  $\varepsilon_W$  under two alternative assumptions. First, we impose again the assumption that  $\alpha_{W,n} = \alpha_W$  for every state  $n$  and calibrate the value of  $\alpha_W$  to equal the cross-state mean value of the states' tax revenue to GDP ratio (*i.e.*,  $\alpha_{W,n} = 0.04$ ). Second, we impose the extreme assumption that public services have no impact on workers' utility (*i.e.*,  $\alpha_{W,n} = 0$  for every state  $n$ ). Under these assumptions, we obtain estimates of  $\varepsilon_W$  equal to 1.25 (0.35) and 1.04 (0.3), respectively.

23. There is a recent literature exploring the properties of shift-share instruments. See Goldsmith-Pinkham *et al.* (2018) and Borusyak *et al.* (2018) for a discussion of identification approaches in this setting. See Adão *et al.* (2018) for discussion of inference procedures.

24. See, *e.g.*, columns 2 and 5 of Online Appendix Table A.11, which shows a regression of the endogenous covariates in (33) on  $\text{BtkP}_{nt}$  and  $\text{BtkTR}_{nt}$ . Online Appendix Table A.13 shows a similar table for firms. Online Appendix D.6 and D.7 provide additional discussion.

TABLE 1  
GMM estimates of worker parameters

Instruments	Restrictions on $\alpha_{W,n}$	$\varepsilon_W$		$\alpha_W$	
		$\chi_W = 0$	$\chi_W = 1$	$\chi_W = 0$	$\chi_W = 1$
$\mathbf{Z}_{nt}^T$	$\alpha_{W,n} = \alpha_W$	1.42*** (0.36)	2.1*** (0.8)	0.23*** (0.07)	0.23*** (0.07)
$\mathbf{Z}_{nt}^B$	$\alpha_{W,n} = \alpha_W$	1.79*** (0.63)	2.25** (0.93)	0.11* (0.06)	0.11* (0.07)
$\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B$	$\alpha_{W,n} = \alpha_W$	1.36*** (0.3)	1.73*** (0.52)	0.16*** (0.06)	0.16*** (0.07)
$\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B$	$\alpha_{W,n} = \frac{R_n}{GDP_n}$	0.75*** (0.23)	1.48*** (0.33)		
$\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B$	$\alpha_W = 0.04 = \text{Mean} \frac{R_n}{GDP_n}$	1.19*** (0.32)	1.25*** (0.35)		
$\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B$	$\alpha_W = 0$	1.04*** (0.3)	1.04*** (0.3)		

Notes: This table shows the GMM estimates for structural parameters entering the labour mobility equation. The data are at the state-year level. Each column uses information on 712 observations. Every specification includes state and year fixed effects. Observations are weighted using state population. The instrument vectors used to compute the estimates in each row are indicated under the heading “Instruments”. Similarly, restrictions on  $\alpha_{W,n}$  are described under the heading “Restrictions on  $\alpha_{W,n}$ ”. Robust standard errors are in parentheses and \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

As columns 1 and 3 in Table 1 show, imposing instead the assumption that public goods are non-rival (*i.e.*,  $\chi_W = 0$ ) does not affect the estimated value of  $\alpha_W$ , and only slightly decreases the estimates of  $\varepsilon_W$ . [Online Appendix D.6](#) provides additional estimates, robustness tests, and discussion.

*Interpretation of estimates of worker preferences.* Our model assumes that workers can move across locations without any need to pay a fixed cost of moving. Consequently, the estimating equation in (33) predicts that the share of workers located in a state in any given period depends exclusively on that period’s values of after-tax labour earnings and real government spending. In a more general model with fixed costs of mobility, the population share in a location in a period  $t$  would depend on the corresponding share in every location in period  $t - 1$ . Furthermore, in this general model, a permanent change in any of the economic determinants of workers’ locations will have a different impact on the short and long run. While building a fully dynamic model of worker location is beyond the scope of this article, we present in [Online Appendix D.8](#) simulation results that explore how close our estimates are to capturing the long-run impact of after-tax real earnings and real government spending on the number of workers living in each state.<sup>25</sup> Our simulation shows that, given the large amount of persistence in all the regressors entering (33), our estimates of  $\{(a_{0,n}, a_{1,n})\}_{n=1}^N$  are closer to the true long-run than to the short-run impact of changes in these regressors on the number of workers living in each state. Consistent with this finding, re-estimating  $\varepsilon_W$  and  $\alpha_W$  under the assumption that each period in our model corresponds to a half-decade yields only modestly larger estimates for  $\varepsilon_W$  and very similar estimates of  $\alpha_W$ .

**6.2.2. Estimation of firms’ location preferences and value of public goods.** Combining the pricing equation in (23), the definition of productivity in (25), the firm-location equation in (26), and the definition of profits in (A.10), our model yields the following expression for the

25. For general equilibrium models of labour mobility that allow for migration costs, see [Aruç et al. \(2010\)](#) and [Caliendo et al. \(2015\)](#).

share of firms in state  $n$ :

$$\ln M_{nt} = b_0 \ln((1 - \bar{t}_n) MP_{nt}) + b_1 \ln c_{nt} + b_2 \ln \tilde{R}_{nt} + \psi_t^M + \xi_n^M + v_{nt}^M, \quad (40)$$

where  $b_0 \equiv (\varepsilon_F / (\sigma - 1)) / (1 + \chi_F \alpha_F \varepsilon_F)$ ,  $b_1 \equiv -\varepsilon_F / (1 + \chi_F \alpha_F \varepsilon_F)$ , and  $b_2 \equiv -\alpha_F b_1$ ;  $\psi_t^M$  is a time effect, and  $\xi_n^M + v_{nt}^M$  accounts for state effects and deviations from state and year effects in log productivity,  $\ln z_{nt}$ . Unit costs are  $c_{nt} = (w_{nt}^{1-\beta} r_{nt}^\beta)^\gamma P_{nt}^{1-\gamma}$ .<sup>26</sup>  $MP_{nt}$  is the market potential of state  $n$  in year  $t$ ,

$$MP_{nt} = \sum_{n'} E_{n't} \left( \frac{\tau_{n't}}{P_{n't}} \frac{\sigma}{\sigma - \bar{t}_{n't}} \frac{\sigma}{\sigma - 1} \right)^{1-\sigma}, \quad (41)$$

where  $E_{n't} \equiv P_{n't} Q_{n't}$  denotes aggregate expenditures in state  $n'$ . The market potential of state  $n$  is a measure of the market size for a firm located in state  $n$ , once trade costs with other states are taken into account. Details on how we construct measures of all the covariates entering (41) are in [Online Appendix D.2.1](#).

Given values of the reduced-form parameters  $b_0$ ,  $b_1$ , and  $b_2$ , the impact of government spending on productivity is identified as  $\alpha_F = -b_2/b_1$ .<sup>27</sup> The parameters  $\varepsilon_F$  and  $\chi_F$  are however not separately identified from the coefficients in (40) alone. We thus present estimates of the parameter  $\varepsilon_F$  conditional on different values of  $\chi_F$ .

The problem of endogeneity in this case arises from the potential that unobserved productivity shocks in  $v_{nt}^M$  may be positively correlated with local wages, and therefore with  $c_n$ . Since firms are likely to locate in more productive places, such a shock might bias  $b_1$  towards a positive value. This bias, in turn, may bias  $\alpha_F$  towards zero, and may even result in a negative value. We overcome this problem by using a similar set of instruments as the ones we use to estimate the worker location equation.

