# State Taxes and Spatial Misallocation*

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**Abstract**

We study state taxes as a potential source of spatial misallocation in the United States. We build a spatial general-equilibrium framework that incorporates salient features of the U.S. state tax system, and then we use changes in state tax rates between 1980 and 2010 to estimate parameters that determine how worker and firm location respond to changes in state taxes. Our results strongly suggest spatial misallocation from state taxes. Eliminating spatial dispersion in taxes accounting for 4% of GDP while keeping the distribution of government spending constant would increase worker welfare by 0.2%. The potential losses from greater tax dispersion can be large. Moving from no tax dispersion to twice as much dispersion as what is currently observed would reduce worker welfare by 0.6%.

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# 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 other countries, such as Australia, Canada, Germany, Italy, Spain, the United States, or Switzerland, these governments have varying degrees of autonomy to introduce or abolish taxes, set tax rates, and grant tax breaks. As a result, tax rates applied to both workers and firms vary across regions in these countries. A fundamental concern is that these regional differences in taxes have aggregate consequences. The standard reasoning from recent research studying dispersion in distortions – across 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 differences in taxes may have negative aggregate effects through distortions in the spatial allocation of resources. To the best of our knowledge, there is so far no quantitative evidence on the general-equilibrium trade offs between centralized and decentralized fiscal structures.[1]

In this paper, we provide this evidence by quantifying the aggregate effects of dispersion in tax rates across U.S. states. As we discuss in more detail in Section 3, the U.S. is a typical example of a country with a decentralized fiscal structure, both in terms of the share of total tax revenue collected by regional governments and the degree of spatial dispersion in tax rates.[2] We develop a spatial general-equilibrium framework that incorporates salient features of the U.S. state tax code, and then we use the more than 350 changes in state tax rates between 1980 and 2010 to estimate key model parameters that determine how workers and firms reallocate in response to changes in state taxes. Using the estimated model, we compute the aggregate effects of replacing the current state tax distribution with counterfactual distributions with varying levels of disparity in state tax rates.

Our main counterfactual evaluates the potential welfare and GDP gains from replacing the current distribution of taxes across U.S. states with a counterfactual harmonised fiscal regime. In this harmonised regime, all states set the same tax rates but continue to provide the same amount of public goods as in the current scenario thanks to a system of inter-state transfers. Our results therefore isolate the allocative impact of tax dispersion without diving into broader considerations of how responsibility over government *spending* should be allocated across different levels of government.[3] From a theoretical perspective, the question of how taxes impact the allocation of factors given a distribution of government spending across regions is distinct from the question of which

[1] In his essay on "Fiscal Competition or Harmonization? Some Reflections", Oates (2001) writes: "*there is a huge literature on this topic, and it is overwhelmingly theoretical in character.*"

[2] According to data for 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%); only significantly lower than that in Canada (39.7%), and significantly larger than what is observed in Australia (15.3%) and Italy (11.7%).

[3] These broader considerations have been discussed theoretically in a vast literature on fiscal federalism. See Gordon (1983) and Oates (1999) for a review. As this literature has pointed out, adding to our analysis an empirical evaluation of the welfare impact of changes in the distribution public spending across states would crucially require data on variables that are neither observed nor easily inferred given the information provided in standard datasets (e.g., heterogeneity across each level of government in both the information they have about individuals' preferences for public services and their efficiency in providing public goods).

level of government should be involved in the provision of public goods.[4] This distinction is not just a theoretical construct; instead, it reflects the empirical reality that, in every country with sub-central governments, there exist multiple mechanisms to transfer tax revenues across government entities, making it relevant to quantify the allocative impact from regions' tax policy separately from their spending policy.[5]

The foundation of our model includes key features from canonical environments used in the fiscal competition literature.[6] As in these models, we consider an environment consisting of many states, several factors of production which may be fixed (land and structures) or mobile (workers and firms), and state governments that use tax revenue and transfers from the federal government to supply public services which may be valued by workers or used as an intermediate in production. However, providing a quantitative assessment of the welfare effects of tax dispersion requires a framework that can match salient features of the spatial distribution of economic activity in the U.S. and that can account for how the resource allocation and public spending respond to changes in the fiscal structure. Therefore, we build on this foundation in several ways.

First, we include each of the main sources of tax revenue of U.S. state governments: sales, personal income, and corporate income taxes apportioned through both firm sales and factor usage. Second, our model flexibly accounts for the fact that states may be heterogeneous in terms of productivity, amenities valued by workers, endowment of fixed factors, factor intensities in production, and trade frictions with other regions, the modeling of which follows the standard approach from quantitative trade models such as Eaton and Kortum (2002) and Anderson and Van Wincoop (2003). These ingredients enable the model to rationalize the observed distributions of workers, wages, income, and trade flows across states as an equilibrium outcome for any given distribution of tax rates. Third, we depart from perfect competition, assuming instead that firms are monopolistically competitive as in Dixit and Stiglitz (1977) and Krugman (1980).[7] Finally, workers and firms respectively draw idiosyncratic preferences and productivities across states. This assumption, which is common in the local labor markets literature (Moretti, 2011), gives the model enough flexibility to match the observed responses of workers and firms to changes in taxes.

Workers in the model decide where to locate based on each state's taxes, wage, cost of living, and amenity level; while firms decide where to locate, how much to produce, and where to sell based on each state's taxes, productivity, factor prices, and market potential (a measure of other states' market sizes discounted by trade frictions). Despite the complexity of this economic geography model extended with a real-world US state tax code, its features can be mapped to a standard quantitative models of trade and economic geography. Specifically, keeping constant the provision

[4] E.g., Wildasin (1980) refers to the conditions leading to an efficient outcome given any arbitrary distribution of public spending as "locational efficiency".

[5] According to data the for year 2011 from the OECD Fiscal Decentralization Database, the share of the total sub-central government expenditure that is due to transfers from the central government is: U.S., 18.9%; Germany, 14.0%; Spain, 55.6%; Switzerland, 25.1%; Canada, 18.8%.

[6] For a recent summary of these models see Keen and Konrad (2013). We discuss the connection with this literature in more detail in the literature review section below.

[7] Under perfect competition, the model would lack operational notions of firms or equilibrium profits. These are needed to quantify the effects of U.S. corporate taxes and to make contact with observed data on firm mobility in response to these taxes.

of public goods, higher income or sales taxes in one state are equivalent to a lower amenity level in that state, resulting in lower labor supply, lower pre-tax wages, and, firm entry. Higher corporate taxes are equivalent to lower productivity, while a change in the sales apportionment of corporate taxes is shown to be equivalent to a particular set of changes in trade costs. Additionally, public-goods provision depends on state taxes and tax bases, and on transfers from the federal government, through the budget constraint of each state government. As a result, firm and worker decisions depend on taxes both in partial equilibrium – given relative prices and state spending – and in general equilibrium through the impact of taxes on prices and public-service provision.[8]

We use a simpler version of the model to characterize how the result of our counterfactual may depend on parameters. We demonstrate that our model does not impose an answer to whether the tax-harmonisation counterfactual leads to positive or negative effects on either worker welfare or output per worker. Qualitatively, these responses depend on the correlation between tax dispersion and the fundamentals of each state (e.g., productivity or amenities), and on parameters that govern the degree of labor mobility, congestion through the use of fixed factors in production, or preferences for public goods. For example, a reduction in tax dispersion is more likely to increase worker welfare for sufficiently low labor mobility; intuitively, workers pick the best among many location options, implying that higher variance in the appeal of available options can be beneficial when workers are not especially attached to specific locations. Therefore, whether an harmonized tax scheme raises or lowers welfare and real output given an arbitrary distribution of government spending is an empirical question that depends on the model's parameters. We discipline these parameters by matching features from the cross-sectional U.S. distribution of economic activity as well as worker and firm responses to actual tax changes.

Four structural parameters, in particular, are key for the results: the elasticities of worker and firm mobility with respect to after-tax real wages and profits, respectively, and the weights of public services in worker preferences and firm productivity. To estimate these parameters, we use equilibrium relationships from our model and a longitudinal dataset on the distribution of workers, establishments, tax rates, and government revenue across states from 1980 to 2010. Our model generates a worker-location equation that predicts each state's employment share as a function of after-tax real wages and state government spending, and a firm-location equation that predicts each state's share of establishments as a function of after-tax market potential, factor prices, and state government spending. Intuitively, higher partial elasticities of employment and firm shares with respect to government spending in the data correspond to higher weights of public services in worker preferences and firm productivity in our model.

Our estimation approach uses taxes in other states to instrument for each state's factor prices and government spending. We estimate a partial elasticity of state employment with respect to after-tax real wages slightly above 1, and with respect to government spending of about 0.2. Compared to these estimates, firms are relatively more responsive to taxes and market size than to

[8]Even though our key counterfactuals keep government spending constant, we need to include government spending in the model in order to implement these counterfactuals, i.e., to find the levels of tax rates and transfers that guarantee that each state can maintain the observed level of public spending in the counterfactual scenario without tax dispersion.

government spending.[9] We calibrate the remaining parameters (production technologies and state fundamentals) such that the model exactly reproduces, as an equilibrium outcome, the distribution of factor shares, wages, employment, and trade flows across states in 2007, the most recent year in which all the data we need are available. As an over-identifying check, we compare the model's predictions for variables that are not targeted by the parametrization with the data. We find that the distributions across states of GDP and tax revenue share in GDP implied by the estimated model are highly correlated with those observed in the data.

Our results strongly suggest spatial misallocation from state taxes. Keeping government spending constant through a system of cross-state transfers, eliminating tax dispersion would increase worker welfare by 0.2% (relative to a 4% share of state taxes in GDP). Accounting for the progressivity of state income taxes yields considerably larger worker welfare gains from tax harmonisation, which increase to 0.4%. The gains in terms of aggregate real income and consumption are approximately half as large. We also find that the potential losses from greater tax dispersion can be large: moving from a scenario with no tax dispersion to one with twice as much dispersion as what is currently observed (while also keeping government spending constant through cross-state transfers) would reduce worker welfare by about 0.6%. Without cross-state transfers, a revenue-constant elimination of the current tax dispersion leads to a 0.8% gain, and moving from no tax dispersion to twice as much dispersion as what is currently would lead to a 1.7% loss.

We establish the robustness of these findings in several ways. The model predictions for the impact of a tax harmonisation that keeps government spending constant are robust to different approaches to estimate the parameters that govern the mobility of firms and workers and the weight of government services in preferences and productivity. For instance, the prediction that this change in taxes will increase welfare by 0.2% holds both in the extreme case in which we assign zero weight to public services in preferences and productivity, and in the case in which we assume that the observed government size in each state reflects workers preferences for public services. We also show that our results are robust to using different methods for measuring state tax rates. For example, the conclusion that there are positive allocative gains from harmonising taxes across U.S. states is robust to using progressive tax rates as well as adjusting our measures of state corporate tax rates for state subsidies and for the different fiscal treatment of C-corporations and S-corporations.

The rest of the paper is structured as follows. Section 2 relates our work to the existing literature. Section 3 describes the features of the U.S. state tax system that motivate our analysis. Section 4 develops the model and describes its general-equilibrium implications. Section 5 studies theoretically how dispersion in taxes affects welfare and aggregate production in a simplified version of our model. Section 6 presents the estimation, and Section 7 presents the counterfactuals. Section 8 concludes. Detailed derivations, additional figures and details on both estimation and data sources are shown in an Online Appendix.

[9] These estimates are in the range of existing work that has estimated similar elasticities; e.g., Bound and Holzer (2000), Notowidigdo (2013), Suárez Serrato and Wingender (2014), Diamond (2015), Suárez Serrato and Zidar (2015), and Giroud and Rauh (2015). See Section 6.3 and Appendix D.4 for details.

## 2 Relation to the Literature

**Misallocation** Our paper contributes to the literature on the aggregate effects of misallocation. A common approach consists of measuring distortions across firms as an implied wedge between an observed allocation and a model-implied undistorted allocation, as in Hsieh and Klenow (2009), and then undertaking counterfactuals to inspect the aggregate effects of dispersion in these wedges. Recent papers have adopted a similar methodology to analyze misallocation across geographic units, such as Desmet and Rossi-Hansberg (2013) and Brandt et al. (2013).[10] These wedges capture distortions that may be due to multiple sources. Rather than inferring distortions from wedges, we focus on the spatial misallocation generated by state taxes that we directly observe in the data. We use observed variation in these taxes to estimate key model parameters.

**Trade and Economic Geography** Our framework combines ingredients from quantitative economic-geography models that introduce labor mobility into quantitative trade models, such as Allen and Arkolakis (2014), Ramondo et al. (2015), Redding (2015), Gaubert (2015), and Monte et al. (2015). Our research question – the impact of state taxes on the U.S. economy – distinguishes our paper from this previous literature. This focus drives our modeling choices, estimation approach, and counterfactuals. Our model combines a number of ingredients appearing in these and in previous studies,[11] plus a few new ones dictated by our question. Importantly, we incorporate a real-world tax code encompassing the main taxes used by U.S. states and by the federal government, and a government sector that uses these taxes to finance public services valued by workers and firms and transfers to the states.[12] Relative to this literature, a central feature of our analysis is the focus on performing counterfactuals with respect to policy variables that are directly observed (U.S. state tax rates), and the use of observed variation in these same policies to identify the key model parameters.[13]

**Fiscal Competition and Fiscal Federalism** The literature on fiscal competition in the tradition of Flatters et al. (1974), Wilson (1986), and Zodrow and Mieszkowski (1986), summarized among others by Oates (1999), Wilson and Wildasin (2004), and Keen and Konrad (2013), typically considers static and perfectly competitive economies with two or more regions and two factors of production, one immobile and one perfectly mobile, which may be used to produce a consumption good and a non-traded public good. These basic ingredients are included in our model. As have

[10] See also Behrens et al. (2011) and Hsieh and Moretti (2015) for environments with spatial distortions across cities. A related literature on spatial misallocation considers 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 (2015) study whether these income gaps reflect spatial misallocation.

[11] Our model includes an endogenous number of monopolistically competitive firms in each location similarly to Krugman (1991) and Helpman (1998), the use of differentiated products as intermediates as in Krugman and Venables (1995), and workers with idiosyncratic preferences for location as in Tabuchi and Thisse (2002).

[12] Another novel ingredient is imperfect firm mobility in the form of idiosyncratic productivity draws across states. For a quantitative setup also featuring imperfect mobility of several factors of production see Galle et al. (2015).

[13] Bartelme (2015) estimates labor and wage elasticities with respect to market potential using Bartik instruments. In an international-trade context, Caliendo and Parro (2014) estimate trade elasticities using variation in tariffs.

mentioned, our model generalizes this structure to a multi-region setting in which the distribution of state characteristics can be disciplined by 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. It is well understood from this previous literature that the answer to this question depends on the specific features of the environment in which it is considered, such as: which set of tax instruments jurisdictions may control (e.g., taxes on mobile or fixed factors), how agents value government spending (e.g., whether there is congestion in access to public services), what the objective function of policy-makers is (e.g., rent-seeking, maximizing social welfare, or maximizing the welfare of only fixed or mobile factors), or what information each level of government has (e.g., how much each government knows about local preferences).[14] Our approach is to perform a counterfactual exercise in which all key economic forces at play can be disciplined by data. Consequently, we focus in our analysis on a counterfactual that, conditional on our estimates of the key model parameters, does not require taking a stand on the objective function or the information sets of policy-markers, or on the process through which observed taxes are determined. Assumptions on how taxes are determined are only relevant at the moment of estimating the parameters, and we discuss these identification assumptions in detail in Section 6.[15]

In a seminal paper of the local public finance literature, Tiebout (1956) illustrates how heterogeneous preferences for government services can play a central role in determining the location of workers. 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, we show that our counterfactual results are robust to several approaches to measuring the valuation that workers have for government services. Specifically, since our main counterfactuals hold real government spending fixed, worker location decisions in our counterfactuals depend only on how each worker responds to changes in after-tax real wages (and not on the changes in government services provided in each state).