Conditional on assumed values of  $\chi_F$  and  $\sigma$ , we estimate parameters  $\varepsilon_F$  and  $\alpha_F$  using an optimal two-step GMM estimator that uses the following moment conditions:

$$\mathbb{E}[v_{nt}^M * (\mathbf{Z}_{nt}^M, \boldsymbol{\xi}^M, \boldsymbol{\psi}^M)'] = 0, \quad (42)$$

where  $\mathbf{Z}_{nt}^M = (\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B, MP_{nt}^*)$  is a vector of instruments,  $\boldsymbol{\xi}^M$  denotes a full set of state dummies, and  $\boldsymbol{\psi}^M$  denotes a full set of year dummies. The instrument vector  $\mathbf{Z}_{nt}^T$  is as defined in (37). The instrument vector  $\mathbf{Z}_{nt}^B$  combines the instrument  $\text{BtkTR}_{nt}$  defined in (38) with the following Bartik-type instrument:

$$\text{BtkW}_{nt} = \sum_k \frac{L_{kn,1974}}{L_{n,1974}} \frac{W_{kt} - W_{k,t-10}}{W_{k,t-10}},$$

where  $W_{kt}$  denotes the average hourly wage in industry  $k$  and year  $t$ . The reason why we substitute the instrumental variable  $\text{BtkP}_{nt}$  used in the estimation of workers' location preferences and public goods for the instrumental variable  $\text{BtkW}_{nt}$  is that the endogenous variable in this case is unit costs, which depend on hourly wages rather than total earnings. Finally, the instrument  $MP_{nt}^*$  is an exogenous shifter of market potential, as defined in [Online Appendix D.3](#).

26. We define here the unit cost exclusive of the federal payroll tax, which is absorbed by the time effect. That is,  $\psi_t^M \equiv -\varepsilon_F / ((\sigma - 1)(1 + \chi_F \alpha_F \varepsilon_F)) \ln(\sigma \bar{\pi}_t) + b_1(1 - \beta) \gamma \ln(1 + t_{fed}^w)$  and  $\xi_n^M + v_{nt}^M \equiv (1 - \alpha_F) \varepsilon_F / (1 + \chi_F \alpha_F \varepsilon_F) \ln z_{nt}$ .

27. One could try to identify the parameter vector  $\sigma$  using (40) and (41). However, the identification of  $\sigma$  from these equations is very sensitive to the particular proxy that we adopt for the trade costs between any two regions  $n$  and  $n'$ ,  $\tau_{n't}$ . Given that we do not have a precise measure of these trade costs, we fix  $\sigma$  to a standard value in the international trade literature (see Section 6.1 for details).

TABLE 2  
GMM estimates of firm parameters

Instruments	Restrictions on $\alpha_F$	$\varepsilon_F$		$\alpha_F$	
		$\chi_F = 0$	$\chi_F = 1$	$\chi_F = 0$	$\chi_F = 1$
$\mathbf{Z}_{nt}^T$	None	2.45*** (0.27)	2.84*** (0.62)	0.06 (0.07)	0.06 (0.07)
$\mathbf{Z}_{nt}^B$	None	2.81*** (0.36)	2.46*** (0.46)	-0.05 (0.08)	-0.05 (0.08)
$\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B$	None	2.44*** (0.27)	2.63*** (0.46)	0.03 (0.06)	0.03 (0.06)
$\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B$	$\alpha_F = 0.04 = \text{Mean} \frac{R_n}{GDP_n}$	2.43*** (0.26)	2.7*** (0.32)		
$\mathbf{Z}_{nt}^T, \mathbf{Z}_{nt}^B$	$\alpha_F = 0$	2.45*** (0.26)	2.45*** (0.26)		

Notes: This table shows the GMM estimates for structural parameters entering the firm mobility equation. The data are at the state-year level. Each column uses information on 587 observations. The number of observations is lower than in Table 1 due to missing data in variables required to construct the measures of market potential and unit costs (see [Online Appendix D.3](#) for details). Every specification includes state and year fixed effects. The instrument vectors used to compute the estimates in each row are indicated under the heading “Instruments”. Similarly, restrictions on  $\alpha_F$  are described under the heading “Restrictions on  $\alpha_F$ ”. Robust standard errors are in parentheses and \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

As Table 2 shows, conditional on assuming that public goods enjoyed by firms are rival (*i.e.*,  $\chi_F = 1$ ) and relying solely on the external tax instruments,  $\mathbf{Z}_{nt}^T$ , we obtain estimates of  $\varepsilon_F$  and  $\alpha_F$  equal to 2.84 and 0.06, with standard errors 0.62 and 0.07, respectively. As in Table 1, the second row estimates only use the Bartik-type instruments in the vector  $\mathbf{Z}_{nt}^B$ , which yields an estimate of  $\varepsilon_F$  equal to 2.46 (0.46), and an estimate of  $\alpha_F$  that, although negative, is not statistically different from zero. The third row combines both types of instruments, which yields our baseline firm estimates for  $\varepsilon_F$  and  $\alpha_F$  of 2.63 and 0.03, respectively. The final two rows present estimates in which we calibrate  $\alpha_F$  and estimate  $\varepsilon_F$  subject to the calibrated value of  $\alpha_F$ . We use two different calibration strategies for  $\alpha_F$ . First, similar to the calibration performed on  $\alpha_W$  above, we assume that  $\alpha_F$  is equal to the cross-state average of tax revenue over GDP; *i.e.*,  $\alpha_F = 0.04$ . As our baseline estimate of  $\alpha_F$  is very close to this value, the impact of this calibration on our estimate of  $\varepsilon_F$  is minimal. Second, we impose the extreme assumption that firms’ productivity is unaffected by the provision of government services; *i.e.*,  $\alpha_F = 0$ . In this case, we obtain an estimate of  $\varepsilon_F$  that is somewhat smaller than the baseline estimate when public goods are assumed to be rival,  $\chi_F = 1$ , and almost the same as the baseline estimate when they are assumed to be non-rival,  $\chi_F = 0$ . [Online Appendix D.7](#) provides supplemental estimates and discussion.

### 6.3. Reduced-form elasticities

The estimated coefficients from the third row of Table 1, which is our baseline, imply that the change in employment in state  $n$  is consistent with the estimated relationship:

$$\ln L_{nt} = 1.14 * \ln \tilde{y}_{nt} + 0.22 * \ln \tilde{R}_{nt} + 1.36 * \ln A_{nt} + \psi_t^L + \xi_n^L + v_{nt}^L. \quad (43)$$

Similarly, the estimated coefficients from the third row of Table 2 imply that the change in the number of firms in state  $n$  is consistent with the estimated relationship

$$\ln M_{nt} = 0.81 * \ln((1 - \bar{t}_n) MP_{nt}) - 2.44 * \ln c_{nt} + 0.07 * \ln \tilde{R}_{nt} + \psi_t^M + \xi_n^M + v_{nt}^M. \quad (44)$$

For these values of the parameter vector, workers are about five times more responsive to after-tax real earnings than to government spending, while firms are about twelve times more responsive

to after-tax market potential than to government spending. We note that the assumed values of  $\chi_W$  and  $\chi_F$  do not matter for these reduced form elasticities.

#### 6.4. Over-identification checks

This section shows that our model's predictions for moments that are not targeted in our calibration align well with the data.

First, Figure 2a compares the model implications for the share of each state in national GDP against the data in 2007. Model predictions and data line up almost perfectly, which reflects that, in the data, state GDP is roughly proportional to state sales (which our calibration matches), as our model predicts. Similarly, Figure 2b shows that the model's share of firms in each state against the actual share in 2007 lines up closely as well, also reflecting that the number of firms and total sales are close to proportional in the model and in the data.

Second, we verify the implications of the estimated model for the share of government revenue in state GDP. Figure 2c compares the model-implied share of government revenue in GDP with its empirical counterpart; there is a positive correlation between both, although the model tends to over-predict the share of government revenue in GDP.