**Factor Mobility in Response to Tax Changes** Empirically, the general-equilibrium effects implied by our analysis depend on the elasticities of firm and worker location with respect to taxes. Evidence on the effects of taxes on worker mobility includes Bartik (1991) and, more recently, Moretti and Wilson (2015). 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

[14] E.g., Keen (1989) and Lockwood (1997) establish conditions under which some forms of commodity-tax harmonisation may be superior to an observed tax distribution resulting from competition across governments under alternative assumptions on whether governments supply public goods.

[15] A recent example of the literature on fiscal competition is Ossa (2015). He 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. State subsidies are in fact often financed through exemptions from corporate taxes, and their value amounts to about 10% of the state tax revenue that we consider. Our results barely change when we adjust corporate state taxes by effective subsidy rates by state (see Section 7.6.1). Ossa (2015) does not incorporate state taxes nor uses observed variation in policy to estimate parameters, which are two of the key features of our analysis.

impact of local policies on business location.[16] Suárez Serrato and Zidar (2015) provide evidence on the impact of corporate taxes on worker and firm mobility, and Suárez Serrato and Wingender (2014) show that local economic activity responds to public spending. While these papers quantify the local effects of actual policy changes, our framework allows us to quantify how counterfactual policy changes in one state or in many states simultaneously, such as a tax harmonisation, impact general-equilibrium outcomes in every state individually and in the U.S. economy as a whole.[17]

# 3 Background on the U.S. State Tax System

Our benchmark analysis focuses on three sources of tax revenue: personal income, corporate income, and sales taxes. The revenue raised by these taxes accounted, respectively, for 35%, 5%, and 47% of total states' tax revenue in 2012, and collectively amounted to 4% of U.S. GDP. In this section, we first describe how we measure each tax rate. We then present statistics that summarize the dispersion in tax rates across states. We conclude with evidence on the relationship between state tax revenue and government spending. Appendix F details the sources of the data discussed in this section.

## 3.1 Main State Taxes

**Personal Income Tax** States tax the personal income of their residents. The base for the state personal income tax includes both labor and capital income. In our benchmark analysis, we use a flat state income tax rate, and we then explore how our counterfactual results change if we account for the progressivity of income taxes at both the state and federal levels.[18] We compute an income tax rate for each state using the average effective tax rate from NBER TAXSIM, which runs a fixed sample of tax returns through different tax schedules every year and accounts for most features of the tax code (see Appendix F.1 for details). In 2010, the average across states was 3%; the states with the highest income tax rates were Oregon (6.2%), North Carolina (5.2%), and Hawaii (5.0%), while seven states had no income tax.

[16] E.g., 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 labor apportionment of corporate income taxes on the location of manufacturing employment, Hines (1996) exploits foreign tax credit rules to show that investment responds to state corporate tax conditions, and Giroud and Rauh (2015) show that C-corporations reduce their activity when states increase corporate tax rates. Chirinko and Wilson (2008) and Wilson (2009) also provide evidence consistent with the view that state taxes affect the location of business activity.

[17] Our paper is also related to the literature that has analyzed 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 analyzing large changes in policy. See Nechyba (1996) for an early CGE model of local public goods. Albouy (2009) studies how federal tax progressivity impacts the allocation of workers. 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.

[18] The schedule of state income tax rates tends to be progressive, but it is typically much flatter than the federal income tax schedule. We compare the progressivity of state and federal income tax rates when we introduce progressive income taxes in Section 7.5.

**Corporate Income Tax** States also tax businesses. The tax base and tax rate on businesses depend on the legal form of the corporation. The tax base of C-corporations is national profits.[19] State tax authorities determine the share of a C-corporation's national profits allocated to their state using apportionment rules, which aim to capture the corporation's activity share within their state. To determine that activity share, states put different weight on three apportionment factors: payroll, property, and sales. Payroll and property factors depend on where goods are produced and typically coincide; the sales factor depends on where goods are consumed.[20] In 2012, the average corporate income tax rate across states was 6.4%; the states with the highest corporate tax rates were Iowa (12%), Pennsylvania (10%), and Minnesota (10%), while six states had no corporate tax. Apportionment through sales tends to be more prevalent: nineteen states exclusively apportion through sales, while roughly half of the remaining states apply either a 50% or 33% apportionment through sales. Since C-corporations account for the majority of net income in the United States, in our benchmark analysis we treat all businesses as C-corporations.[21] We also explore how our results change when we apply alternative corporate tax rates that adjust for the fraction of C-corporations in total revenue in each state, or that account for tax subsidies that some states grant to firms, reducing their effective corporate tax rate.

**Sales Tax** Sales taxes are usually paid by the consumer upon final sale, and states typically do not levy sales taxes on firms for intermediate inputs or goods that they will resell.[22] In 2012, the average sales tax rate was 5%; the states with the highest sales tax rates were New Jersey (10%), California (7.5%), and Indiana (7%), while five states had no sales taxes. In our benchmark analysis, we define the sales tax rate as the statutory general sales tax rate applied only to final consumer sales.

### 3.2 Dispersion in Tax Rates and in Tax Revenue across States

Both tax rates and tax bases vary considerably across states. Panel (a) of Figure 1 shows the 2010 distribution of sales, income, corporate, and sales-apportioned corporate tax rates.[23] For each tax, rates vary across states, corporate tax rates being the most dispersed; the 90-10 percentiles of the distributions of sales, average personal income, and corporate income tax rates are 7%-1%, 5%-0%, and 9%-0%, respectively. For each type of tax, there are at least five states with 0% rates.

[19] Most states limit the tax base to profits earned within the "water's edge," i.e., profits from domestic activity.

[20] For example, a single-plant firm $j$ located in state $i$ with export share $s^j_{ni}$ to each state $n$ pays a corporate tax rate of $\overline{t}^j = t^{corp}_{fed} + t^l_i + \sum_n s^j_{ni} t^x_n$, where $t^{corp}_{fed}$ is the federal tax rate, $t^x_n = \theta^x_n t^{corp}_n$ is the corporate tax apportioned through sales in state $n$ (where $t^{corp}_n$ is the corporate tax rate of state $n$ and $\theta^x_n$ is its sales apportionment), and $t^l_i = (1 - \theta^x_i)\, t^{corp}_i$ is the corporate tax apportioned through property and payroll in state $i$.

[21] C-corporations accounted for 66% percent of total business receipts in 2007 (PERAB, 2010).

[22] Most states make some kind of exception of sales tax for firms purchasing goods. These exemptions vary widely across states, but generally, if a firm purchases material and uses it as an input in production, it is exempt from the sales tax. For example in Alabama, property that becomes an ingredient or component part of products manufactured or compounded for sale constitutes an exempt wholesale sale. (Ala Code Sec. 40-23-1(a)(6); Ala Code Sec. 40-23-1(a)(9b); Ala Code Sec. 40-23-60(4)(b); Ala Admin Code r. 810-6-1-.91; Ala Admin Code r. 810-6-1-.137).

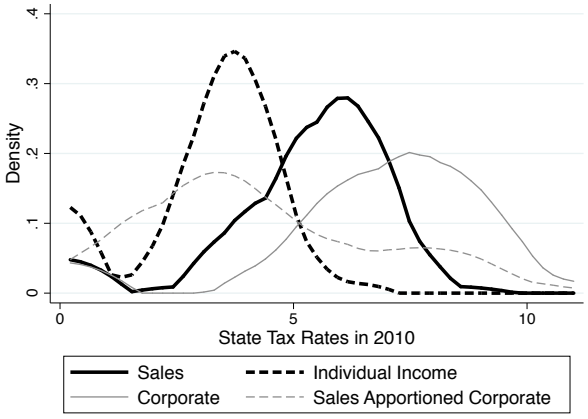
[23] The sales-apportioned corporate tax rate is the product of the sales apportionment factor (which is between 0 and 1) and the corporate rate; i.e., it is $t^x_n = \theta^x_n t^{corp}_n$ defined in footnote 20. Table A.2 in Appendix F.2 shows the state tax rates in 2007 in all 50 states. Table A.1 shows the federal income, corporate, and payroll tax rates in 2007.

These differences in tax structures across states are associated with differences in total tax revenue collected. Panel (b) of the same figure shows the distribution in tax revenue as share of GDP across states. The share of the sum of income, sales, and corporate tax revenue in GDP varies across states between 2% and 7%. While most states collect both income and sales taxes, some rely almost exclusively on sales tax revenue, such as Texas and Nevada, while others are sales-tax free, like New Hampshire and Oregon.

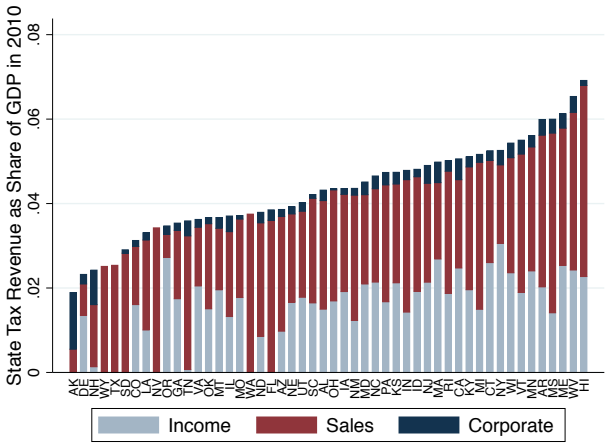
Local (sub-state) governments also tax residents. Overall, state taxes amount to roughly 60% of state and local tax revenue combined.[24] Heterogeneity in tax rates across states is also present when both state and local taxes are taken into account. Figure A.1 in the online appendix reproduces Panel (a) of Figure 1 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.

Figure 1: Dispersion in State Taxes in 2010

(a) Distribution of Tax Rates Across States




(b) Tax Revenue as Share of GDP Across States in 2010




### 3.3 Relationship Between State Tax Revenue and Government Spending

Besides the three types of taxes discussed in Section 3.1, a major source of revenue of U.S. state governments is the transfers that they receive from the federal government. On average, these transfers amount to roughly 6% of state GDP. 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 the level of transfers enjoyed by each state in each year is complex. However, empirically, for the period 1980 to 2010, the size of the total direct expenditures of each state is very well approximated as a state-specific multiplier of state tax revenue. That is, letting $E_{nt}^G$ be state $n$'s expenditures in year $t$, $\psi_n > 0$ be a state-specific multiplier of state tax revenue, and $R_{nt}$ be state tax revenue, the

[24] Local governments rely more heavily on property taxes than income, corporate, and sales taxes. State tax revenue make up roughly 90%, 85%, and 80% of consolidated state and local revenue from income, corporate, and sales taxes, respectively, but only 3% of consolidated property tax revenue.

estimates of the regression

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

yield an $R^2$ of 0.97.[25] Therefore, our model assumes the relationship $E_{nt}^G = R_{nt} + T_n^{fed \to st}$, where $T_n^{fed \to st} = \psi_n R_{nt}$ is the part of state spending financed through federal transfers.[26]

# 4 Quantitative Geography Model with State Taxes and Public Goods

## 4.1 Model Overview

We model a closed economy with $N$ states indexed by $n$ or $i$. A mass $M$ of firms and $L$ of workers respectively receive idiosyncratic productivity and preference shocks, which govern how they sort across states. We let $M_n$ and $L_n$ be the measure of workers and firms that locate in state $n$. Changing $M$ or $L$ does not affect the allocation, resulting only in a scaling up of $M_n$ or $L_n$ everywhere; therefore, we normalize $M$ and $L$ to 1, implying that $M_n$ and $L_n$ are the fractions of firms and workers located 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. To produce, they use the fixed factor, workers, and intermediate inputs using technologies that may vary across states. Workers receive only labor 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 $t_n^y$ , sales taxes $t_n^c$, and corporate income taxes apportioned through sales, $t_n^x$, or through payroll and fixed factors, $t_n^l$. Each state uses the tax revenue to finance the provision of public services, which enter as shifters both of that state's amenity and of the productivity of firms that locate in that state. The weight of public services in preferences may vary across states.

The federal government collects personal income taxes $t_{fed}^y$, payroll taxes $t_{fed}^w$, and corporate taxes $t_{fed}^{corp}$. Federal taxes are included because they affect effective state tax rates and are used to finance both federal transfers to the state governments and federal public goods that are equally valued by consumers independently of where they locate (e.g., we assume that federal spending in national defense equally benefit any U.S. worker regardless of where that worker is located).

[25] We measure the variable $E_{nt}^G$ as the "state direct expenditures" from the Census of Governments. The main direct-expenditure items included in this measure are education, public welfare, hospitals, highways, police, correction, natural resources, parks and recreation, government administration, and utility expenditure.

[26] It is worth noting that the fit of a regression that assumes that the amount of federal transfers enjoyed by each state in every year can be approximated as a state-specific constant (rather than a state-specific multiplier of tax revenue) yields a worse fit. Specifically, the estimates of the regression that assumes that $E_{nt}^G = \psi_n + R_{nt} + \varepsilon_{nt}$ yield an $R^2$ of 0.83.

### 4.2 Production Technologies

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

$$Q_n = \left( \sum_i \int_{j \in J_i} \left( q_{ni}^j \right)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

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 $i$ and 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

$$P_n = \left( \sum_i \int_{j \in J_i} \left( p_{ni}^j \right)^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}}. \tag{3}$$

Each variety $j$ is produced by a different firm; to produce $q_i^j$ in region $i$, firm $j$ combines its own productivity in that location $z_i^j$, the fixed factor $h^j$, workers $l^j$, and intermediate inputs $i^j$, through a Cobb-Douglas technology:

$$q_i^j = z_i^j \left[ \frac{1}{\gamma_i} \left( \frac{h^j}{\beta_i} \right)^{\beta_i} \left( \frac{l^j}{1-\beta_i} \right)^{1-\beta_i} \right]^{\gamma_i} \left( \frac{i^j}{1-\gamma_i} \right)^{1-\gamma_i}, \tag{4}$$

where $\gamma_i$ is the value-added share in production of every firm in state $i$, and $1-\beta_i$ is the labor share in value added in state $i$. The existence of a fixed factor is one of the sources of congestion in the model; the higher the number of firms and workers located in a given state, the higher the relative price of this fixed factor. Production functions are allowed to vary by state; this flexibility is needed to match the heterogeneity in the shares of total payments to labor and intermediate inputs expenditures in states' GDP observed in the data.[27]

The final good $Q_n$ is non-traded and can be used by consumers (workers and capital-owners) for aggregate consumption ($C_n$), 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 public services:

$$Q_n = C_n + I_n + G_n + G_n^{fed}. \tag{5}$$

### 4.3 Workers

A continuum of workers $l \in [0,1]$ decide in which state to work and consume. The indirect utility of worker $l$ in state $n$ is $v_n^l = v_n \epsilon_n^l$, where the vector $\left\{ \epsilon_n^l \right\}_{n=1}^N$ captures worker $l$'s idiosyncratic preferences for living in each state and $v_n$ is common to all workers who locate in $n$. This common

[27] This heterogeneity in the production function may be thought of as a way of capturing differences in sectoral composition across states; in the presence of multiple sectors, the labor and intermediate-input shares of each state would be endogenous and change in the counterfactuals, but we abstract from this margin in our analysis.

component is

$$v_n = u_n \left( \frac{G_n}{L_n^{\chi_W}} \right)^{\alpha_{W,n}} \left( (1 - T_n) \frac{w_n}{P_n} \right)^{1-\alpha_{W,n}}, \tag{6}$$

where we define the workers' tax keep-rate (i.e., the fraction of real income, $w_n/P_n$, kept by workers after paying sales and income taxes) as

$$1 - T_n \equiv \frac{(1 - t_{fed}^y)(1 - t_n^y) - t_{fed}^w}{1 + t_n^c}. \tag{7}$$

Equations (6) and (7) imply that workers have preferences over amenities, public goods, and final consumption goods.[28] First, the coefficient $u_n$ 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 only by workers.[29] For simplicity, we refer to this term as simply "amenities". Second, the appeal of state $n$ also depends on real government spending, $G_n$, normalized by $L_n^{\chi_W}$. The parameter $\chi_W$ captures rivalry in public goods, and ranges from $\chi_W = 0$ (non-rival) to $\chi_W = 1$ (rival).[30] Third, workers care about the quantity of final goods that they can consume in state $n$. This quantity equals after-tax wages, $\left(\left(1 - t_{fed}^y\right)(1 - t_n^y) - t_{fed}^w\right) w_n$, normalized by the after-tax price, $(1 + t_n^c) P_n$.[31] As a result, real consumption equals the pre-tax wage, $w_n/P_n$, adjusted by income and sales taxes, $1 - T_n$. The parameter $\alpha_{W,n}$ captures the weight of state-provided services in preferences. The weight of public services in preferences, $\alpha_{W,n}$, may vary across states, reflecting complementarities between state-specific features such as the weather or natural amenities and government services.

The idiosyncratic taste draw $\epsilon_n^l$ is assumed to be i.i.d. across consumers and states, and it follows a Fréchet distribution, $\Pr\left(\epsilon_n^l < x\right) = e^{-x^{-\varepsilon_W}}$, with $\varepsilon_W > 1$. A worker $l$ locates in a state $n$ if $n = \arg\max_{n'} v_{n'} \epsilon_{n'}^l$. Reminding the reader that we have normalized the mass of workers to 1, the fraction of workers located in state $n$ is

$$L_n = \left( \frac{v_n}{v} \right)^{\varepsilon_W}, \tag{8}$$

[28] The framework could easily be generalized to allow for direct consumption of the fixed factor by workers in the form of housing. In that specification, the price of land would also enter as part of the cost of living. Additionally, the effective tax keep-rate could be modified to also account for average property taxes, and housing supply could be allowed to be elastic. While extending the model with these forces would be straightforward, quantifying them would be less so because property taxes are largely imposed at the local (sub-state) level, and housing supply elasticities vary considerably across cities within states, as documented by Saiz (2010).

[29] The coefficient $u_n$ may also capture utility from a national public good provided by the federal government. More specifically, (6) is consistent with first defining $v_n = u_{n,0} G^{fed} \left( \frac{G_n^W}{L_n^{\chi_W}} \right)^{\alpha_{W,n}} \left( (1 - T_n) \frac{w_n}{P_n} \right)^{1-\alpha_{W,n}}$, where $u_{n,0}$ are natural characteristics, $G^{fed}$ is the amount of national public services provided by the federal government, $G_n^W = z_n^W \theta_n^W G_n$ are government services valued by workers, $z_n^W$ is the efficiency or the quality of real spending in services valued by workers, and $\theta_n^W$ is the fraction of the state budget dedicated to services valued by workers. Starting from this initial definition, (6) corresponds to defining $u_n = G_n^W u_{n,0} \left( z_n^W \theta_n^W \right)^{\alpha_{W,n}}$.

[30] This is a similar modeling approach to existing papers in the fiscal competition literature, e.g. see Boadway and Flatters (1982).

[31] Note that equation 7 takes into account that state income taxes can be deducted from federal taxes. In our benchmark analysis, we abstract from the progressivity of both federal and state income taxes. In Section 7.5, we relax this assumption and allow the federal and the state personal income tax rates to be a function of state wage.

where

$$v \equiv \left( \sum_n v_n^{\varepsilon_W} \right)^{1/\varepsilon_W}. \tag{9}$$

Under the Fréchet distribution, both the ex-ante expected utility of a worker before drawing $\left\{\epsilon_n^l\right\}_{n=1}^N$ and the average ex-post utility of agents located in any state are identical and proportional to $v$; hence, we adopt it as our measure of worker welfare.[32]

A larger value of $\varepsilon_W$ implies that the 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 larger response in the fraction of workers who choose to locate there. From the definitions of $v_n$ and $L_n$ in (6) and (8), it follows that $\varepsilon_W\left(1-\alpha_{W,n}\right)$ is the partial elasticity of the fraction of workers who locate in state $n$ with respect to after-tax real wages, $(1-T_n)(w_n/P_n)$, while $\varepsilon_W \alpha_{W,n}$ is the partial elasticity with respect to real government services per worker, $G_n/L_n^{\chi_W}$. We rely on these relationships to estimate $\{\varepsilon_W, \alpha_{W,n}\}$ in Section 6.3.

### 4.4 Capital Owners

Immobile capital owners in state $n$ own a fraction $b_n$ of a portfolio that includes all firms and fixed factors, independently of the state in which they are located. We do not need to specify the number of capital owners located in each state $n$ for our computations. In the model, a larger ownership rate relative to other states results in larger trade imbalances. Therefore, we will calibrate the ownership shares $b_n$ to match the observed trade imbalances across states.[33] Capital owners spend their income locally, pay sales taxes on consumption, and pay both federal and state income taxes on their income.[34]

### 4.5 Firms

A continuum of firms $j \in [0,1]$ decide in which state to produce and how much to sell to every state. Each firm $j$ produces a differentiated variety and is endowed with a vector of productivities $\{z_i^j\}_{i=1}^N$ across states. Firms are monopolistically competitive; when a firm $j$ located in state $i$ sets its price $p_{ni}^j$ in state $n$, the quantity exported to state $n$ is $q_{ni}^j = Q_n(p_{ni}^j/P_n)^{-\sigma}$. We first describe the profit maximization problem faced by firms located in a given state, and then solve the firms' location problem. We finally discuss some of the aggregation properties of our model.

[32] The constant of proportionality equals $\Gamma\left(\frac{\varepsilon_W-1}{\varepsilon_W}\right)$, where $\Gamma(\cdot)$ is the gamma function.

[33] See Section 6.2 for details. 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. In contrast, our current approach allows us to discipline the assumptions on factor ownership with observed data on trade imbalances.

[34] When considering progressive federal and state income in Section 7.5, we will assume that capital owners are subject to the highest marginal federal and state income tax rates. Cooper et al. (2015) show that the majority of business income accrues to very high income earners.

**Profit Maximization given Firm Location** Consider a firm $j$ located in state $i$ whose productivity is $z_i^j$. Then, its profits are

$$\pi_i\left(z_i^j\right) = \max_{\{q_{ni}^j\}} \left(1 - \bar{t}_i^j\right) \left(\sum_{n=1}^{N} x_{ni}^j - \frac{c_i}{z_i^j} \sum_{n=1}^{N} \tau_{ni} q_{ni}^j\right), \tag{10}$$

where $\bar{t}_i^j$ 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 $c_i = (w_i^{1-\beta_i} r_i^{\beta_i})^{\gamma_i} P_i^{1-\gamma_i}$ is the the cost of the cost-minimizing bundle of factors and intermediate inputs, where $r_i$ stands for the cost of a unit of land and structures in state $i$.[35]

All firms face corporate taxes apportioned through sales, payroll, and land and structures.[36] A firm $j$ located in state $i$ whose share of sales to state $n$ is $s_{ni}^j$ pays $s_{ni}^j t_n^x$ times the pre-tax national profits in corporate taxes apportioned through sales to state $n$. Firms located in $i$ also pay $t_i^l$ times the pre-tax national profits in corporate income taxes apportioned through payroll and land and structures to state $i$, and a rate $t_{fed}^{corp}$ in federal corporate income taxes. As a result, the corporate tax rate of firm $j$ is:

$$\bar{t}_i^j = t_{fed}^{corp} + t_i^l + \sum_{n=1}^{N} t_n^x s_{ni}^j. \tag{11}$$

Due to the sales apportionment of corporate taxes, the decision of how much to sell to each state in (10) is not separable across states as in the standard CES maximization problems with constant marginal production costs in Krugman (1980) or Melitz (2003). When a firm increases the fraction of its sales to state $n$ (i.e., when $s_{ni}^j$ increases), the average tax rate changes depending on the sales-apportioned corporate tax in state $n$, $t_n^x$, relative to that in other states. Since the corporate tax base is national profits, firms 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.

**Pricing Distortion Through Corporate Taxes** Despite the non-separability of the sales decision across markets, the solution to the firm optimization problem retains convenient properties from the standard CES maximization problem that allow for aggregation; we describe these properties here and refer to Appendix B.1 for details. Specifically, all firms located in a state $i$ have 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 (11), this leads to a common corporate tax rate across firms, $\bar{t}_i^j = \bar{t}_i$. 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

[35] Note that the definition of $c_i$ accounts for the fact that, unlike consumers, firms do not face the sales tax when purchasing the final good to be used as an intermediate. See footnote (22).

[36] This assumption implies that we treat all companies as C-corporations. In practice, many companies are set up as S-corporations and partnerships. These companies are not subject to corporate income taxes. We ignore them in our baseline model because they represent a small fraction of U.S. business revenues – see our previous discussion in Section 3.1. However, in Section 7.6.1, we perform a robustness check where corporate tax rates are adjusted by the actual share of C-corporations in each state.

in state $i$ is:

$$p_{ni}(z) = \tau_{ni} \frac{\sigma}{\sigma - \tilde{t}_{ni}} \frac{\sigma}{\sigma - 1} \frac{c_i}{z}, \tag{12}$$

where

$$\tilde{t}_{ni} \equiv \frac{t_n^x - \sum_{n'} t_{n'}^x s_{n'i}}{1 - \bar{t}_i}. \tag{13}$$

The term $\tilde{t}_{ni}$ is a pricing distortion created by heterogeneity in the sales-apportioned corporate tax rates. The pricing distortion increases with the sales tax in the importing state, $t_n^x$, relative to other states, implying higher prices for states with higher sales-apportioned corporate taxes. If there is no dispersion in the sales-apportioned corporate tax rates ($t_n^x = t^x$ for all $n$), the pricing decision becomes the same as in the standard CES maximization problem ($\tilde{t}_{in} = 0$ for all $i$ and $n$).

**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 that locate in $i$ and a firm-state specific component $\epsilon_i^j$: $z_i^j = z_i^0 \epsilon_i^j$. The common component of productivity is:

$$z_i^0 = \left( \frac{G_i}{M_i^{\chi_F}} \right)^{\alpha_F} z_i^{1-\alpha_F}. \tag{14}$$

As in the case of amenities, 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 real government spending $G_i$ normalized by $M_i^{\chi_F}$, where the parameter $\chi_F$ captures rivalry among firms in access to public goods. The exogenous part captures both 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.[37] Firm $j$ decides to locate in state $i$ if $i = \arg\max_{i'} \pi_{i'}(z_{i'}^j)$. The idiosyncratic component of productivity, $\epsilon_i^j$, is i.i.d. across firms and states and is drawn from a Fréchet distribution, $\Pr(\epsilon_i^j < x) = e^{-x^{-\varepsilon_F}}$. This distribution implies that firm-level profits, $\pi_i(z_i^j)$, are also Fréchet-distributed with shape parameter $\varepsilon_F / (\sigma - 1) > 1$.[38] As a result, and reminding the reader that we have normalized the mass of firms to 1, the fraction of firms located in state $i$ is

$$M_i = \left( \frac{\pi_i\left(z_i^0\right)}{\bar{\pi}} \right)^{\frac{\varepsilon_F}{\sigma - 1}}, \tag{15}$$

[37] More specifically, (14) is consistent with first defining $z_i^0 = \left( \frac{G_i^F}{M_i^{\chi_F}} \right)^{\alpha_F} z_{i,0}^{1-\alpha_F}$, where $z_{i,0}$ are natural characteristics, $G_i^F = z_i^F (1 - \theta_i) G_n$ are government services valued by firms, $z_n^F$ is the efficiency or the quality of real spending in services valued by firms, and $\theta_i^F$ is the fraction of the state budget dedicated to services valued by firms. Starting from this initial definition, (14) corresponds to defining $z_i = z_{i,0}^{1-\alpha_F} \left( z_i^F \theta_i^F \right)^{\alpha_F}$. Reminding the reader that $\theta_i^W$ is the fraction of the state budget dedicated to services valued by workers (see Footnote 29), we note that $\theta_i^F + \theta_i^W$ may be greater than 1. I.e., it is possible that the same government spending is valued by both workers and firms.

[38] This follows from the fact that, combining (10) and (14), we can express the profits of firm $j$ when it locates in state $i$ as the product of a common and an idiosyncratic component: $\pi_i(z_i^j) = \pi_i(z_i^0)(\epsilon_i^j)^{\sigma-1}$.

where $\pi_i\left(z_i^0\right)$ is the profit of a firm with productivity $z_i^0$ located in $i$ and $\bar{\pi}$ is proportional to the expected profits before drawing $\{\epsilon_i^j\}_{i=1}^N$.[39]Equation (15) says that the fraction of firms located in $n$ depends on the common component of profits in $n$, $\pi_i\left(z_i^0\right)$, relative to that in other locations. A larger value of $\varepsilon_F/\left(\sigma-1\right)$ implies that the idiosyncratic productivity draws are less dispersed across states; as a result, locations become closer substitutes and an increase in the relative profitability of a location (an increase in $\pi_i\left(z_i^0\right)/\bar{\pi}$) leads to a larger response in the fraction of firms that choose to locate there.

**Equilibrium State Productivity Distribution** Because firms self-select into each state based on their productivity draws, the productivity distribution in each state is endogenous. However, as in Melitz (2003), aggregate outcomes (in our case, at the state level) can be formulated as a function of a single moment $\tilde{z}_i$ of the the productivity distribution in each state $i$. This productivity level is endogenous and can be expressed as a function of the number of firms that optimally choose to locate in each state $i$:[40]

$$\tilde{z}_i = z_i^0 M_i^{-\frac{1}{\varepsilon_F}}. \tag{16}$$

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., $\tilde{z}_i/z_i^0 > 1$), reflecting selection. This equation describes an additional congestion force in the model: because firms are heterogeneous and self-select based on productivity, a higher number of firms locating in a state $i$ is associated with a lower average productivity in state $i$.

State-$i$ aggregate outcomes can then be constructed as if in equilibrium all the $M_i$ firms located in state $i$ had (endogenous) productivity level $\tilde{z}_i$. Appendix B.2 presents the expression for all the state-level outcomes needed to compute the general-equilibrium of the model.

**Contrast with Models with Free Entry** As in a standard economic-geography model with free entry of homogeneous firms such as Helpman (1998) or Redding (2015), our model predicts that the number of firms in each state is endogenous and proportional to aggregate sales in that location.[41] The main reason to assume mobility of heterogeneous firms instead of free-entry of homogeneous firms is that, in order to analyze corporate taxes, it is convenient to use a model with aggregate profits in every state, whereas free-entry models lead to zero profits. Additionally, this approach allows us to use data on patterns of firm mobility to estimate a single parameter, $\varepsilon_F$, which determines the elasticity of the firm count in each state with respect to taxes, and to directly

[39]Specifically, expected profits before drawing $\{\epsilon_i^j\}_{i=1}^N$ are $\Gamma\left(1-\frac{\sigma-1}{\varepsilon_F}\right)*\bar{\pi}$, where $\bar{\pi}=\left(\sum_i \pi_i\left(z_i^0\right)^{\frac{\varepsilon_F}{\sigma-1}}\right)^{\frac{\sigma-1}{\varepsilon_F}}$ and $\Gamma(\cdot)$ is the gamma function.

[40]By definition, $\tilde{z}_i=(\int_{j\in J_i}(z_i^j)^{\sigma-1}dj)^{\frac{1}{\sigma-1}}$. To reach (16), we use the property that the Fréchet assumption on the distribution of productivity draws implies $\pi\left(\tilde{z}_i\right)=\bar{\pi}$ in every state together with (15) and the relationship $\pi_i\left(z_i^0\right)/\pi_n\left(\tilde{z}_i\right)=\left(z_i^0/\tilde{z}_i\right)^{\sigma-1}$.

[41]Specifically, from (A.9) and the distributional assumption on the productivity draws, it follows that the number of firms in state $i$ can be expressed as $M_i=\frac{1-\bar{t}_i}{\bar{\pi}}\frac{X_i}{\sigma}$. If, instead, we had assumed free-entry of homogeneous firms with entry cost equal to $f_i$ units of the cost-minimizing bundle of factors and inputs in each state, the number of firms in state $i$ would have been $M_i=\frac{1-\bar{t}_i}{c_i f_i}\frac{X_i}{\sigma}$.

compare our estimates with existing work which has already estimated elasticities of firm location with respect to taxes in the public-finance literature.[42]

### 4.6 State Government

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

$$P_n G_n = R_n + T_n^{fed \to st}. \tag{17}$$

The tax revenue collected by state $n$ is

$$R_n = R_n^{corp} + R_n^{y} + R_n^{c} \tag{18}$$

where $R_n^{corp}$, $R_n^{c}$, and $R_n^{y}$ , are government revenue from corporate, sales, and income taxes, respectively. These expressions are defined in (A.23) to (A.19) in Appendix B.2.