Third, Figure 2d–f compare, for each type of tax, the model-implied and the observed share of revenue from this tax in total state tax revenue. There is a positive correlation between the data and the model-implied shares, although the model tends to over-predict the importance of corporate income taxes and to under-predict the importance of individual income taxes. These differences are due in part to the model assumption that all companies are C-corporations and, therefore, pay corporate taxes.

## 7. COUNTERFACTUALS

In this section, we quantify the aggregate impact of changes in U.S. state taxes. We parametrize the fundamentals of each state as described in Section 6, and, unless otherwise indicated, use the parameter estimates reported in the third row of Tables 1 and 2.

*Aggregate outcomes.* For each counterfactual change in taxes that we consider, we compute our model's predicted changes in worker welfare expressed as equivalent changes in private consumption. Specifically, by combining (7) and (8), worker welfare in a counterfactual equilibrium relative to its actual value may be written as an employment-weighted average of the changes in the appeal of every state

$$\widehat{v} = \left( \sum_n L_n \widehat{v}_n^{\epsilon_W} \right)^{\frac{1}{\epsilon_W}}, \quad (45)$$

where  $L_n$  is the fraction of U.S. workers living in state  $n$  in the initial equilibrium, and  $\widehat{v}_n$  is the value of state  $n$ 's appeal in the counterfactual equilibrium relative to its initial value. Any combination of changes in private consumption and provision of public goods across states leading to a change in welfare equal to  $\widehat{v}$  can be chosen as an equivalent welfare metric. In particular, the welfare change  $\widehat{v}$  is equivalent to a particular  $100(\widehat{c} - 1)$  percent increase in private consumption in every state, keeping labour supply and the consumption of public goods constant. In most of our parametrizations, where  $\alpha_{W,n}$  does not vary by state,  $\widehat{c} = \widehat{v}^{\frac{1}{1-\alpha_W}}$ . We report the

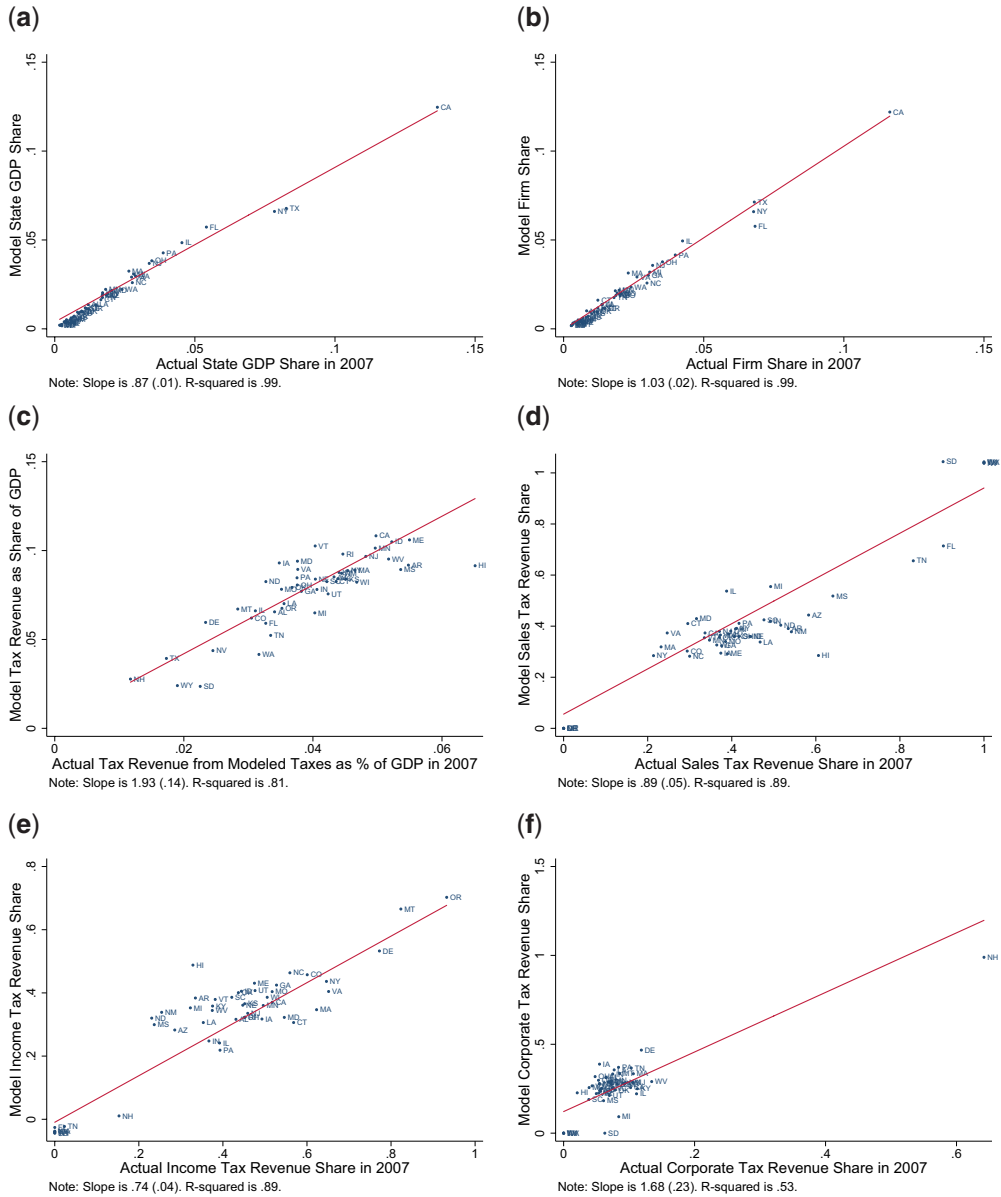


FIGURE 2

Over-identifying moments: model versus data. (a) State GDP share; (b) state firm share; (c) state tax revenue as share of GDP; (d) sales tax revenue share; (e) income tax revenue share; (f) corporate tax revenue share.

*Notes:* This figure compares 2007 data with model predictions for non-targeted moments. (a) Shows state GDP shares, (b) plots state firm shares, and (c) displays state tax revenue as a share of state GDP. (d)–(f) Plot general sales, individual income, and corporate income tax revenue as a share of total tax revenue, respectively.

relative welfare increase in terms of this private consumption equivalent measure in the tables below.<sup>28</sup>

We also report model-predicted changes in aggregate real GDP and in the real private consumption of workers and capital-owners. Equations (A.12) to (A.14) in [Online Appendix B.2](#) report the expressions used to construct these variables.

*G-Constant counterfactuals.* For every counterfactual change in taxes we analyse, we report results both using the full general equilibrium equations of our model and using a “G-constant” version of our model in which we artificially keep government spending constant in every state ( $\hat{G}_n = 1$  for all  $n$ ). These “G-constant” counterfactuals generate changes in welfare that are exclusively due to the impact that different distributions of state taxes have on allocative efficiency. To implement these “G-constant” counterfactuals, we keep government spending constant in every state and drop the budget constraint of each state’s government as a restriction that must be satisfied in the counterfactual equilibrium. A possible interpretation of these counterfactuals is that they implement both a change in state taxes and a transfer of revenue from the federal government to the states such that the initial level of public expending remains feasible for every state.

### 7.1. General equilibrium impact of the North Carolina income tax cuts

To illustrate some of the key forces at work, we start by studying the impact of a tax reform affecting one single state in isolation. We focus on North Carolina, which over the past decade has substantially reduced the level and progressivity of its individual income tax schedule ([Washington Post, 2017](#)). In 2007, North Carolina had a progressive tax schedule with a top rate of 8.25%. In contrast, the individual income tax rate in 2016 was a flat rate of 5.5%. We use our model to compute the general equilibrium impact of a change in the state tax parameters ( $a_{NC, state}^y, b_{NC, state}^y$ ) that mimics the change in taxes that North Carolina experienced between 2007 and 2016. Figure A.3 in [Online Appendix A.3](#) shows the actual and estimated tax schedules before and after the reform.