Consistent with the empirical evidence shown in Section 3.3, we assume that transfers from the federal government to the state governments in state $n$ are proportional to the tax revenue collected by these state governments, where the constant of proportionality $\psi_n$ may vary by state: $T_n^{fed \to st} = \psi_n R_n$. Combined with (17), this implies that $P_n G_n = (1 + \psi_n) R_n$.[43] The federal government therefore subsidizes a fraction $\frac{\psi_n}{1+\psi_n}$ of spending in state $n$.[44]

### 4.7 Federal Government

As we have noted, taxes are also collected by the federal government. Expression (A.20) in Appendix B.2 shows the expression for total taxes levied by the federal government in state $n$. The federal government uses these taxes either to finance transfers to state governments, $T_n^{fed \to st}$, or to purchase the final good produced in each state, $G_n^{fed}$, as an input in the production of a national public good, $G^{fed}$. Therefore, our analysis assumes away issues related to how the public services generated by the federal government impact on worker location.

[42] The cost of assuming mobility of heterogeneous firms instead of free-entry of homogeneous firms is that, in the former, taxes do not affect the total number of firms in the economy. We note, however, that in our model the fraction of the total number of firms located in each state is determined independently from the total number of firms (here normalized to 1). Therefore, when studying the impact of changing the distribution of state taxes, allowing for free entry would not affect the welfare changes that are due to improvements in the spatial distribution of economic activity, which is the focus of our analysis. If the changes in the distribution of taxes were to have an impact on the total number of firms in the U.S. economy, this would enter as an additional effect in our analysis, orthogonal to the effect due to changes in the distribution of firms and workers across states. Furthermore, as our focus is on counterfactuals in which we modify the spatial dispersion of state taxes and not the general level of these taxes, one could expect the impact of this change in policy on the total number of firms to be smaller than the reallocation effects on the set of existing firms.

[43] In terms of the notation in regression (1), we have $P_n G_n = E_n^g$.

[44] While the distribution of federal transfer rules $\{\psi_n\}$ impacts all the model outcomes in levels, after conditioning the parameters of the model on the observed data as in Section 6, the specific values of $\{\psi_n\}$do not have any impact on the *changes* in any endogenous variable in response tax changes. Of course, we are assuming, when we implement the counterfactual, federal transfers rules remain constant.

### 4.8 General Equilibrium

**Definition** A general equilibrium of this economy consists of distributions of workers and firms $\{L_n, M_n\}_{n=1}^N$, aggregate quantities $\left\{Q_n, C_n, I_n, G_n, G_n^{fed}\right\}_{n=1}^N$, wages and rents $\{w_n, r_n\}_{n=1}^N$, and prices $\{P_n\}_{n=1}^N$ such that: i) final-goods producers optimize, so that final-goods prices are given by (3); ii) workers make consumption and location decisions optimally, as described in Section 4.3; iii) firms make production, sales, and location decisions optimally, as described in Section 4.5; iv) government budget constraints hold, as described in Section 4.6; v) goods markets clear in every location, i.e., (5) holds for all $n$; vi) the labor market clears in every state, i.e., labor supply (8) equals labor demand (given by (A.7) in Appendix B.2) for all $n$; vii) the land market clears in every location, i.e., equation (A.8) in Appendix B.2 holds; and viii) the national labor market clears, i.e., $\sum_n L_n = 1$.

**Adjusted Fundamentals** The model implies that taxes in any given state may affect outcomes in every state. These cross-state effects are complex, but can be better understood using a general-equilibrium system that determines wages and employment in every state, $\{w_n, L_n\}_{n=1}^N$ , and welfare, $v$, as functions of the model's primitives (see Appendix B.3). In this system, these outcomes are affected by state taxes $\left\{t_n^c, t_n^y, t_n^x, t_n^l\right\}_{n=1}^N$ through their impact on the *adjusted fundamentals*, $\{\{\tau\}_{i=1}^N, z_n^A, u_n^A\}_{n=1}^N$:

$$z_n^A = (1-\bar{t}_n)^{\frac{1}{\sigma-1}-\left(\frac{1}{\varepsilon_F}+\alpha_F\chi_F\right)}\left(\frac{P_nG_n}{GDP_n}\right)^{\alpha_F} z_n^{1-\alpha_F}, \tag{19}$$

$$\tau_{in}^A = \frac{\sigma}{\sigma-\tilde{t}_{in}}\tau_{in}, \tag{20}$$

$$u_n^A = (1-T_n)^{1-\alpha_W}\left(\frac{P_nG_n}{GDP_n}\right)^{\alpha_W} u_n, \tag{21}$$

where $P_nG_n/GDP_n$ is the share of state government spending in GDP derived in Appendix B.2.[45] The adjusted fundamentals are functions of state fundamentals (productivity $z_n$, amenity $u_n$, and trade costs $\tau_{in}$), tax rates, and government size. In general equilibrium, the distribution of outcomes across states depends on the distribution of adjusted fundamentals, $\left\{z_n^A, \tau_{in}^A, u_n^A\right\}$, similarly to how it would depend on the "regular" fundamentals, $\{z_n, \tau_{in}, u_n\}$, in regular economic-geography models. Since the latter mapping is well known (e.g., see Allen and Arkolakis (2013) or Redding (2015)), understanding the impact of each tax on outcomes in our case amounts to understanding the impact of each tax on the vector of adjusted fundamentals. Conditions (19) to (21) readily imply that corporate taxes in any state shift the entire distribution of adjusted trade costs and productivity, while state and income taxes shift the adjusted amenities of the own state only. In addition, taxes in any state impact the entire distribution of adjusted productivities and amenities through government size relative to GDP.

[45] In addition to the adjusted fundamentals, taxes also impact wages, employment and welfare through their effects on trade imbalances, as shown in (A.25).

**Agglomeration Forces, Congestion Forces, and Uniqueness** The model features several agglomeration and congestion forces. Due to the agglomeration forces, workers and firms tend to locate in the same state, whereas the congestion forces imply that workers and firms tend 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 states with low price indices and large markets; in turn, the price index decreases with the number of firms, and market size increases with the number of workers. Our model also features agglomeration through public-services provision: states with a larger number of firms and workers have higher tax revenue and spending; therefore, larger market size leads to higher utility per worker (see (6)) or firm productivity (see (14)). This agglomeration force decreases with the parameters $\chi_W$ and $\chi_F$.

Our model features congestion through: immobile factors in production, leading to a higher marginal production cost in a state when employment increases in that state (see (A.8) in Appendix B.2); through selection of heterogeneous firms, leading to a lower average firm productivity in a state when the number of firms increases (see (16)); and through the presence of immobile capital-owners, who spend their income where they are located.

In light of these agglomeration and congestion forces, it is natural to ask whether the general equilibrium is unique. Allen et al. (2014) establish conditions for existence and uniqueness in a class of trade and economic geography models. Our model fits in that class when technologies are homogeneous across states ($\beta_n = \beta$ and $\gamma_n = \gamma$ for all $n$), there is no dispersion in sales-apportioned corporate taxes across states ($t_n^x = t^x$ for all $n$), and there is no cross-ownership of assets across states. Appendix B.4 shows a uniqueness condition from Allen et al. (2014) applied to this restricted model. The condition is satisfied by the parameter values estimated in Section 6, under which we compute the counterfactual results presented in Section 7.[46]

# 5 Impact of Tax Dispersion in a Simpler Version of the Model

Our main counterfactuals eliminate tax dispersion while keeping the government spending in every state, $\{G_n\}$, constant. Our analysis focuses on two aggregate outcomes, worker welfare $v$ defined in (9), and the aggregate real income of all factors. We remind the reader that $v$ corresponds to the ex-ante utility (i.e., before drawing the idiosyncratic preference draws) of a representative worker. Aggregate real income equals the sum of aggregate real consumption and real government expenditures.[47]

[46] Changing one parameter at a time around our estimates, we find that these sufficient conditions for uniqueness are violated if the elasticities of firm and labor mobility ($\varepsilon_F$ and $\varepsilon_W$) or the importance of government spending for firms and workers ($\alpha_F$ and $\alpha_W$) are sufficiently high, or if congestion in the provision of public goods ($\chi_W$ and $\chi_F$) or the elasticity of substitution $\sigma$ are sufficiently low. When numerically computing the impact of counterfactual distribution of taxes on the equilibrium of our model, we experiment with different starting values of our algorithm and always find the same results, suggesting that the system of equations we employ to compute such equilibrium indeed has a unique solution.

[47] As we discussed in Section 4.4, the returns to firms and land are owned by immobile agents in each state. Therefore, in addition to the representative worker, the model includes 50 different types of capital owners, one for

**Proposition.** *Assume no trade costs ($\tau_{in} = 1$ for all $i, n$), perfect substitutability ($\sigma \to \infty$), and homogeneous firms ($\varepsilon_F \to \infty$). Also assume assume no cross-state dispersion in labor's income share in value added ($\beta_n = \beta$ for all $n$) and preferences for government spending ($\alpha_{W,n} = \alpha_W$). Then, letting*

$$Z_n \equiv (1-\beta)^{1-\beta} \left(\frac{z_n^0}{\gamma_n}\right)^{\frac{1}{\gamma_n}} \left(\frac{H_n}{\beta}\right)^{\beta} (u_n G_n^{\alpha_W})^{\frac{1}{1-\alpha_W}},$$

*and*

$$\zeta \equiv \frac{1-\alpha_W}{1/\varepsilon_W + \alpha_W \chi_W + (1-\alpha_W)\beta},$$

*eliminating the dispersion in $\{T_n\}$:*

*i) increases worker welfare if corr $\left[Z_n^{\zeta}, (1-T_n)^{\zeta}\right]$ is low enough, and it decreases it if that correlation is large enough;*

*ii) increases worker welfare if $\zeta < 1$ and corr $\left[Z_n^{\zeta}, (1-T_n)^{\zeta}\right] \leq 0$, and it decreases it if $\zeta > 1$ and corr $\left[Z_n^{\zeta}, (1-T_n)^{\zeta}\right] \geq 0$;*

*iii) may increase or decrease real income depending on the joint distribution of $T_n$, $u_n$, and $G_n$; and*

*iv) if $\varepsilon_W \to \infty$, $\alpha_W = 0$, and there is no dispersion in amenities ($u_n = u$ for all $n$), it necessarily increases real income.*

A key implication of the proposition is that our model does not impose an answer to the question of whether reducing dispersion in income and sales taxes (entering through $T_n$) keeping government spending constant has a positive or negative effect on either worker welfare or aggregate real income. That is, depending on the value of the parameters, the elimination of tax dispersion implemented in the counterfactuals may increase or decrease worker's welfare and real income. We discuss in Section 6 the procedure that we follow to estimate the different model parameters.[48]

To grasp the intuition for the predictions in the proposition, note that worker welfare $v$, defined in (9), increases with dispersion in the distribution of state-specific "appeal", $v_n$, defined in (6). This property follows from the discrete-choice nature of the location problem: workers choose the best among many options, implying that higher variance in the appeal of available options is preferable.[49] Understanding the impact of eliminating dispersion in the worker tax keep-rate $T_n$ on

each state. In the quantitative analysis we also report results for the changes in the aggregate real consumption of workers and capital-owners combined.

[48] The assumptions in the proposition eliminate bilateral spatial interactions as well as any role for firms or corporate taxes in affecting state outcomes. The resulting market structure is equivalent to perfect competition. Our more general model with trade costs features agglomeration through home-market effects whereby the returns of a firm to locating in a state increase with the number of workers and firms located in that state and in close-by states. It is understood that this impacts the allocation and real income similarly to external economies of scale in a perfectly competitive model, potentially leading to inefficiencies in the allocation; e.g. see Abdel-Rahman and Fujita (1990) and Allen and Arkolakis (2014). Eeckhout and Guner (2015) find that heterogeneity in income taxes across cities may be welfare-maximizing in a setup with externalities from city size.

[49] I.e., worker's welfare is defined as the expectation of the maximum utility across locations, $v \propto \mathbb{E}\left[\max_n \left\{v_n \epsilon_n^l\right\}\right]$, and the maximum operator is convex in its arguments. Note that this logic does not rely on worker heterogeneity or in the Fréchet distribution. Specifically, it is easy to show that the steps behind the proposition go through when workers are homogeneous (formally, when $\varepsilon_W \to \infty$), which corresponds to a model with perfect mobility. Indeed, everything else equal, a given increase in the dispersion of appeal, $v_n$, across locations has a larger positive impact

worker welfare then boils down to understanding whether eliminating dispersion in taxes translates to more or less dispersion in the distribution of state appeal, $\{v_n\}$. In equilibrium that distribution depends on worker keep-rates $1 - T_n$ (which directly impact $v_n$) and fundamentals, as captured by the summary measure $Z_n$.[50]

Part i) of the result then says that, when the correlation between keep rates and fundamentals is sufficiently large, so is dispersion in state appeal, and as a result eliminating dispersion in taxes lowers welfare. The opposite happens when the correlation between keep rates and fundamentals is sufficiently low. Part ii) determines what "sufficiently large" and "sufficiently low" exactly means once further restrictions are imposed on the parameter $\zeta$. Specifically, if $\zeta > 1$ ($\zeta < 1$) eliminating tax dispersion increases (decreases) welfare if the correlation between keep rates and fundamentals is positive (negative).

Part ii) is specially useful to understand how different forces shape the impact of eliminating dispersion. Consider, specifically, the case in which keep rates and fundamentals are independent, i.e., $corr\left[Z_n^{\zeta}, (1-T_n)^{\zeta}\right] = 0$. A direct corollary of part ii) is then that eliminating tax dispersion increases welfare if $\zeta < 1$, or

$$(1 - \alpha_W)(1 - \beta) > 1/\varepsilon_W + \alpha_W \chi_W, \tag{22}$$

and it reduces it $\zeta > 1$. Condition (22) implies that eliminating tax dispersion is likely to increase worker welfare when the parameters $\alpha_W$, $\beta$, and $\chi_W$ are large, and when $\varepsilon_W$ is small. Specifically, under perfect mobility ($\varepsilon_W \to \infty$) and either no preference for public services or no congestion ($\alpha_W = 0$ or $\chi_W = 0$), eliminating tax dispersion necessarily reduces worker welfare; while for sufficiently small worker mobility ($\varepsilon_W \to 1$) or labor share ($\beta \to 1$), it necessarily increases it. Again, the intuition for these results follows from the impact of dispersion in keep rates on dispersion in state appeal. Since taxes directly impact state appeal through real consumption, a smaller share of consumption of final goods in preferences naturally tempers the direct gains from tax dispersion. In general, tax dispersion leads to labor-supply dispersion, and the more so the more likely workers are to switch regions (the higher is $\varepsilon_W$). This dispersion in labor-supply affects dispersion in state appeal through two different channels. First, larger congestion in access to public services (higher $\chi_W$) implies that less variation in state appeal results from such increase in labor-supply dispersion. Second, dispersion in labor supply translates into dispersion in wages depending on the curvature in labor demand: a larger labor share (smaller $\beta$) implies that more wage dispersion and, therefore, more dispersion in $v_n$ results from any given increase in labor dispersion.

Part iii) of the proposition implies that the impact of tax dispersion on net aggregate aggregate real income is ambiguous. Note that, in this case of the model, the aggregate real income of of all factors is the sum of output in all regions, net of what is used as an intermediate input. This

on welfare the larger $\varepsilon_W$ is. In the case without workers heterogeneity, $v = \max_n \{v_n\}$ and, in equilibrium, $v = v_n$ for al $n$.