Consider first the effect that the North Carolina tax changes would have if government spending were to be kept constant in every state. From (32), the reduction in the income tax rate in North Carolina is analogous to an increase in the amenity level in this state. Attracted by this change in amenities, workers migrate to North Carolina and, as a result, the North Carolina workforce increases by 0.3%. This increase in labour supply decreases the equilibrium nominal wage before taxes. The larger workforce and lower nominal wages make North Carolina more attractive for firms, both through a decrease in production costs and through a bigger market size; as a result, the number of firms increases by 0.11%. Combined, the inflow of workers and firms increases real GDP by 0.13%.

However, once we take into account the impact of the North Carolina tax changes on government spending, our model predictions are reversed. According to our model, the tax reform leads to a 1.8% decrease in government spending in North Carolina. This decrease in government spending reduces amenities and firm productivity in North Carolina. This negative effect offsets

28. As shown in [Online Appendix E.1](#), this is also the consumption equivalent welfare change under any monotone transformation of the workers’ indirect utility. Hence, the computation of the consumption equivalent welfare metric  $\hat{c}$  does not rely on the assumption that the indirect utility of an individual  $l$  located in a state  $n$  is linear in  $v_n \epsilon_n^l$ ; it would also be a valid consumption equivalent metric if we had assumed instead that the welfare of individual  $l$  located in  $n$  is  $W(v_n \epsilon_n^l)$ , for any monotone transformation  $W(\cdot)$ . See [Shourideh and Hosseini \(2018\)](#) for derivations of similar properties under alternative extreme-value distributions of the idiosyncratic shocks. When  $\alpha_{W,n}$  varies by state, the relative change  $\hat{c}$  is chosen such that  $(\sum_n L_n \hat{c}^{(1-\alpha_{W,n})\epsilon_W})^{\frac{1}{\epsilon_W}} = \hat{v}$ .

TABLE 3  
*The North Carolina income tax cuts*

Change in	Government spending	
	Constant	Variable
Employment	0.31	0.02
(Pre-Tax) nominal wage	-0.17	-0.06
Firms	0.11	-0.06
Real GDP	0.13	-0.08
Real government spending	0.00	-1.77
Consumption of K	0.02	-0.02
Consumption of L	0.55	0.33

*Notes:* This table reports the percentage changes in several outcome variables associated with the 2014–16 individual income tax cuts in North Carolina. Counterfactual income tax parameters,  $a_{NC,2016}^y$  and  $b_{NC,2016}^y$ , are estimated as explained in [Online Appendix F.1](#). Counterfactual predictions are based on the general equilibrium conditions described in Section 4.7. Parameters are calibrated as in Section 6.1. Worker and firm parameters are set equal to the estimates from the third row of Tables 1 and 2, respectively.

the direct positive effect of the lower tax rates. Overall, North Carolina's employment is fairly stable and its total number of firms and state GDP shrink.

The data show that the tax revenue coming from corporate, individual, and general sales taxes did actually decrease in North Carolina between 2007 and 2015 by 11.4%, exceeding the average tax revenue decline (of 4.9%) across other states in the same U.S. Census division. Relative to these states, employment changes were similar, establishment growth was lower, and GDP growth was higher in North Carolina. Because several other fundamentals may have changed simultaneously to the implementation of the tax cuts, and because our model is aimed to capture long-run effects of changes in taxes, we do not expect our model predictions to quantitatively match the observed changes in economic activity experienced by North Carolina in the years that immediately followed the implementation of the tax changes.

## 7.2. Tax harmonization

Various countries have harmonized regional tax policies over the last few decades, and some recent proposals in the U.S. have advocated for increased tax coordination across states.<sup>29</sup> We now ask how dispersion in state taxes impacts aggregate outcomes in the U.S. Table 4 presents our model predictions for the impact of replacing the actual distribution of state taxes in 2007 with counterfactual tax distributions that feature less dispersion across states. The first row considers a counterfactual scenario in which all sales, corporate, and individual income tax rates are replaced by their mean values across all U.S. states. In the second row, we perform a more limited harmonization: we eliminate dispersion in tax rates across states located in the same Census region, but allow for differences in taxes across these broad geographic regions. The results presented in the last row correspond to an even more limited tax harmonization: we homogenize tax rates only within each of the nine Census divisions (see Figure 3a for a representation of the different Census regions and divisions).

We find worker welfare gains from tax harmonization, and the welfare gains are larger the larger the geographical area on which we impose tax harmonization. However, our results also show that, conditional on holding government spending constant, most of the gains of a

29. Canada adopted a Harmonized Sales Tax in 1997. In 2000, Australia replaced state-level sales taxes as well as other regional duties through state cooperation. Most recently, India harmonized regional taxes by introducing a Goods and Services Tax nationwide in 2017. In the U.S., [Alden and Strauss \(2014\)](#) and [Wilson \(2015\)](#) suggest that tax collaboration in the spirit of a WTO-like agreement across states may improve overall welfare. Other U.S. institutions, such as the Streamlined Sales Tax Governing Board, facilitate tax policy coordination across states.



TABLE 4  
Tax harmonization

Case	Welfare		U.S. GDP		$C_K$		$C_L$	
	G Con	G Var	G Con	G Var	G Con	G Var	G Con	G Var
Within All U.S.	0.61	1.17	0.03	-0.16	0.26	0.12	-0.05	0.62
Within regions	0.57	1.06	0.02	-0.11	0.28	0.17	-0.07	0.49
Within divisions	0.37	1.08	0.01	-0.02	0.20	0.19	0.05	0.45

*Notes:* This table reports the percentage changes in welfare in terms of private consumption equivalent units, U.S. GDP, consumption of capital owners, and consumption of workers associated with tax harmonization to the national, region, and division means. Counterfactual predictions are based on the general equilibrium conditions described in Section 4.7. Parameters are calibrated as in Section 6.1. Worker and firm parameters are set equal to the estimates from the third row of Tables 1 and 2, respectively.

hypothetical nationwide tax harmonization are due to the harmonization of taxes across states that are geographically close to each other. Simply harmonizing tax rates across states within the same Census division generates 61% of the welfare gains when states' government spending is held constant, and almost all of the gains when we account for how spending would change in reaction to the change in tax rates. Conditional on harmonizing tax rates within Census divisions or regions, the gains from further doing so for the entire country are negligible. Therefore, our results suggest that the main distortive effects of the overall U.S. tax dispersion are due to dispersion in tax rates across states that are geographically close to each other.<sup>30</sup>

We can link these results to the theoretical analysis in Section 5. As shown in Proposition 1, given any distribution of spending in public services across states, a necessary condition for efficiency in a simpler version of our model is equalization of tax payments per capita across states. Therefore, if the forces highlighted in the proposition operate in the more general model on which we base our counterfactual predictions, we should observe a greater reduction in dispersion in tax payments when we harmonize taxes nationally than when we do so only at the Census region or Census division level. Figure 3 verifies that this result applies: we see a larger reduction in the dispersion of per capita tax payments across states in those cases in which our model predicts larger welfare gains.