[50] Note that $v_n$ is a function of employment and wage in each location. Both variables are determined through local labor-market clearing, and the variable $Z_n$ includes demand shifters (i.e., productivity, value added share in production, and endowments of fixed factors) and supply shifters (i.e., amenities and government spending) that impact on the local labor market clearing condition.

ambiguity then naturally follows from departures from equalization of marginal products of labor across regions. Consider for example an even more restricted version of our model with homogeneous workers ($\varepsilon_W \to \infty$) and no congestion in public goods ($\chi_W = 1$). Because workers are homogeneous, they must be indifferent across locations. From (6) this implies $v = u_n G_n^{\alpha_W} \left((1 - T_n) MPL_n\right)^{1-\alpha_W}$ for all $n$, where we have imposed the property that the wage equals the marginal product of labor, $w_n = MPL_n$. Therefore, the marginal product of labor is equalized across all states only if the compensating differentials $u_n G_n^{\alpha_W} (1 - T_n)^{1-\alpha_W}$, which capture a region's appeal due to reasons other than the real wage, do not vary across locations. It is then straightforward to construct examples in which an elimination of tax dispersion reduces output; for example, this result may happen in cases in which there is initially a negative correlation between taxes and amenities.[51] If, part iv) of the proposition implies, we assume homogeneous workers ($\varepsilon_W \to \infty$), no preference for public goods ($\alpha_W = 0$), and no dispersion in amenities ($u_n = u$ for all $n$), eliminating tax dispersion while keeping the mean of taxes constant necessarily increases output because in this case there is no dispersion in these compensating differentials.[52]

# 6 Data and Estimation

As discussed in the previous section, removing tax dispersion may increase or decrease worker's welfare and aggregate real income depending on the model's parameters. This section describes our procedures to estimate and calibrate the model's parameters. Section 6.1 describes our data. Section 6.2 discusses the calibration of parameters that determine the technologies of production, state fundamentals, and ownership of capital by state. Section 6.3 derives and estimates labor and firm mobility equations and recovers the elasticities of factor mobility and the weights of public goods on preferences and productivity, respectively. Section 6.4 shows that the model matches data on the distribution of economic activity that are not used in our calibration or estimation.

## 6.1 Data

We use a variety of data sources to measure different aspects of the U.S. economy. Appendix F provides a full description of our data sources. We use data from the Economic Census to calibrate

[51] E.g.,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 taxes, $B_1 = \frac{1}{A_1}$ and $B_2 = \frac{1}{A_2}$. In this case output is maximized because marginal products are equalized ($v^{1/(1-\alpha_W)} = MPL_n$ for $n = 1, 2$). Therefore, eliminating tax dispersion increases dispersion in marginal products, reducing output. Hopenhayn (2014) studies how the impact of dispersion in distortions depends on their correlation with productivity in general cases.

[52] In this case the model becomes formally equivalent to a static version of Restuccia and Rogerson (2008) or to a single-sector version of Hsieh and Klenow (2009) in which the only distortion in these environments is a labor distortion. The states here would correspond to firms in these environments, whereas the income tax $T_n$ here would impact the allocation similarly to a labor distortion $T_n / (1 - T_n)$ in these environments. Note that, through the worker's indifference condition, the definition of worker's welfare $v$ in this case becomes the same as the after-tax real wage, i.e. $v = (1 - T_n) w_n$ for all $n$. Letting $L_n^* (w_n)$ be labor demand, labor-market clearing then implies $\sum_n L_n^* \left(\frac{v}{1-T_n}\right) = 1$. If $L_n^* \left(\frac{1}{x}\right)$ is convex in $x$, then an increase in the dispersion of $1 - T_n$ raises the after-tax real wage, $v$. Under Cobb-Douglas, $L_n^* \left(\frac{1}{x}\right) \propto x^{1/\beta}$ is convex in $x$. More generally, the convexity of labor demand depends on the third derivative of the production function. This also implies that, broadly speaking, an elimination of tax dispersion is more likely to lower the real wage under Cobb-Douglas than under more flexible functional forms.

the technology parameters state fundamentals and ownership rates. These calibrations, which are described in Section 6.2, require data on employment $L_n$, wages $w_n$, total sales, GDP, and total expenditures $P_nQ_n$ that are most recently available for year 2007. Finally, we complement these data with a recently-developed data series by the B.E.A. on Personal Consumption Expenditures as our measure of aggregate consumption by state, $P_nC_n$.

Since the model is cast in closed economy, we construct a measure of total sales in the model, $X_n$, by subtracting each state's exports to the rest of the world from their total sales.[53] Intermediate-input expenditures, $P_nI_n$, are constructed as the difference between each state's sales and GDP. Total expenditures, $P_nQ_n$, are the sum of personal consumption expenditures, intermediate-goods expenditures, and government expenditures. To construct bilateral sales shares $s_{in}$ and expenditure shares $\lambda_{in}$, we use information on bilateral trade flows from the Commodity Flow Survey (CFS) and define own-state sales as the difference between total sales and trade flows to every other state.[54]

We use yearly data from 1980 to 2010 on state-level economic activity to estimate the labor and firm mobility elasticities and the weights of government spending in preferences and firm productivity in Section 6.3. Since data from the Economic Censuses are only available every five years, we rely on the County Business Patterns (CBP) for data on the number of workers and firms.[55] We use data from the Current Population Survey (CPS) to construct an hourly wage measure by state. We use regional price indices from the Bureau of Labor Statistics. As detailed in Appendix F.1, the data on tax rates and total tax revenues are drawn from the Annual Survey of Governments, NBER TAXSIM, the Book of States, and Suárez Serrato and Zidar (2015). We measure state tax revenue as the sum of tax revenue from personal income, corporate income, and sales taxes.

## 6.2 Calibrated Parameters

**Technologies** We set the state-specific value-added shares, $\gamma_n$, and shares of labor in value added, $1-\beta_n$, so that the intermediate-input and employment shares predicted by the model in (A.6), (A.7), and (A.9) match their empirical counterparts for each state in the year 2007.[56] The averages across states of our calibrated parameters are: $N^{-1}\sum_n(1-\gamma_n) = 0.62$ and $N^{-1}\sum_n(1-\beta_n) = 0.68$.

**Fundamentals** The system of equations that characterizes the general equilibrium impact of changes in taxes, described in Appendix B.5, is a function of all fundamentals (endowments of land and structures $H_n$, productivities $z_n$, amenities $u_n$, and trade costs $\tau_{in}$) for every state or pair of states. However, these fundamentals only enter this system of equations through the composite

[53] To measure each state's exports, we use the total value of all merchandise exported to the rest of the world from the U.S. Department of Commerce International Trade Administration's TradeStats Express dataset.

[54] The data on sales from the Economic Census aggregates across all sectors; trade data from the CFS is available only for a subset of sectors. Specifically, the CFS includes the following industries: mining, manufacturing, wholesale trade, and select retail and services. Therefore, our definition of own-state sales assumes that sales revenue from all sectors not accounted for in the CFS data is obtained in the home state.

[55] The information on number of workers and establishments reported in the CBP is consistent with that reported by the Census in those years when both are available.

[56] I.e. $1-\gamma_n = \frac{\sigma}{\sigma-1}\frac{P_nI_n}{X_n}$ and $1-\beta_n = \frac{\sigma}{\sigma-1}\frac{w_nL_n}{\gamma_nX_n}$. For these calculations, we use the value of $\sigma$ described below.

$A_{in}$ defined in (A.34) in Appendix B.3. This feature implies that we do not need to calibrate the value of all fundamentals separately as long as we calibrate the the composite parameter $A_{in}$.[57] To calibrate this composite, we use the function of expenditure shares, wages, and employment described in equation (A.32). As a result, the parametrized model exactly matches the distributions of bilateral expenditure shares, bilateral sales shares, wages, and employment across states in 2007.

**Ownership Rates** Expression (A.27) in Appendix B.2 shows that the set of parameters $\{b_n\}_{n=1}^N$ are uniquely identified as a function of observables, technology 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.[58]

**Other Parameters** In our model, the parameter $1-\sigma$ is the partial elasticity of import shares with respect to bilateral trade costs.[59] 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 will set its value to 4, which is a central value in the range of estimates in the international trade literature; see Head and Mayer (2014). The final set of parameters that we calibrate are the congestion parameters $(\chi_W, \chi_F)$. As we show in the next section, these parameters are not separately identified from firm- and labor-mobility elasticities $(\varepsilon_F, \varepsilon_W)$. We remain agnostic on the value of the parameters $(\chi_W, \chi_F)$ and estimate the remaining parameters and present counterfactuals conditional on $\chi_W$ and $\chi_F$ taking a range of values in the parameter space.

### 6.3 Estimated Elasticities

In this section, we describe how we use the model's equilibrium conditions from Section 4 and the data described in Section 6.1 to estimate the parameters governing the dispersion of worker preferences across states, $\varepsilon_W$, the share of public goods in worker preferences, $\alpha_{W,n}$, the dispersion of firms' productivity across states, $\varepsilon_F$, and the share of public goods in firms' productivity, $\alpha_F$. As the firm- and worker-level parameters are identified by separate equilibrium conditions, we discuss the estimation and identification of parameter vector ($\varepsilon_W$,$\alpha_{W,n}$) separately from the estimation and identification of the parameter vector ($\varepsilon_F$,$\alpha_F$). Importantly, Appendix D.4 shows that our estimates are in line with the previous literature, which rely on independent identifying variation.

[57] This feature of our model is shared by the models of trade and economic geography 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.

[58] Our model implies that an alternative procedure to calibrate the ownership rates, $b_n$, is to identify them from data on the share of national dividend, interest, and rental income earned in each state in 2007, as reported in the BEA regional data on personal incomes (CA 30). The ownership rates that arise from this calibration procedure are positively correlated with those obtained using exclusively information on trade imbalances. In particular, in 2007, we estimate that $b_n = 0.14 + 1.36 SHARE_n$ where the standard errors for the intercept and slope are 0.018 and 0.28, respectively.

[59] See expression (A.11) in the appendix. In addition to bilateral trade costs, our model also includes the bilateral pricing distortion $\tilde{t}_{ni}$ which is endogenous to trade flows.

**Estimation of ($\varepsilon_W$,$\alpha_W$)**

We obtain an expression for the share of labor in state $n$ in year $t$ by combining the labor supply equation in (8), the definition of the state effect in (6), and the government budget constraint in (17):

$$\ln(L_{nt}) = a_{0,n}\ln(\tilde{w}_{nt}) + a_{1,n}\ln(\tilde{R}_{nt}) + \psi_t^L + \xi_n^L + \nu_{nt}^L, \tag{23}$$

where $a_{0,n} \equiv \varepsilon_W(1-\alpha_{W,n})/(1+\chi_W\varepsilon_W\alpha_{W,n})$ and $a_{1,n} \equiv \varepsilon_W\alpha_{W,n}/(1+\chi_W\varepsilon_W\alpha_{W,n})$ are functions of structural parameters; $\psi_t^L \equiv -\varepsilon_W/(1+\chi_W\varepsilon_W\alpha_W) * \ln(v_t)$ is a time effect that captures welfare at time $t$;[60] $\xi_n^L + \nu_{nt}^L \equiv \varepsilon_W/(1+\chi_W\varepsilon_W\alpha_W) * \ln(u_{nt})$ accounts for state effects and deviations from state and year effects in amenities, $u_{nt}$; $\tilde{w}_{nt} \equiv (1-T_{nt})(w_{nt}/P_{nt})$ is after-tax real wage; and $\tilde{R}_{nt} = R_{nt}/P_{nt}$ is real government spending. The slopes $a_{0,n}$ and $a_{1,n}$ are functions of three structural parameters: $\varepsilon_W$, $\alpha_{W,n}$ and $\chi_W$. Given identification of $a_{0,n}$ and $a_{1,n}$, the preference for government spending is identified by $\alpha_{W,n} = a_{1,n}/(a_{0,n}+a_{1,n})$. Since the parameters $\varepsilon_W$ and $\chi_W$ are not separately identified, we present estimates of $\varepsilon_W$ conditional on different values of $\chi_W$.

Given equation (23), data on $\tilde{w}_{nt}$, $\tilde{R}_{nt}$, a fixed value of $\chi_W$, and a vector of instruments $\boldsymbol{Z}_{nt}^L$, one may identify the parameters $\varepsilon_W$ and $\alpha_{W,n}$ using moment conditions implied by the following mean independence assumption

$$\mathbb{E}[\nu_{nt}^L | \boldsymbol{Z}_{nt}^L, \boldsymbol{\xi}^L, \boldsymbol{\psi}^L] = 0, \tag{24}$$

where $\boldsymbol{\xi}^L$ denotes a set of state fixed effects and $\boldsymbol{\psi}^L$ denotes a set of year fixed effects. This orthogonality restriction assumes that the state-year specific amenity shocks, $\nu_{nt}^L$, are mean independent of the vector of instruments $\boldsymbol{Z}_{nt}^L$. Our model, however, predicts amenities in a state to be negatively correlated with its after-tax real wages and positively correlated with its real government spending. Intuitively, higher amenities in a state attract workers, shift out the labor supply curve, and lower wages. Similarly, an increase in the number of workers raises tax revenue and thus increases government spending. Our model thus predicts that the mean independence assumption in equation (24) will not hold if real wages, $\tilde{w}_{nt}$, or real government spending, $\tilde{R}_{nt}$, are included as elements of the instrument vector $\boldsymbol{Z}_{nt}^L$.[61] To obtain consistent estimates of $\varepsilon_W$ and $\alpha_{W,n}$, we use a vector of "external" state tax rates as instruments. Specifically, our estimator employs a vector of inverse-distance weighted average of sales, income, and sales-apportioned corporate tax rates in every state other than $n$ as instrument vector $\boldsymbol{Z}_{nt}^L$; i.e., $\boldsymbol{Z}_{nt}^L = (t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$, where

$$t_{nt}^{*z} \equiv \sum_{i \neq n} \omega_{ni} t_{it}^z, \quad \text{with} \quad \omega_{ni} = \frac{\ln(dist_{ni})^{-1}}{\sum_{i' \neq n}\ln(dist_{ni'})^{-1}} \quad \text{for} \quad z = c, x, y. \tag{25}$$

Given the estimating equation in (23) and the mean independence restriction in equation (24), we derive a set of unconditional moment conditions and use a Generalized Method of Moments (GMM) estimator to obtain estimates of $\varepsilon_W$ and $\alpha_{W,n}$. We follow different approaches to use

[60] We have normalized total employment to 1 in the model. Time variation in aggregate labor supply leads to changes in $v_t$, hence $\psi_t^L$ implicitly accounts for changes in aggregate labor supply.

[61] More precisely, our model predicts that a GMM estimator based on using real wages, $\tilde{w}_{nt}$, or real government spending, $\tilde{R}_{nt}$, as instruments will be biased downwards in the case of $a_0$ and biased upwards in the case of $a_1$. These biases in $a_0$ and $a_1$ would therefore imply an upward bias in the estimate of $\alpha_W$.

Table 1: GMM Estimates of Worker Parameters

| | $\varepsilon_W$ | | $\alpha_W$ | |
|---|---|---|---|---|
| Case | $\chi_W = 0$ | $\chi_W = 1$ | $\chi_W = 0$ | $\chi_W = 1$ |
| Estimate $\alpha_W$ | 1.24*** | 1.57*** | .17* | .17* |
| | (0.32) | (0.58) | (0.09) | (0.09) |
| Estimate $\alpha_{W,n} = \alpha_0 + \alpha_1 POL_n$ | | | [.14,.18] | [.16,.17] |
| $\alpha_W = 0$ | 1.04*** | 1.04*** | | |
| | (0.31) | (0.31) | | |
| $\alpha_W = .05$ =Mean $\frac{R_n}{GDP_n}$ | 1.15*** | 1.22*** | | |
| | (0.32) | (0.36) | | |
| $\alpha_{W,n} = \frac{R_n}{GDP_n}$ | 1.25*** | 1.4*** | | |
| | (0.36) | (0.49) | | |

NOTES: This table shows the GMM estimates for structural parameters entering the labor mobility equation. The dependent variable is log state employment, $\ln L_{nt}$. The data are at the state-year level. Each column has 712 observations. Real variables – after-tax real wages $\ln \tilde{w}_{nt}$ and real government expenditures $\ln \tilde{R}_{nt}$ – are divided by a price index variable from the BLS, which is available for a subset of states that collectively amount to roughly 80 percent of total U.S. population. Every specification includes state and year fixed effects. Row 1 estimates both $\varepsilon_W$ and $\alpha_W$. Row 2 estimates auxiliary parameters $\alpha_0$ and $\alpha_1$ given the values of $\varepsilon_W$ from row 1. For $\chi_W = 0$, $\hat{\alpha}_0 = .16^{*}(.09)$ and $\hat{\alpha}_1 = .006(.043)$. For $\chi_W = 1$, $\hat{\alpha}_0 = .17^{**}(.07)$ and $\hat{\alpha}_1 = -.003(.025)$. The table shows the resulting [Min,Max] values across states. Rows 3-5 calibrate $\alpha_W$ as described in the Case column. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

the data available to estimate the elasticity of workers mobility and the workers' preferences for public goods. The outcome of these different approaches is reported in Table 1. In Section 7, we explore how sensitive our predictions for the impact on welfare and aggregate real GDP of the counterfactual of interest are to the estimates generated by these different approaches.