A comparison of the first two columns of Table 4 shows that the welfare effects of tax harmonization are magnified through the general equilibrium response of government spending to the tax changes. To guide our understanding of where these additional gains come from, we return to a simpler version of our model analogous to that analysed in Proposition 1.<sup>31</sup> As shown in Online Appendix E.2, to a first-order approximation around an initial equilibrium, in the simpler model, the change in the welfare of workers associated with a change in income or sales taxes is:

$$d \ln v = \sum_n L_n d \ln GDP_n + \sum_n L_n \left( \frac{\alpha_W - G_n / GDP_n}{1 - G_n / GDP_n} \right) d \ln \left( \frac{G_n}{GDP_n} \right). \quad (46)$$

The first term reflects that, keeping government spending constant, the effects of tax changes on welfare are captured, to a first-order approximation, by a population-weighted sum of the changes

30. We find welfare gains from tax harmonization of about 1% in consumption-equivalent terms. To put this magnitude in perspective, Albouy (2009) reports welfare losses from the heterogeneous geographic burden of federal taxation equivalent to 0.23% of income whereas Altig et al. (2001) find welfare gains equivalent to 4.5% of GDP when simulating several federal tax reforms in a dynamic model.

31. Specifically, we consider a special case with no trade costs ( $\tau_{in} = 1$  for all  $i, n$ ), perfect substitutability across varieties ( $\sigma \rightarrow \infty$ ), homogeneous firms ( $\varepsilon_F \rightarrow \infty$ ), constant labour supply ( $h_n$  constant), and identical preferences for government spending across states ( $\alpha_{W,n} = \alpha_W$  for all  $n$ ).

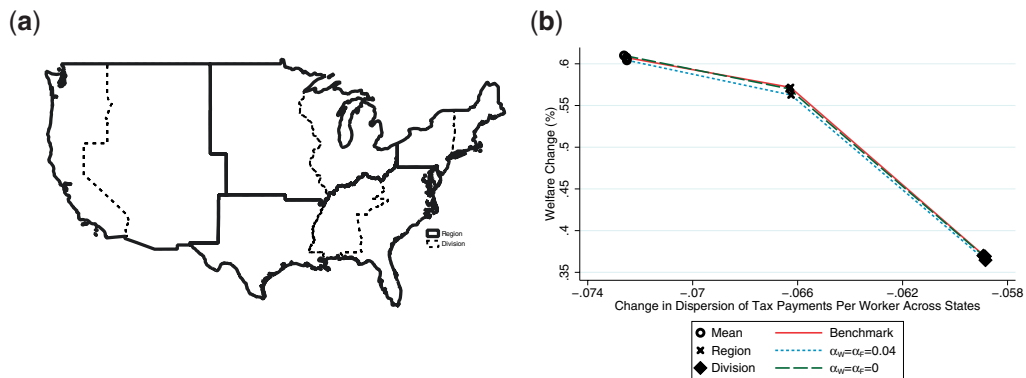


FIGURE 3

U.S. census regions and divisions and the dispersion of tax payments. (a) U.S. census regions and divisions; (b) changes in dispersion of tax payments.

*Notes:* (a) Shows U.S. Census regions and divisions. The Census splits the U.S. territory into four regions (Northeast, Midwest, South, and West), each of which contains two or more divisions. (b) Plots the change in welfare in terms of private consumption equivalent units against the change in dispersion of tax liabilities per worker associated with tax harmonization to the national, region, and division means under constant government spending.

in GDP in each state.<sup>32</sup> The second term reflects the impact of changes in government spending, and it predicts that an increase in government spending as a share of GDP in a state  $n$  has a positive effect on worker welfare as long as the share of government spending in that state's GDP in the initial equilibrium is less than the weight of government spending in preferences,  $\alpha_W$ .

The second term in (46) shows why workers' welfare gains from tax harmonization are magnified through the response of government spending. According to our benchmark estimation, the ratio of public spending to GDP is below  $\alpha_W$  in every state. When taxes are harmonized, taxes and government spending increase in states with an initially low public spending share of GDP. In these states, the numerator of the gradient of welfare improvement from higher spending,  $\alpha_W - G_n/GDP_n$ , is relatively large. At the same time, taxes and spending shrink in states with a relatively high initial spending share of GDP, where this gradient is smaller. Moreover, in the initial allocation, population shares are larger in states with lower spending and taxes and, consequently, most of the U.S. population is concentrated in states that benefit the most from the changes in public spending implied by tax harmonization. These forces can be seen in Figure 4. Government spending increases where the gains of raising spending are larger, and the best linear fit of the relationship between the changes in government spending predicted in the counterfactual and the welfare gradient with respect to these changes is steeper when states are weighted by their initial population shares.

The remaining columns of Table 4 indicate the impact of tax harmonization on aggregate U.S. GDP and real consumption of workers and capital owners. Columns 3 and 4 illustrate that welfare and GDP may move in opposite directions, as implied by our discussion in Section 5. When holding government spending in every state constant, predicted changes in GDP are negligible, and they generally become negative when we allow government spending to vary. In

32. However, as discussed in Section 5, for large changes in tax rates such as those that we implement, and keeping government spending constant, changes in value added are not sufficient to assess the overall changes in welfare.

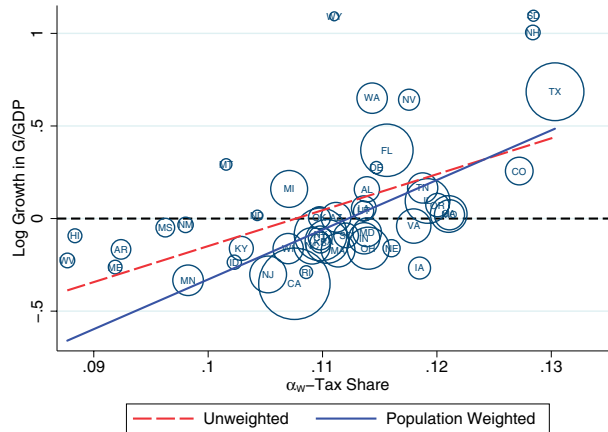


FIGURE 4

Changes in spending and gradient of welfare gain.

*Notes:* This figure plots the growth in government spending as a share of state GDP against the difference between the weight of public services in worker utility and government spending as a share of GDP (*i.e.*,  $\alpha_W - \frac{G_n}{GDP_n}$ ) for the full tax harmonization counterfactual under variable government spending.

the counterfactuals that hold government spending constant, we also predict negligible changes in the real private consumption of workers, implying that the predicted welfare gains are due to a reallocation of workers to states with higher compensating differentials. However, the private consumption gains of workers are considerable when government spending changes.

Figure 5 shows that states experiencing higher GDP growth are concentrated in the West and South, while the Northeast is the main loser from tax harmonization. However, there is considerable variation in the effects on state GDP, even within Census regions. Some of the biggest winners, such as Texas, Florida, Nevada, and New Hampshire, are states that, as shown in Figure 4 experience large increases in government spending as a share of GDP.

*Alternative distributions of fundamentals.* As the discussion in Section 5 suggests, the effect of eliminating dispersion in state taxes while keeping government spending constant depends on the correlation between the initial state tax rates and the state fundamentals (*i.e.* amenities and productivities). This mechanism is also present in the more general model that we use in our counterfactual analysis. The dependence of the counterfactual results on the correlation between initial tax rates and fundamentals is important, as it implies that the effects of eliminating tax dispersion across regions of a country may be both qualitatively and quantitatively different in other countries.

Table 5 shows the results from eliminating tax dispersion in scenarios where wages, income, and trade flows across states are the same as those observed in the initial equilibrium, but state employment shares are reassigned across states so as to maximize or minimize their correlation with the initial state tax rates.<sup>33</sup> As we increase the cross-state correlation between initial worker

33. As discussed in Section 6.1, state fundamentals impact the system of equations that we use to compute the effect of counterfactual changes in taxes through a composite that we measure using information on the observed number of workers, wages, income, and trade flows across states in an initial equilibrium. Thus, changing the initial value of the state fundamentals in our system of equations is equivalent to changing the initial value of the variables used to recover those state fundamentals.