First, we assume that $\alpha_{W,n} = \alpha_W$, which increases precision by reducing the number that need to be estimated. We estimate the parameter vector $(\varepsilon_W, \alpha_W)$ using the set of moment conditions $\mathbb{E}[\nu^L_{nt} * (\boldsymbol{Z}^L_{nt}, \boldsymbol{\xi}^L, \boldsymbol{\psi}^L)'] = 0$. As reported in the first row in Table 1, conditional on imposing that public goods enjoyed by workers are rival (i.e. $\chi_W = 1$), our estimates of $\varepsilon_W$ and $\alpha_W$ equal 1.57 and 0.17, with standard errors 0.58 and 0.09, respectively.

Second, we allow for state-specific workers' preferences for public goods in two ways. As a first approach, we explore whether the political ideology of state residents correlates with workers' preferences for government spending across states. Specifically, we assume that $\alpha_{W,n} = \alpha_0 + \alpha_1 POL_n$, where $POL_n$ is a standardized political index constructed by Ceaser and Saldin (2005) that takes higher values for states with higher Republican party vote shares in national and state elections. We then estimate the parameters $\alpha_0$ and $\alpha_1$ using the set of moment conditions $\mathbb{E}[\nu^L_{nt} * (\boldsymbol{Z}^L_{nt}, \boldsymbol{\xi}^L, \boldsymbol{\psi}^L, POL_n)'] = 0$ and calibrating $\varepsilon_W$ to the values in row 1. Conditional on $\chi_W = 1$, we estimate $\hat{\alpha}_0 = 0.17$ (0.07) and $\hat{\alpha}_1 = -0.003$ (0.025), which implies that states with higher Republican party vote have a smaller preference parameter for government spending. As a second

approach to allow for heterogeneous preferences for public goods across states, we use the observed ratio of tax revenue to GDP by state to calibrate the dispersion in workers' preference for public goods. Specifically, we assume that $\alpha_{W,n} = \phi + R_n/GDP_n$, where $\phi$ is a constant such that the cross-state average of these calibrated $\{\alpha_{W,n}\}$ coincides with the benchmark value of 0.17.[62] This approach yields estimates of $\alpha_{W,n}$ between 0.147 and 0.218. Conditional on these calibrated values of the parameter vector $\{\alpha_{W,n}\}$ and $\chi_W = 1$, we use the set of moment conditions $\mathbb{E}[\nu_{nt}^L * (\boldsymbol{Z}_{nt}^L, \boldsymbol{\xi}^L, \boldsymbol{\psi}^L)'] = 0$ to estimate the parameter $\varepsilon_W$. The resulting estimate of $\varepsilon_W$ is 1.4 (0.49), which is very similar to that obtained in the two alternative approaches above.

An important conclusion from the results presented in Section 7 is that, conditional on using the restrictions implied by the equilibrium equation in (23) and the mean independence restriction in (24) to estimate the elasticity of worker mobility, $\varepsilon_W$, the implications of our counterfactual of interest are very robust to the particular parametrization we employ for the vector of workers' preferences for public goods, $\{\alpha_{W,n}\}$. To make this conclusion transparent, we further re-estimate $\varepsilon_W$ under the alternative assumptions that the public services provided by state governments have a low impact on worker's utility (i.e., $\alpha_{W,n} = 0.05$ set to correspond to the mean $\frac{R_n}{GDP_n}$) or, in the extreme, have no impact on workers' utility (i.e., $\alpha_{W,n} = 0$). We obtain estimates of $\varepsilon_W$ of 1.22(0.36) and 1.04 (0.31), respectively, and we include these extreme parametrizations in the set of parameters considered in the counterfactuals of Section 7.

As the first column in Table 1 shows, imposing the opposite assumption that public goods are non-rival ($\chi_W = 0$) does not affect the estimate of $\alpha_W$ when this parameter is computed using the restrictions implied by equations (23) and (24), and only slightly decreases the estimates of $\varepsilon_W$ that result from the different estimation approaches described above. Finally, we find similar, if slightly, larger effects using 5-year changes. [63]

**Estimation of ($\varepsilon_F$,$\alpha_F$)**

We obtain an expression for the share of firms in state $n$ and year $t$ by combining the firm-location equation in (15) with the definition of profits in (A.10), the pricing equation in (12), and the definition of productivity in (14):

$$\ln M_{nt} = b_0 \ln\left((1-\bar{t}_n)\, MP_{nt}\right) + b_1 \ln c_{nt} + b_2 \ln(\tilde{R}_{nt}) + \psi_t^M + \xi_n^M + \nu_{nt}^M, \tag{26}$$

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 $\xi_n^M + \nu_{nt}^M$ accounts for state effects and deviations from state and year effects in log productivity, $\ln(z_{nt})$.[64] Unit costs are given by $c_{nt} = (w_{nt}^{1-\beta_n} r_{nt}^{\beta_n})^{\gamma_n} P_{nt}^{1-\gamma_n}$ and the term $MP_{nt}$ is

[62] Specifically, $\phi = 0.17 - N^{-1}\sum_n (R_n/GDP_n)$.

[63] We also re-estimate $\varepsilon_W$ and $\alpha_W$ under the assumption that each period in our model corresponds to a half-decade. This approach yields modestly larger estimates for $\varepsilon_W$ and very similar estimates of $\alpha_W$. However, as a consequence of time aggregation, the number of observations in the sample decrease and, therefore, the resulting estimates have larger standard errors.

[64] I.e., $\psi_t^M \equiv -\varepsilon_F/((\sigma-1)(1+\chi_F\alpha_F\varepsilon_F)) * \ln(\sigma\bar{\pi}_t)$ and $\xi_n^M + \nu_{nt}^M \equiv (1-\alpha_F)\varepsilon_F/(1+\chi_F\alpha_F\varepsilon_F) * \ln(z_{nt})$.

the market potential of state $n$ in year $t$,

$$MP_{nt} = \sum_{n'} E_{n't} \left( \frac{\tau_{n'nt}}{P_{n't}} \frac{\sigma}{\sigma - \tilde{t}_{n'nt}} \frac{\sigma}{\sigma - 1} \right)^{1-\sigma}, \tag{27}$$

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.[65] Details on how we construct measures of all the covariates entering the right-hand side of (27) are contained in Appendix D.1.

The slopes $b_0$, $b_1$, and $b_2$ are functions of four structural parameters: $\varepsilon_W$, $\alpha_W$, $\chi_W$ and $\sigma$. Given identification of the parameters $b_0$, $b_1$, and $b_2$, the impact of government spending on productivity is identified by $\alpha_F = -b_2/b_1$. Because the term $MP_{nt}$ depends on the parameter $\sigma$, the identification of $\sigma$ from equation (26) is very sensitive to the particular proxy that we adopt for the trade costs between any two regions $n$ and $n'$, $\tau_{n'nt}$. Given that we do not have a precise measure of these trade costs, $\sigma$ is fixed to a standard value in the international trade literature, as we have mentioned above. Since the parameters $\varepsilon_F$ and $\chi_F$ are not separately identified we present estimates of $\varepsilon_F$ (and of our counterfactual results from Section 7) conditional on $\chi_F$ taking the extreme values 0 or 1.

Conditional on assumed values for $\chi_F$ and $\sigma$, equation (26) contains three reduced-form parameters (i.e., $b_0$, $b_1$, and $b_2$) that jointly identify the two structural parameters $\varepsilon_F$ and $\alpha_F$. We identify the parameters $\varepsilon_F$ and $\alpha_F$ using a a vector of instruments $\boldsymbol{Z}_{nt}^M$ that, together with equation (26), form the following moment conditions:

$$\mathbb{E}[\nu_{nt}^M * (\boldsymbol{Z}_{nt}^M, \boldsymbol{\xi}^M, \boldsymbol{\psi}^M)'] = 0, \tag{28}$$

where $\boldsymbol{\xi}^M$ denotes a set of state fixed effects and $\boldsymbol{\psi}^M$ denotes a set of year fixed effects. These moment conditions assume that the state-year specific productivity shocks $\nu_{nt}^M$ are mean independent of the vector of instruments $\boldsymbol{Z}_{nt}^M$, which invalidates including unit production costs, $c_{nt}$, real government spending, $\tilde{R}_{nt}$, or market potential, $MP_{nt}$, as elements of the instrument vector $\boldsymbol{Z}_{nt}^M$.[66] The instrument vector $\boldsymbol{Z}_{nt}^M$ incorporates a vector of inverse-distance weighted average of sales, income, and sales-apportioned corporate tax rates in every state other than $n$; i.e., $(t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$ where each of this covariates is constructed as indicated in equation (25). Additionally, the vector $\boldsymbol{Z}_{nt}^M$ also incorporates an exogenous shifter $MP_{nt}^*$ of the market potential term. This exogenous shifter of market potential is constructed similarly to market potential $MP_{nt}$ in (27), but differs from it in that we substitute the components $E_{nt}$, $P_{nt}$, and $\{\tilde{t}_{n'nt}\}_{n'=1}^N$, which according to our model are correlated with $\nu_{nt}^M$, with functions of exogenous covariates. Appendix D.2 presents the precise definition of $MP_{nt}^*$ (see equation (A.59)).

[65] This is a standard term in multi-country models of trade, e.g. see Redding and Venables (2004).

[66] Furthermore, obtaining good measures of either state marginal production costs or market potential is hard: unit costs depend on the rental rate of capital for each state, which is observed only for one of the years in the sample; and the measure of market potential depends on measures of transport costs between any two states in every year. Measurement error in these covariates would also bias the resulting GMM estimates that use them as instruments to generate moments.

Table 2: GMM Estimates of Firm Parameters

| | $\varepsilon_F$ | | $\alpha_F$ | |
|---|---|---|---|---|
| Case | $\chi_F = 0$ | $\chi_F = 1$ | $\chi_F = 0$ | $\chi_F = 1$ |
| (1) Estimate $\alpha_F$ | 2.75*** | 3.08*** | 0.04 | 0.04 |
| | (0.63) | (1.04) | (0.09) | (0.09) |
| (2) $\alpha_F = 0$ | 2.73*** | 2.73*** | | |
| | (0.61) | (0.61) | | |
| (3) $\alpha_F = .05$ | 2.74*** | 3.16*** | | |
| | (.60) | (0.69) | | |

NOTES: This table shows the GMM estimates for firm mobility parameters. The dependent variable is log of state establishments $\ln M_{nt}$. The data are at the state-year level. Each column has 661 observations. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total U.S. population. After-tax market potential is described in more detail in Appendix D.2. Every specification includes state and year fixed effects. Row 1 estimates both $\varepsilon_F$ and $\alpha_F$. Rows 2-3 calibrate $\alpha_F$ as described in the Case column. Robust standard errors clustered by state are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

Given the set of unconditional moment conditions in equation (28), we use a GMM estimator to obtain estimates of $\varepsilon_F$ and $\alpha_F$. The resulting estimates are reported in Table 2. Conditional on imposing that public goods enjoyed by firms are rival (i.e., $\chi_F = 1$), our estimates of $\varepsilon_F$ and $\alpha_F$ equal 3.08 and 0.04, with standard errors 1.04 and 0.09, respectively. As in Table 1, we also present estimates in which we calibrate $\alpha_F$ and estimate $\varepsilon_F$ subject to the assumed value for $\alpha_F$.[67] In all cases, we obtain estimates of $\varepsilon_F$ that are close to each other. Imposing the opposite assumption that public goods are non-rival does not affect the estimates of $\alpha_F$ and only slightly decreases the estimates of $\varepsilon_F$.

### 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, Panel (a) of Figure A.2 in Appendix D.3 compares the model implications for the share of state $n$ in national GDP against the data in 2007. Model prediction and data line up almost perfectly, which reflects that, in the data, state GDP is roughly proportional to state sales, as our model predicts.[68]

Second, we verify the implications of the estimated model for the share of government revenue in state GDP (see equation (A.28)). Having a sense of whether the model implies a reasonable

[67] We compute our counterfactual of interest for all the estimates presented in Table 2, and show that the main conclusions of our analysis are robust to both the assumptions imposed on the value of the parameters $\chi_F$ and $\sigma$ and to the different approaches followed to quantify the parameters $\varepsilon_F$ and $\alpha_F$.

[68] From (A.12) in Appendix B.2, the share of state $n$ in national GDP in the model is $GDP_n/GDP = (\frac{\gamma_n(\sigma-1)+1}{\sigma})X_n/(\sum_{n'}(\frac{\gamma_{n'}(\sigma-1)+1}{\sigma})X_{n'})$.

government share of GDP is important because changes in this variable as a result of changes in taxes are an important channel through which changes in taxes affect welfare. Panel (b) of Figure A.2 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 predict somewhat larger shares of government revenue in GDP.

Third, panels (c) to (e) of Figure A.2 compare the model-implied share in tax revenue for each type of tax against the the actual shares observed in the data.[69] We see 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 under-predict the importance of individual income taxes. These differences are due in part to the use of average (rather than progressive) income rates for each state and to the model assumption that all companies are C-corporations and therefore pay corporate taxes. In robustness checks, we verify how the results change when we use alternative tax rates that account for progressivity of the income tax and adjust state corporate tax rates for the share of C-corporations in each state.

# 7 Measuring the Spatial Misallocation from State Taxes

In this section, we quantify the impact on welfare and aggregate real GDP of eliminating dispersion in state tax rates while keeping the public spending in every state constant. Specifically, we replace the distribution of all state taxes in 2007, $\left\{t^y_{n,2007}, t^c_{n,2007}, t^l_{n,2007}, t^x_{n,2007}\right\}$, with a counterfactual distribution that features no dispersion in sales, corporate, and personal income tax rates across states. The common levels of tax rates across states in the counterfactual are such that, through a system of inter-state transfers, public spending in every state is kept constant. In our counterfactual scenario, every parameter other than state taxes (including federal taxes) is kept constant. Tables A.1 and A.2 show the 2007 federal and state tax rates. Appendix B.5 shows the system of equations used to compute the changes in the equilibrium generated by the change in the distribution of state taxes.

We compute changes in the two aggregate measures discussed in Section 5, worker welfare and aggregate real income. Combining (8) and (9), worker welfare in the counterfactual scenario relative to its initial value is

$$\widehat{v} = \left(\sum_n L_{n,2007} \widehat{v}_n^{\varepsilon_W}\right)^{\frac{1}{\varepsilon_W}}, \tag{29}$$

where, $\widehat{v}_n$ depends on the changes in after-tax real wages, worker tax keep-rate, and real government spending in state $n$.[70] The change in welfare is an employment-weighted average of the changes in each state's appeal, as captured by the $v_n$'s. This measure does not account for the gains or losses accruing to firms and fixed factors. Therefore, as a second measure, we consider the change

[69] We construct the revenue shares in the data using the same variables as in the model, e.g., panel (c), corresponding to the sales tax, shows the distribution of $R^c_n/R_n = R^c_n/(R^c_n + R^y_n + R^{corp}_n)$ both in the model and in the data.