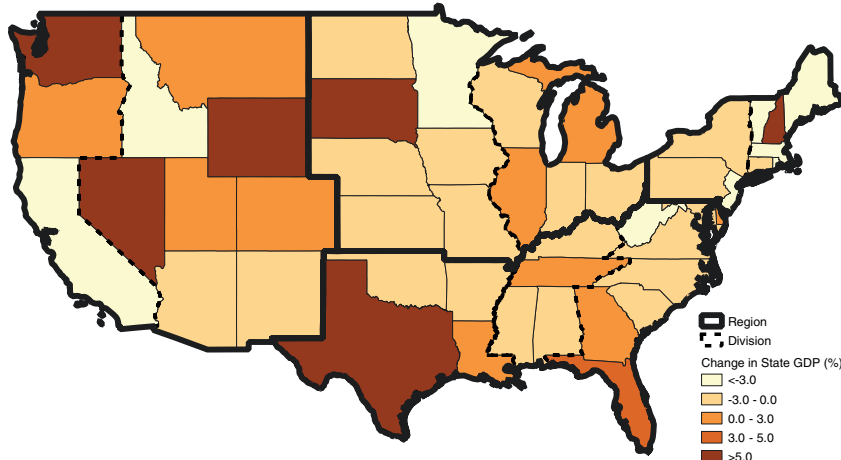


FIGURE 5

Tax harmonization and state-level changes in real GDP.

*Notes:* This map shows the change in real state GDP associated with tax harmonization to the U.S. mean under variable government spending.

TABLE 5  
*Spending constant counterfactual under alternative distribution of fundamentals*

Case	$RankCorr(T_n, L_n) = 1$		Actual Data		$RankCorr(T_n, L_n) = -1$	
	Welfare	GDP	Welfare	GDP	Welfare	GDP
Within All U.S.	1.07	-0.09	0.61	0.03	-1.37	0.20
Within Regions	0.94	-0.07	0.57	0.02	-1.30	0.18
Within Divisions	0.93	-0.04	0.37	0.01	-1.18	0.16

*Notes:* This table reports the percentage changes in welfare in terms of private consumption equivalent units and U.S. GDP associated with tax harmonization to the national, region, and division means under alternative distribution of fundamentals. Counterfactual predictions are based on the general equilibrium conditions described in Section 4.7. Parameters are calibrated as in Section 6.1. Worker and firm parameters are set equal to the estimates from the third row of Tables 1 and 2, respectively.

tax rates and employment shares, the welfare effect of eliminating tax dispersion while keeping the provision of public goods in every state constant increases. This relationship is consistent with Proposition 2 in Section 5. Table 5 also shows that this finding is robust to whether we harmonize taxes only within Census divisions, only within Census regions, or across all states in the country.

### 7.3. Eliminating the state and local tax deduction

When filing a federal income tax return, taxpayers can lower their taxable income by deducting their state and local tax payments. The SALT deduction is one of the largest tax expenditures in the U.S. tax code. Many tax reform plans, such as the 2005 President's Advisory Panel on Federal Tax Reform, have proposed eliminating it, and the 2017 tax reform (also known as the Tax Cuts and Jobs Act) substantially limited it.

The SALT deduction has the largest impact on taxpayers living in places with high state taxes. As a result, eliminating the SALT deduction increases cross-state dispersion in taxes. To study the effects of the SALT deduction within our model, we re-estimate the income tax schedule parameters  $\{a_n^y, b_n^y\}_{n=1}^N$  under the assumption that state tax liabilities are not deductible

TABLE 6  
Eliminating the state and local tax deduction

Case	Welfare		U.S. GDP		$C_K$		$C_L$	
	G Con	G Var	G Con	G Var	G Con	G Var	G Con	G Var
Benchmark	-0.75	-0.89	-0.33	-0.37	-0.32	-0.36	-1.56	-1.60
$\alpha_{W,n} = \frac{R_n}{GDP_n}, \alpha_F = 0$	-0.84	-0.86	-0.33	-0.34	-0.33	-0.33	-1.56	-1.56
$\alpha_W = \alpha_F = .04$	-0.78	-0.84	-0.33	-0.38	-0.32	-0.37	-1.56	-1.61
Mean-constant $a_n^y, b_n^y$	-0.84	-0.88	-0.05	-0.07	-0.04	-0.06	-0.76	-0.78

*Notes:* This table reports the percentage changes in welfare in terms of private consumption equivalent units, U.S. GDP, consumption of capital owners, and consumption of workers associated with the elimination of the SALT deduction. Counterfactual income tax parameters for rows 1–3,  $a_n^y$  and  $b_n^y$ , are reported in Table A.18. In row 4,  $a_n^y$  and  $b_n^y$  are recalibrated so that their mean across states is unchanged. Counterfactual predictions are based on the general equilibrium conditions described in Section 4.7. Parameters are calibrated as in Section 6.1. In rows 1 and 4, worker and firm parameters are set equal to the estimates from the third row of Tables 1 and 2, respectively. In row 2, they are set equal to the estimates from the fourth row of Table 1 and the fifth row of Table 2, respectively. In row 3, they are set equal to the estimates from the fifth row of Table 1 and the fourth row of Table 2, respectively.

for federal income tax purposes. The resulting effective tax rates by state and income group are listed in [Online Appendix Table A.18](#), and their distribution is illustrated in [Online Appendix Figure A.4](#). The elimination of the SALT deduction has two effects. First, the average effective income tax rates faced by workers increases in all states except in those with zero income tax rates. Second, the tax schedule is more dispersed across locations—the standard deviation in average effective tax rates nearly doubles from 1.1 to 2.1 percentage points. To isolate the effect of the second channel, we recalibrate the income tax schedule parameters  $\{a_n^y, b_n^y\}_{n=1}^N$  so that their mean value across states is kept constant at their initial level: only the dispersion in  $a_n^y$  and  $b_n^y$  changes in the counterfactual scenario.

Table 6 reports the results. Eliminating the SALT deduction while keeping state government spending constant reduces welfare, consumption, and real GDP. As discussed in Section 5, this result is a consequence of the increase in the dispersion of tax payments per worker resulting from the elimination of SALT. The effects of eliminating SALT are heterogeneous across states. Figure 6a shows the spatial distribution of predicted changes in real GDP and Figure 6b shows the change in each state's real GDP against the initial income tax rate. States that experience the largest declines in real GDP tend to have high state taxes and high shares of high-income taxpayers, with states in the Northeast like New York and Massachusetts being among the hardest hit, and Southeastern states such as Mississippi, Florida, and Tennessee enjoying the largest gains. The distribution of predicted impacts also reflects the importance of spatial linkages. For example, Mississippi enjoys the largest gains in real GDP despite having positive state income taxes, reflecting the concentration of gains in nearby states. Similarly, the figure shows that among states with no state income tax, Florida and Tennessee enjoy larger gains than states like Nevada and New Hampshire, which are near states with high income tax rates.

#### 7.4. Rolling back taxes

U.S. state taxes have changed substantially over the last thirty years. Tables A.2 and A.19 in [Online Appendix A](#) report the sales, income, and corporate tax rates for each state in 2007 and in 1980. As the first two columns in Table 7 illustrate, states moved away from individual income taxes towards sales and sales-apportioned corporate taxes, with a slight decrease in dispersion.<sup>34</sup>

34. For sales and corporate taxes, these columns report the raw data. For income taxes, we show the changes in the average income tax rate; *i.e.*  $t_n^y(\bar{w}_n)$ , where  $\bar{w}_n$  denotes the average wage of state  $n$ .