[70] From (6), $\widehat{v}_n = \left(\frac{1-T'_n}{1-T_{n,2007}} \frac{\hat{w}_n}{\hat{P}_n}\right)^{1-\alpha_W} \left(\frac{\widehat{G}_n}{\widehat{L}^{XW}_n}\right)^{\alpha_W}$.

in the sum of the aggregate real income of workers, fixed factors, and firm profits. Aggregate real income is defined as the aggregation of real state GDP's: $GDP^{real} = \sum_n GDP_n/P_n$. Equation (A.13) in Appendix B.2 shows the expression for real GDP in the counterfactual relative to the initial scenario.[71]

### 7.1 Employment and Firm Changes in the Counterfactuals

To understand the effects of changing the distribution of taxes on employment and firm location we note that, given how we have parametrized the model, in any counterfactual that we run the changes in employment and in the number of firms predicted by the model will be consistent with the empirical relationships between the number of workers, taxes, wages, and spending estimated from equation (23), and between the number of firms, taxes, market potential, unit costs, and spending estimated from equation (26). For example, whenever we use the estimated coefficients from the first row and second column of Table 1 (i.e., $\alpha_W$ estimated and $\chi_W = 1$), the change in employment in state $n$ in response to any change in taxes (either in the own state or in other states) predicted by the model in the counterfactual will be consistent with the relationship

$$\ln\left(\hat{L_n}\right) = 1.02 * \ln\left(\frac{1-T'_n}{1-T_{n,2007}}\frac{\hat{w_n}}{\hat{P_n}}\right) + 0.21 * \ln\left(\hat{G_n}\right) - 1.23 * \ln\left(\hat{v}\right). \tag{30}$$

Similarly, whenever we use the estimated coefficients from the first row and second column of Table 2 (i.e., $\alpha_F$ estimated and $\chi_F = 1$), the change in the number of firms in state $n$ in response to any change in taxes predicted by the model in the counterfactual will be consistent with the relationship

$$\ln\left(\hat{M_n}\right) = 0.91 * \ln\left(\frac{1-\bar{t}'_n}{1-\bar{t}_n}\frac{\hat{MP_n}}{\hat{\pi}}\right) - 2.74 * \ln\left(\hat{c_n}\right) + 0.11 * \ln\left(\hat{G_n}\right). \tag{31}$$

Under these parametrizations, workers are about 5 times more responsive to after-tax real wages than to government spending, while firms are about 9 times more responsive to after-tax market potential than to government spending. In the counterfactuals, the specific values of the variables $\frac{\hat{w_n}}{\hat{P_n}}$, $\hat{G_n}$, $\hat{v}$, $\frac{\hat{MP_n}}{\hat{\pi}}$ and $\hat{c_n}$ are computed through the general-equilibrium structure of the model.

### 7.2 Single-State Tax Change

We undertake a preliminary exercise that illustrates the forces at work and gives a sense of the magnitudes implied by the estimated model. We compute the effect of a 1 percentage point reduction in the income tax rate of each state, one state at a time, while keeping government

[71] Our welfare analysis is performed under the assumption that the implemented changes in state taxes have no impact on the quantity of the public good provided by the federal government, $G^{fed}$. The quantity provided of this good does not affect the allocation of workers or firms in the model. Therefore, if this were to change, all model predictions about the impact of changes in state taxes on the distribution of workers and firms, wages, prices, and aggregate real GDP would be identical to those reported below. Only the welfare calculations could potentially change, and the exact change would depend on assumptions that would have to be imposed on how changes in the federal purchases in each state, $\{G_n^{fed}\}$, translate into the public good supplied by the federal government, $G^{fed}$ . The model described in Section 4 is agnostic about this production function of the federal government.

spending constant in every state, i.e., imposing $\hat{G}_n = 1$.[72] Table 3 reports average percentage changes across the fifty counterfactuals, both in the state enacting the tax change ("Own") and on average in other states ("Rest of the U.S."). Hence, the table can be interpreted as reporting the response to a 1 percentage point reduction in the income tax for the typical U.S. state without changing public-services supply. In order to compute the numbers in Table 3, we assume that $(\varepsilon_W, \varepsilon_F, \alpha_W, \alpha_F) = (1.57, 3.08, 0.17, 0.04)$, which corresponds to the point estimates obtained under one of the estimation approaches described in Section 6.3.

The first row shows that reducing the income tax rate in up to 1 percentage point[73] is equivalent to a 1.12% increase in workers' disposable income (the average keep-tax rate $1 - T_n$ across states increases from 74% to 75%). From (21), higher keep-tax rates are similar to higher amenities, raising the number of workers in the state lowering its taxes. On average, the workforce of the state that lowers its income tax by 1 percentage point increases by 0.81%. This increase in labor supply reduces the pre-tax nominal wage. The increased workforce and the reduction in nominal wages make the state more attractive for firms, both through a reduction in labor costs and through an expanded market size; as a result, the number of firms increases by 0.41%. The increase in product variety and the presence of trade costs in turn reduces the cost of producing the final good by 0.1% in the state lowering taxes. Combined, the inflow of workers and firms raises real GDP by 0.51%. Despite the increase in congestion in access to public services, after-tax real wages increase, raising the appeal of the state lowering income taxes ($v_n$ defined in (6)) by 0.54%.

Table 3: Lowering Income Tax in One State

| Change in | Own | Rest of U.S. |
|---|---|---|
| Keep Rate $(1 - T_n)$ | 1.12% | 0% |
| Employment | 0.81% | -0.02% |
| (Pre-tax) Nominal Wage | -0.41% | 0.01% |
| Firms | 0.41% | -0.01% |
| Real GDP | 0.51% | -0.01% |
| State Effect $(v_n)$ | 0.54% | 0.01% |

This change in taxes in one state has heterogeneous impacts on other states. To gain intuition about these cross-state effects of changes in taxes, we focus on the reduction in the income tax in one large state, California. Figure A.3 in Appendix E.1 shows the heterogeneous response across states in terms of employment and number of firms. Since government spending is kept fixed, the reduction in the income tax increases employment in California and typically reduces it in every

[72] In the main counterfactual, government spending is kept constant in every state by implementing a system of cross-state transfers. Here, we simply keep government spending constant in every state and drop the government budget constraint as a restriction of the model in the counterfactual outcome. Alternatively, we can think of the results reported here as the outcome of a counterfactual in which we reduce the income tax rate in 1 percentage point allowing government spending to change consistently with the state government budget constraint, and where we simultaneously implement a change in the efficiency at which state governments transform government spending into services (the parameter $z_n^W$ mentioned in Footnote 29) that exactly compensates for the change in spending that would otherwise result from the change in taxes, i.e. $\hat{z_n^W} = (\hat{G_n})^{-1}$. From the perspective of individual workers, all that matters for location and welfare is the product $\hat{z_n^W}\hat{G}_n$.

[73] In states where the average income tax is less than 1 percent we set its value equal to zero.

other state. However, this negative employment effect in other states is smaller in states that trade more with California. In those states, the increase in California's market size implies a larger increase in market potential and a larger reduction in the cost of imported varieties relative to states that trade less with California.

### 7.3 Aggregate Effects of Tax Harmonization

Table 4 presents the results for the spatial-misallocation counterfactual. The different rows show the predictions of our model when we follow the multiple approaches described in Section 6.3 to estimate $\{\alpha_{W,n}\}$, $\varepsilon_W$, $\alpha_F$, and $\varepsilon_F$. In this section we focus on the estimation approaches that rely on the assumption that the public goods enjoyed by firms and workers are both rival ($\chi_W = \chi_F = 1$) and in Section 7.6.2 we report analogous estimates for the case in which we assume that both types of public goods are non-rival ($\chi_W = \chi_F = 0$). In each case, we find the percentile $p$ of the initial cross-state distribution of each tax such that, by bringing each type of tax to that percentile, government spending can be kept constant across all states through a system of cross-state transfers.[74]

The columns labeled "G constant" show the results from the counterfactual in which we eliminate dispersion in state tax rates while keeping the public spending in every state constant. The "R constant" column shows revenue-constant counterfactuals implementing the same change in taxes in every state as in the "G constant" counterfactual, but without implementing the system of transfers that allows each state to keep spending constant. Without the cross-state transfers, the aggregate state tax revenue remains the same as in the initial equilibrium, but state government spending changes are determined by each states' budget constraint.

Table 4: Removing Tax Dispersion: Benchmark

| Parametrization | | $G$ constant | | $R$ constant | |
|---|---|---|---|---|---|
| $\alpha_{W,n}$ | $\alpha_F$ | Welfare | GDP | Welfare | GDP |
| 0.17 | 0.04 | 0.16% | 0.11% | 0.68% | 0.65% |
| $\alpha_0 + \alpha_1 POL_n$ | 0.04 | 0.12% | 0.11% | 0.67% | 0.65% |
| $\frac{R_n}{GDP_n}$ | 0.04 | 0.18% | 0.12% | 0.27% | 0.67% |
| $\frac{R_{n'}}{GDP_{n'}}$ of random $n' \neq n$ | 0.04 | 0.17% | 0.11% | 0.36% | 0.68% |
| 0.00 | 0.00 | 0.21% | 0.10% | 0.16% | 0.10% |
| 0.17 | 0.00 | 0.19% | 0.11% | 0.40% | 0.01% |
| 0.00 | 0.04 | 0.19% | 0.11% | 0.34% | 0.66% |

The first row in Table 4 presents counterfactual results using the estimates of $(\varepsilon_W, \alpha_W, \varepsilon_F, \alpha_F)$

[74] The transfer $\Delta_n$ to state $n$ is defined such that, in the counterfactual, the government budget constraint introduced in (17) is $P'_n G_{n,2007} = R'_n + \left(T_n^{fed \to st}\right)' + \Delta_n$, where a prime denotes the counterfactual scenario. Because these transfers must add up to zero, $\sum_n \Delta_n = 0$, the consolidated budget constraint of all states is $\sum_{n=1}^N P'_n G_{n,2007} = \sum_{n=1}^N R'_n + \left(T_n^{fed \to st}\right)'$. To implement the counterfactual we find a single number, the percentile $p$ of the initial cross-state distribution of each tax such that, by bringing each type of tax to the percentile $p$ of its own distribution, that consolidated budget constraint is satisfied. The benchmark counterfactual is implemented when $p$ is the 43th percentile. This leads to a slight increase in the worker tax rate from $\frac{1}{N}\sum T_n = 25,9\%$ in the observed data to $\frac{1}{N}\sum T_n = 26.1\%$ in the counterfactual.

reported in the first row of Tables 1 and 2.[75] The counterfactual results show that a tax harmonisation that keeps states' spending constant leads to welfare and real GDP gains of roughly 0.16% and 0.11%, respectively. Rows two and three show that these results are robust to allowing for heterogeneity across states in workers' preferences for public goods, no matter whether we measure this heterogeneity as a function of the political preferences or as the observed ratio of tax revenue to GDP in each state.

The last four rows in Table 4 further show that the outcome of the "G constant" counterfactual is basically unaffected by the particular value assigned to the parameters $\{\alpha_{W,n}\}$ and $\alpha_F$. Specifically, in the fourth row in Table 4 we perform an exercise in which we assign to each state $n$ the observed value of the ratio $R_{n'}/GDP_{n'}$ for a different state $n'$ randomly chosen; in row five, we adopt the extreme assumption that government spending is valued neither by firms nor by workers;[76] in row six, we only set to zero the parameter $\alpha_F$ and, in row seven, we do the same with the parameter vector $\{\alpha_{W,n}\}$. Regardless of which parametrization we impose, the welfare and real output gains from a tax harmonisation that keeps public spending constant in every state are always around 0.16% and 0.11%, respectively.

The robustness of our model predictions for the "G constant" counterfactual to the different approaches to quantify the value of the parameters $\{\alpha_{W,n}\}$ and $\alpha_F$ is maybe surprising given that, as we discussed in Section 5, the value of these parameters matter for whether tax dispersion has a positive or a negative impact on welfare in a simpler version of our model.[77] Therefore, the key result is that, once we have conditioned all the parameters on the data as described in detail in Section 6, our specific assumptions for $\{\alpha_{W,n}\}$ and $\alpha_F$ do not have almost any impact on the G constant counterfactual. However, in the case in which we implement the tax harmonisation but do not simultaneously allow for cross-state transfers (i.e., when government spending is allowed to change by state but aggregate state tax revenue is constant), the results reported under the "R constant" columns in Table 4 show that both welfare and real GDP gains are generally larger than when such system of transfers is implemented, and also more sensitive to the different parametrizations of $\{\alpha_{W,n}\}$ and $\alpha_F$.

### 7.4 Varying Levels of Tax Dispersion

The results reported in the previous section show that there are aggregate welfare and real GDP gains from completely eliminating dispersion in tax rates across U.S. states. In this section, we compute analogous effects from alternative amounts of dispersion in taxes.

Figure 2 shows the impact on welfare (both in the "G constant" and in the "R constant" scenarios) of switching from the currently observed distribution of taxes to counterfactual distributions

[75] Note that the estimates in this row rely on the assumption that $\alpha_{W,n} = \alpha_W$ and, under this restriction, are computed using moment conditions generated from the equations (23), (24), (26), and (28).

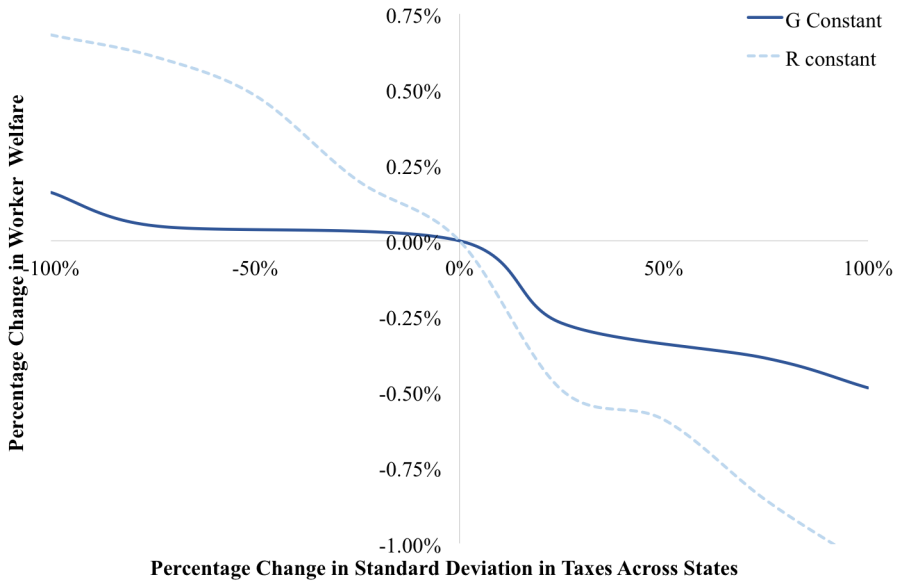
[76] This is an extreme case since, as we discuss in Appendix D.4, the evidence in the literature points towards the existence of a positive effect of government spending on preferences and productivity.

[77] In that section we presented a sufficient (but not necessary) condition on the parameters such that, if it holds in every state in a simpler version of the model, eliminating tax dispersion necessarily leads to welfare and real GDP gains. This condition is satisfied for at least 40 of the 50 states in all the counterfactuals in Table 4, although it is never satisfied in all states.

in which, for each type of tax, the standard deviation of tax rates across states is modified in the quantity indicated in the horizontal axis and the mean of the resulting distribution is set to a value such that, through a system of cross-state transfers, all states can finance the initial levels of public spending. The benchmark counterfactual from Section 7.3, in which we eliminated tax dispersion, corresponds to the leftmost point in the figure. The figure is constructed using the parametrization from the first row of Table 4.

The first result is that, regardless of whether we implement transfers allowing to keep public spending constant in every state, welfare is maximized when dispersion is completely eliminated.[78] Second, we also see that increasing the dispersion in taxes beyond what is currently observed in the US would generate potentially large welfare losses. Moving from a scenario with no tax dispersion to one with twice as much dispersion as what is currently observed would reduce welfare by 0.6% keeping government spending constant (the G constant case), and by 1.7% if government spending is allowed to change but aggregate state tax revenue is kept constant (the R constant case).