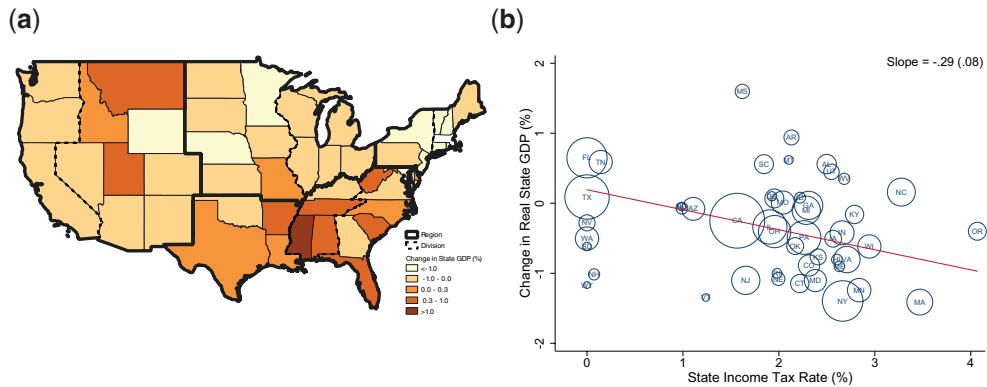


FIGURE 6

Eliminating the state and local tax (SALT) deduction. (a) Change in real state GDP (%); (b) changes in real state GDP and state income tax rates.

*Notes:* (a) Displays the changes in real state GDP associated with the elimination of the SALT deduction under variable government spending. (b) Plots changes in real state GDP against state income tax rates. Counterfactual income tax parameters,  $a_n^y$  and  $b_n^y$ , are reported in Table A.18. Counterfactual predictions are based on the general equilibrium conditions described in Section 4.7. Parameters are calibrated as in Section 6.1. Worker and firm parameters are set equal to the estimates from the third row of Tables 1 and 2, respectively.

TABLE 7  
Rolling back taxes

	80-07 Chg.		Welfare		U.S. GDP		$C_K$		$C_L$	
	Mean	CV	G Con	G Var	G Con	G Var	G Con	G Var	G Con	G Var
Sales	1.36	-0.05	1.47	-2.05	-0.01	-0.69	1.41	0.69	-1.35	-1.77
Income	-0.48	-0.10	-0.54	-0.29	0.01	0.04	0.03	0.06	-0.35	-0.27
Corporate	1.58	-0.04	0.06	-0.66	0.03	-0.12	0.36	0.21	0.00	-0.36
All			0.97	-3.15	0.03	-0.80	1.81	0.92	-1.69	-2.41

*Notes:* This table reports the percentage changes in welfare in terms of private consumption equivalent units, U.S. GDP, consumption of capital owners, and consumption of workers associated with rolling back taxes to 1980. Columns 1 and 2 report the level change in the mean and in the coefficient of variation of general sales, effective individual income tax rates, and corporate income tax rates between 1980 and 2007, respectively. Counterfactual tax rates are reported in Table A.19. Counterfactual income tax parameters are reported in Table A.20. Counterfactual predictions are based on the general equilibrium conditions described in Section 4.7. Parameters are calibrated as in Section 6.1. Worker and firm parameters are set equal to the estimates from the third row of Tables 1 and 2, respectively.

We compute the impact of replacing the 2007 state tax distribution with the distribution of tax rates in 1980. The results thus indicate how different the equilibrium in 2007 would have been if, over the 1980–2007 period, every fundamental of the economy had changed as it did, but state taxes had remained at the initial levels.

Table 7 shows the model predictions for different outcomes. In each of the first three rows, we illustrate the impact of bringing only one type of tax to its 1980 level; and the last row reports results for the case in which all taxes are simultaneously rolled back to 1980. Given that U.S. state taxes have increased on average between 1980 and 2007, our model predicts that, if the public provision of public goods had remained constant, the observed tax increases would have reduced worker welfare. However, following the same logic discussed in the previous section, the 1980–2007 tax increases were associated with an increase in public spending that, overall, caused aggregate welfare to increase by 3.15%. Given that both its rate and base increase over

TABLE 8  
Welfare change under alternative parametrizations

Case	Harmonization		Eliminate Salt		Roll Back	
	G Con	G Var	G Con	G Var	G Con	G Var
Benchmark	0.61	1.17	-0.75	-0.89	0.97	-3.15
$Z_{nt}^T$ Estimates	0.61	1.82	-0.72	-0.97	0.96	-6.08
$Z_{nt}^B$ Estimates	0.61	0.84	-0.87	-0.94	0.98	-1.03
$\alpha_{W,n} = \frac{R_n}{GDP_n}, \alpha_F = 0$	0.59	0.39	-0.81	-0.83	0.94	0.44
$\alpha_W = \alpha_F = .04$	0.60	0.78	-0.78	-0.84	0.97	-1.04
$\alpha_W = \alpha_F = 0$	0.61	0.61	-0.75	-0.75	0.97	0.97

*Notes:* This table reports the percentage changes in welfare in terms of private consumption equivalent units associated with tax harmonization to the national mean, the elimination of the SALT deduction, and rolling back taxes to 1980 under alternative parametrizations. Counterfactual predictions are based on the general equilibrium conditions described in Section 4.7. Parameters are calibrated as in Section 6.1 ( $\chi_W = \chi_F = 0$ ). Row 1 reports benchmark counterfactual changes from Tables 4, 6, and 7. In row 2, worker and firm parameters are set equal to the estimates from the first row of Tables 1 and 2, respectively. In row 3, worker and firm parameters are set equal to the estimates from the second row of Tables 1 and 2, respectively. We set  $\alpha_F = 0$  in this parameterization. In row 4, they are set equal to the estimates from the fourth row of Table 1 and the fifth row of Table 2, respectively. In row 5, they are set equal to the estimates from the fifth row of Table 1 and the fourth row of Table 2, respectively. In row 6, they are set equal to the estimates from the sixth row of Table 1 and the fifth row of Table 2, respectively.

time, the changes in sales taxes account for the the bulk of the welfare gain. The final columns of the table show that the bulk of the consumption gains under variable government spending accrued to workers instead of capital owners.

### 7.5. Alternative parametrizations

We now inspect how the results of our counterfactuals depend on the parameter estimates described in Section 6.2. Each row of Table 8 considers a different parametrization. The first row considers the benchmark case; the second and third rows consider the cases where we use estimates that only rely on  $Z_{nt}^T$  and  $Z_{nt}^B$ , respectively; the fourth row considers the case in which we assume that states' ratio of public spending to GDP reflects workers' preferences for public goods and that these do not affect firms' productivity (*i.e.*,  $\alpha_{W,n} = R_n/GDP_n$  and  $\alpha_F = 0$ ); the fifth row considers the case where we assume that the weight of public goods in workers' preferences and firms' productivity is equal to the U.S. ratio of public spending in GDP, *i.e.*,  $\alpha_{W,n} = \alpha_F = 0.04$ ; and the last row considers the case where we assume that public spending has no impact on amenities and productivity, *i.e.*,  $\alpha_{W,n} = \alpha_F = 0$ . The columns show the change in worker welfare in the different counterfactuals that we have previously discussed.

The alternative parametrizations differ on the value of the parameters that govern workers' and firms' preferences for public goods. Relative to the baseline, the second row uses a slightly higher value of these parameters, and the remaining rows use lower values. For all parametrizations, the results are very similar to the benchmark when public spending is held constant. However, in rows three through six, the lower valuation for public goods reduces the magnification effect that arises through the endogenous adjustment in public spending. When studying the impact of rolling back taxes to their 1980 levels, assuming a parametrization that eliminates workers' and firms' valuation for public goods naturally implies that the tax increases observed between 1980 and 2007 must have been detrimental for welfare. Finally, the effects of eliminating the SALT deduction are similar across the different parametrizations.

### 7.6. Robustness

We now explore the robustness of our results to alternative modelling assumptions and decisions we made when constructing the data. We also explore further the impact that labour and firm

TABLE 9  
Welfare change robustness

Case	Harmonization		Eliminate Salt		Roll Back	
	G Con	G Var	G Con	G Var	G Con	G Var
Benchmark	0.61	1.17	-0.75	-0.89	0.97	-3.15
Free entry	0.85	1.19	-1.02	-1.29	1.62	-2.45
Alternate def. of corp. Taxes	0.58	0.71	-0.75	-0.90	0.71	1.29
State and local taxes	0.95	0.71	-0.59	-0.71	2.50	-4.73
High $\varepsilon_W$	0.58	1.16	-1.04	-1.19	0.99	-3.08
Low $\varepsilon_W$	0.63	1.18	-0.62	-0.75	0.95	-3.17
High $\varepsilon_F$	0.64	1.17	-0.75	-0.89	0.99	-3.16
Low $\varepsilon_F$	0.62	1.17	-0.75	-0.89	0.98	-3.15
No worker heterogeneity	0.67	1.06	-0.42	-0.54	0.94	-3.18
No Int. margin labor supply	0.52	1.08	-1.29	-1.36	1.00	-3.13

*Notes:* This table reports the percentage changes in welfare in terms of private consumption equivalent units associated with tax harmonization to the national mean, the elimination of the SALT deduction, and rolling back taxes to 1980 under alternative modeling and data construction assumptions. Counterfactual predictions are based on the general equilibrium conditions described in Section 4.7. Row 1 reports benchmark counterfactual changes from Tables 4, 6, and 7. Row 2 allows for free entry of firms, *i.e.*,  $\chi_{FE} = 1$ . In row 3, state corporate tax rates are adjusted for the state share of C-corporations. In row 4, state tax rates are adjusted to account for local taxation. In rows 5–6,  $\varepsilon_W$  is 5 and 1.01, respectively. In rows 7–8,  $\varepsilon_F$  is 5 and 3.01, respectively. In row 9, worker parameters are set equal to the estimates from the third row of Table A.8. In row 10, worker parameters are set equal to the estimates from the third row of Table A.9.

mobility elasticities have on our results. We compare the results to our benchmark numbers, which are reported in the first row of Table 9.

The second row of Table 9 shows the results when, as discussed in Section 4.4, we assume free entry of homogeneous firms instead of mobility of a fixed mass of ex-ante heterogeneous firms. In this case, we find larger gains from tax harmonization when government spending is kept constant, as well as larger losses from eliminating the SALT deduction. Formally, the key impact of allowing for free entry is to modify the composite elasticities entering the system of equilibrium conditions.<sup>35</sup> We can inspect how these elasticities magnify the welfare changes by considering similar arguments to those used in Section 7.2. Figure A.5 in Online Appendix E.6 reproduces Figure 3b for the benchmark and for the free entry case. Under free entry, the reduction in the dispersion of tax payments from each harmonization counterfactual is larger than in the benchmark, and so are the aggregate welfare gains.

The third row in Table 9 shows results under an alternative definition of corporate taxes. Contrary to the baseline assumption in our model, some firms (S-corporations, partnerships, and sole proprietorships) do not pay corporate taxes; only personal income taxes are paid by their owners when profits are distributed. To account for this fact, we scale down the statutory corporate tax rate used in our benchmark analysis by the share of establishments registered as C-corporations in each state in 2010 relative to the total number of establishments in that state. As a result, we obtain less dispersion in the initial tax distribution, implying somewhat smaller gains from tax harmonization.

Our benchmark analysis ignores the existence of local taxes. To account for them, in the fourth row, we compute adjusted tax rates that account for average local tax rates within each state, as

35. See the composite elasticities (A.30)–(A.32) entering in the system of equilibrium conditions (A.24)–(A.28) in Online Appendix B.3. The coefficient  $\chi^{FE}$  entering in that system is equal to one in the free entry case and zero in the benchmark model. At the U.S. level, the case with free entry leads to a negligible change in the number of firms. This property follows from the fact that, under free entry and constant markups, the number of firms in each state is proportional to the number of workers in each state. Hence, aggregate firm entry is limited by the aggregate supply of workers in the U.S.



reported in [Online Appendix Figure A.1](#).<sup>36</sup> Allowing for state and local taxes increases the initial dispersion and, therefore, the magnitude of the tax harmonization, also increasing the welfare gains.

The following four rows implement our counterfactuals under either higher or lower values of the labour and firm mobility elasticities,  $\varepsilon_W$  or  $\varepsilon_F$ , than in our baseline parametrization. We choose a high value of  $\varepsilon_W$  and  $\varepsilon_F$  equal to 5, which is above the upper bound of existing parameter estimates reviewed in [Online Appendix D.9](#). For their low values, we choose numbers for  $\varepsilon_W$  and  $\varepsilon_F$  equal to 0.01 plus their lower theoretical bounds of 1 and  $\sigma - 1$ , respectively. We find that increasing or reducing  $\varepsilon_F$  and  $\varepsilon_W$  relative to the benchmark (while keeping all other parameters constant) does not have a strong impact on the welfare predictions. Finally, the last two rows shut down the channels of skill dispersion within each state ( $\zeta_n \rightarrow \infty$ ) and intensive margin of labour supply (fixing the number of hours  $h_n$  to be constant at the initial value). The welfare effects are quite similar to those predicted by the baseline model in both cases.

## 8. CONCLUSION

In this article, we quantify the effects of dispersion in U.S. state tax rates on aggregate real income and worker welfare in the U.S. economy. We develop a spatial general equilibrium framework that incorporates salient features of the U.S. state tax system. Implementing counterfactuals in our framework requires simultaneously using a mapping from changes in fundamentals to changes in outcomes that is standard in existing trade and economic geography models, as well as a mapping from changes in taxes to equivalent changes in fundamentals that is specific to our environment.

We estimate the key model parameters that determine how workers and firms reallocate in response to changes in state taxes using the over 350 changes in state tax rates implemented between 1980 and 2010. Using the estimated model, we compute the effects on worker welfare and aggregate real income of replacing the current U.S. state tax distribution with counterfactual distributions with different levels of regional tax dispersion.

We find that tax dispersion leads to aggregate losses. Keeping the government spending of every state constant, eliminating tax dispersion would increase worker welfare, measured in private consumption equivalent terms, by 0.6%. Through the endogenous responses of state spending to the tax changes, these gains increase to 1.2%. Our results suggest that regional coordination of tax policies could achieve most of the gains from harmonization across all U.S. states. We also evaluate past and proposed policies. We find that the changes in the U.S. state tax distribution that have taken place over the last thirty years have increased worker welfare. Additionally, we conclude that the elimination of SALT deduction would generate welfare losses through an increase in the dispersion of state tax rates.

The framework and estimation approach we introduce could be combined with data from European countries to inform ongoing debates concerning cross-country tax harmonization within the European Union, or with data from other countries featuring large tax dispersion across sub-national entities (*e.g.* Switzerland) to study the impact of tax dispersion in those contexts. It could also be used to study other related questions, such as how the state tax structure affects states' responses to state- or aggregate-level shocks (*e.g.* productivity shocks), what the advantages and

36. We scale our baseline income, sales, and corporate tax rates by the ratio of state plus local to state tax revenue. While property taxes are a minimal source of tax revenue for states, they are key for local entities; therefore, we also include consolidated local and property taxes in this version of the model, and model them as a tax on the return of the fixed factor in each state. In this counterfactual, we interpret the budget constraint of each state government as the consolidated budget constraint of that state government and all local governments located in the same state.

disadvantages of corporate-, sales-, or income-based tax systems are, or to characterize the optimal distribution of state taxes.

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### Supplementary Data

Supplementary data are available at *Review of Economic Studies* online.

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