Figure 2: Welfare Effects of Changes in Tax Dispersion




## 7.5 Progressive Income Taxes

The results reported in Section 7.3 use a flat state and federal income tax. In practice, both the federal government and most states have progressive income tax schedules. In this section, we explore how our counterfactual results vary if we account for the progressivity of income taxes. We implement three changes with respect to the definition of taxes in our benchmark: we take

[78] A similar result holds for aggregate real GDP. It is important to notice that our results do not indicate that complete tax homogenization generates higher worker welfare and aggregate real GDP than any feasible alternative distribution of taxes. Figure 2 only compares distributions in which we modify the dispersion in taxes without affecting the relative taxes across pairs of states. Computing the optimal level of taxes across all states involves an optimization over 196 control variables (4 tax rates for each of the 49 states considered in the analysis). Evaluating welfare at every feasible level of tax rate for each type of tax and state is numerically infeasible.

into account the progressivity in state income taxes, we incorporate progressivity in federal income taxes, and we allow the income tax rate on capital owners to differ from that on workers.

We use data from NBER TAXSIM on average effective income tax rates by state, year, and income group to estimate a linear function of income that best fits the actual relationship between income and average tax rates by state in 2007. Using the estimates $\{\hat{a}_n, \hat{b}_n\}_{n=1}^N$, we construct the income tax rate that workers in state $n$ must pay if their wage were $w$ as $t_n^{y,prog}(w) = \hat{a}_n + \hat{b}_n w$. Following the same procedure, we construct a federal income tax rate $t_{fed}^{y,prog}(w) = \hat{a}_{fed} + \hat{b}_{fed} w$.[79] Because our model does not specify the number of capital owners living in a state and, therefore, does not yield a measure of capital income per capita, we assume that every capital owner in a state $n$ pays the highest income tax rate that the progressive tax schedule in state $n$ imposes (i.e., the income tax rate for the highest income bracket).[80]

Table 5: Removing Tax Dispersion under Progressive Income Taxes

| Parametrization | | $G$ constant | | $R$ constant | |
|---|---|---|---|---|---|
| $\alpha_{W,n}$ | $\alpha_F$ | Welfare | GDP | Welfare | GDP |
| A. State Progressive Only | | | | | |
| 0.17 | 0.04 | 0.40% | 0.11% | 1.26% | 0.84% |
| 0.00 | 0.00 | 0.49% | 0.10% | 0.49% | 0.10% |
| $\frac{R_n}{GDP_n}$ | 0.04 | 0.45% | 0.11% | 0.74% | 0.85% |
| B. State and Federal Progressive | | | | | |
| 0.17 | 0.04 | 0.45% | 0.11% | 1.58% | 1.01% |
| 0.00 | 0.00 | 0.56% | 0.10% | 0.56% | 0.10% |
| $\frac{R_n}{GDP_n}$ | 0.04 | 0.51% | 0.11% | 0.93% | 1.01% |

The introduction of progressive tax schedules in our model generalizes our benchmark results by allowing state income tax rates to change as a result of changes in states' nominal wages. Specifically, when accounting for progressive tax schedules, heterogeneity in wages in the initial allocation translates into an initial dispersion in income tax rates across states that is larger than the dispersion from the flat income rates in Section 7.3.

Table 5 reports the results for our tax harmonisation counterfactual. We bring the constant and slope of the state progressive tax income schedule in every state to the same values (and simultaneously eliminate dispersion in sales and corporate taxes) while keeping government spending constant in every state through inter-state transfers. In Panel A, the only departure from the benchmark progressivity in state income taxes, while in Panel B we allow for progressivity in both federal and state income taxes.[81]

The main conclusion is that, in this context, the impact of eliminating tax dispersion on welfare

[79] Measuring $w$ in thousands of dollars, we find $(\hat{a}_n, \hat{b}_n) = (0.32, 0.04)$ for the average state, and $(\hat{a}_{fed}, \hat{b}_{fed}) = (8.3, 0.1)$. Hence, state income taxes are on average 2.5 times flatter than federal income taxes.

[80] Cooper et al. (2015) show that business income is largely owned by high-earners. In particular, they estimate that 69% of total pass-through income and 45% of C-corporate income (as proxied by dividends) accrues to households in the top-1%.

[81] The progressive federal income schedule is not modified in the counterfactual. Albouy (2009) studies how federal tax progressivity impacts the allocation of workers across U.S. cities.

is larger than when income tax rates are independent from economic conditions, which is consistent with adverse effects of tax dispersion. Note that the bulk of the increase in spatial misallocation is due to the introduction of the progressive state taxes. Once we account for these, additionally accounting for progressive federal income taxes has a relatively small effect. The effect of introducing progressivity on our predictions for changes in welfare are much larger than the effects on aggregate GDP.

## 7.6 Robustness

### 7.6.1 Alternative Definitions of Corporate Taxes

Table 6 reports the results of the "G constant" and "R constant" elimination in dispersion in state taxes under two alternative ways of measuring corporate tax rates.

**Corporate Taxes Adjusted for Subsidies** Some states grant firms reductions in their corporate tax liabilities. These subsidies modify the effective corporate tax rate that firms face. To account for these subsidies, we scale down the statutory corporate tax rate, used in our benchmark analysis, by the ratio of corporate tax revenue net of subsidies to total corporate tax revenue in each state; as in Ossa (2015), we use data from the *New York Times* subsidy database (see Appendix F.1 for details). We find that this adjustment reduces spatial misallocation slightly. The reason for the smaller impact of tax harmonisation when accounting for subsidies is that subsidy-adjusted rates are less disperse. The lower dispersion in the initial tax distribution implies that the gains from tax harmonisation are also smaller.

**Corporate Taxes Adjusted by Share of C-Corporations** In our benchmark model, all firms pay state corporate taxes on their profits and, additionally, firm owners pay income taxes on after-tax profits, matching the actual tax treatment of the C-corporations. However, pass-through businesses (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 the fact that not all firms are C-corporations, 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.[82] This adjustment reduces the welfare and real-income effects of misallocation. The reason for the smaller impact of tax harmonisation when accounting for the share of C-corps is analogous to that indicated above when discussing the impact of adjusting for subsidies: once we adjust for the share of C-corps, the dispersion in the resulting corporate rates is significantly smaller than in the benchmark.

[82]Data on the share of employment in C-corporations by state is obtained from the County Business Patterns. An alternative would be to adjust corporate tax rates by the share of employment in C-corporations in each state in 2010 relative to the total employment. C-corporations are on average much larger than S-corporations; adjusting by employment instead of by establishment count would yield adjusted corporate tax rates that are closer to those employed in Section 7.3.

Table 6: Removing Tax Dispersion under Alternative Definitions of Corporate Taxes

| Parametrization | | $G$ constant | | $R$ constant | |
|---|---|---|---|---|---|
| $\alpha_{W,n}$ | $\alpha_F$ | Welfare | GDP | Welfare | GDP |
| A. Corporate Taxes Adjusted for Tax Subsidies | | | | | |
| 0.17 | 0.04 | 0.11% | 0.09% | 0.60% | 0.63% |
| 0.00 | 0.00 | 0.14% | 0.07% | 0.14% | 0.07% |
| $\frac{R_n}{GDP_n}$ | 0.04 | 0.12% | 0.09% | 0.23% | 0.65% |
| B. Corporate Taxes Adjusted for Share of C-Corps | | | | | |
| 0.17 | 0.04 | 0.07% | 0.04% | 0.41% | 0.32% |
| 0.00 | 0.00 | 0.09% | 0.04% | 0.09% | 0.04% |
| $\frac{R_n}{GDP_n}$ | 0.04 | 0.07% | 0.05% | 0.10% | 0.37% |

### 7.6.2 Varying Congestion

Our benchmark parametrization assumes that the parameters $\chi_W$ and $\chi_F$, which determine congestion in access to public services, equal 1. These parameters govern the intensity of agglomeration forces in the model. Table 7 reports the results for for congestion levels equal to 0. For each of these cases, we re-estimate the parameters $\varepsilon_W$, $\alpha_W$, $\varepsilon_F$, and $\alpha_F$ under the same exogeneity assumptions imposed to obtain our benchmark estimates.[83] The results from the both the "G constant" and the "R constant" counterfactuals are extremely similar to those obtained under the assumption that both the public goods enjoyed by firms and workers are rival.

Table 7: Removing Tax Dispersion: No Congestion ($\chi_W = \chi_F = 0$)

| Parametrization | | $G$ constant | | $R$ constant | |
|---|---|---|---|---|---|
| $\alpha_{W,n}$ | $\alpha_F$ | Welfare | GDP | Welfare | GDP |
| 0.17 | 0.04 | 0.16% | 0.11% | 0.68% | 0.65% |
| $\frac{R_n}{GDP_n}$ | 0.04 | 0.18% | 0.11% | 0.27% | 0.67% |
| $\frac{R_{n'}}{GDP_{n'}}$ of random $n' \neq n$ | 0.04 | 0.18% | 0.11% | 0.35% | 0.68% |
| 0.00 | 0.00 | 0.21% | 0.10% | 0.16% | 0.10% |
| 0.17 | 0.00 | 0.17% | 0.10% | 0.40% | 0.01% |
| 0.00 | 0.04 | 0.19% | 0.11% | 0.33% | 0.66% |

## 8 Conclusion

In this paper we quantify the effect that dispersion in U.S. state tax rates has on aggregate real income and welfare in the U.S. economy. We build on the recent trade and economic geography literature and construct a model that incorporates both the key forces emphasized in this literature and salient features of the U.S. state tax system. We estimate the key model parameters using variation in taxes and economic activity across states. Using the estimated model, we measure the allocative inefficiencies caused by the currently observed dispersion in tax rates across U.S. states.

[83] See Table 1for the estimates.

Our results strongly suggest spatial misallocation from the existing dispersion in state taxes. Keeping government spending constant through a system of cross-state transfers, eliminating tax dispersion would increase real GDP and worker welfare by 0.2% (relative to a 4% share of state taxes in GDP). Accounting for progressivity of state income taxes leads to worker welfare gains that are twice as large. We also find that the potential losses from greater tax dispersion can be sizable: doubling tax dispersion (while also keeping government spending constant through cross-state transfers) would reduce real GDP and welfare by 0.5%. Without cross-state transfers, an elimination of tax dispersion would lead to a 0.8% welfare gain, and doubling tax dispersion would lead to a 1% loss.

The framework we introduce can be readily applied 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), or which are the advantages and disadvantages of sales- relative to income-based tax systems. In addition to contributing to the ongoing debate about the impact of the state tax structure in the U.S., our framework could be combined with data from European countries to inform the debates concerning cross-country tax harmonisation taking place within the European Union.

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# Appendices for Online Publication

## A Appendix to Section 3 (Background)

Figure A.1: Dispersion in State + Local Tax Rates in 2010

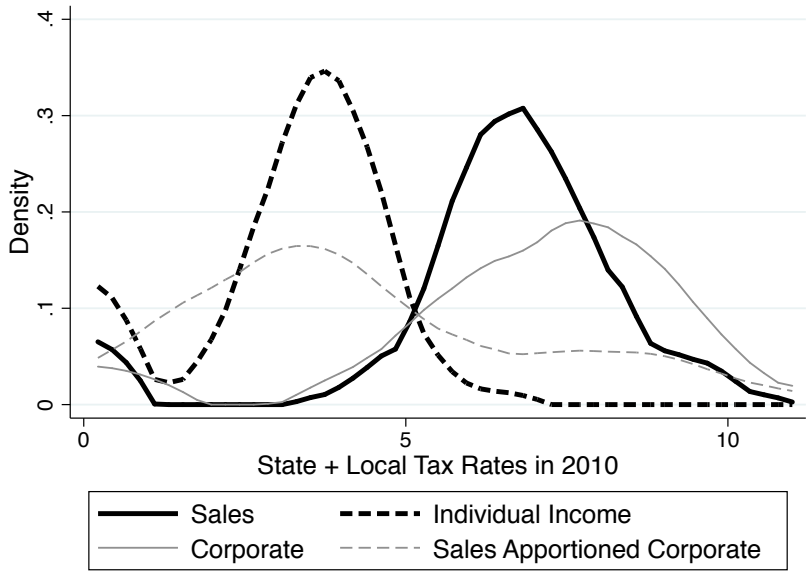



Table A.1: Federal Tax Rates from 2007

| Type | Federal Tax Rate |
|---|---|
| Income Tax $t^{y}_{fed}$ | 11.7 |
| Corporate Tax $t^{corp}_{fed}$ | 18.0 |
| Payroll Tax $t^{w}_{fed}$ | 7.3 |

NOTES: This table shows federal tax rates in 2007 for personal income, corporate, and payroll taxes. The income tax rate is the average effective federal tax rate from NBER's TAXSIM across all states in 2007. The TAXSIM data that we use provides the effective federal tax rate on personal income after accounting for deductions. The corporate tax rate is the average effective corporate tax rate: we divide total tax liability (including tax credits) by net business income less deficit, using data from IRS Statistics of Income on corporation income tax returns. Finally, for payroll tax rates, we use data from the Congressional Budget Office on federal tax rates for all households in 2007. This payroll rate is similar to the employer portion of the sum of Old-Age, Survivors, and Disabilty Insurance and Medicare's Hospital Insurance Program. See section F.1 for additional details.

Table A.2: State Tax Rates from 2007

| State | Income $t_n^y$ | Sales $t_n^c$ | Corporate $t_n^{corp}$ | Sales Apportioned $t_n^x$ |
|---|---|---|---|---|
| AL | 3.2 | 4 | 6.5 | 1.8 |
| AR | 4.4 | 6 | 6.5 | 2.7 |
| AZ | 2.3 | 5.6 | 7 | 3.4 |
| CA | 3.6 | 7.2 | 8.8 | 3.6 |
| CO | 3.2 | 2.9 | 4.6 | 1.3 |
| CT | 3.8 | 6 | 7.5 | 3.1 |
| DE | 3.6 | 0 | 8.7 | 2.4 |
| FL | 0 | 6 | 5.5 | 2.3 |
| GA | 3.9 | 4 | 6 | 4.4 |
| HI | 4.9 | 4 | 6.4 | 1.7 |
| IA | 4.4 | 5 | 12 | 9.8 |
| ID | 4.7 | 6 | 7.6 | 3.1 |
| IL | 2.6 | 6.3 | 4.8 | 3.9 |
| IN | 3.1 | 6 | 8.5 | 4.2 |
| KS | 3.9 | 5.3 | 7.3 | 2 |
| KY | 4.3 | 6 | 7 | 2.9 |
| LA | 3.3 | 4 | 8 | 6.6 |
| MA | 4.2 | 5 | 9.5 | 3.9 |
| MD | 3.5 | 6 | 7 | 2.9 |
| ME | 5 | 5 | 8.9 | 7.3 |
| MI | 2.3 | 6 | 1.9 | 1.4 |
| MN | 3.5 | 6.5 | 9.8 | 6.3 |
| MO | 3.6 | 4.2 | 6.3 | 1.7 |
| MS | 3.3 | 7 | 5 | 1.4 |
| MT | 4.1 | 0 | 6.8 | 1.8 |
| NC | 5.2 | 4.3 | 6.9 | 2.8 |
| ND | 2.1 | 5 | 7 | 1.9 |
| NE | 4.1 | 5.5 | 7.8 | 6.4 |
| NH | .4 | 0 | 8.5 | 3.5 |
| NJ | 2.9 | 7 | 9 | 3.7 |
| NM | 3 | 5 | 7.6 | 2.1 |
| NV | 0 | 6.5 | 0 | 0 |
| NY | 4.5 | 4 | 7.5 | 6.1 |
| OH | 3.7 | 5.5 | 8.5 | 4.2 |
| OK | 3.6 | 4.5 | 6 | 1.6 |
| OR | 6.2 | 0 | 6.6 | 5.4 |
| PA | 3 | 6 | 10 | 5.7 |
| RI | 3.5 | 7 | 9 | 2.5 |
| SC | 4 | 6 | 5 | 4.1 |
| SD | 0 | 4 | 0 | 0 |
| TN | .5 | 7 | 6.5 | 2.7 |
| TX | 0 | 6.3 | 0 | 0 |
| UT | 4.4 | 4.7 | 5 | 2 |
| VA | 4.1 | 5 | 6 | 2.5 |
| VT | 2.5 | 6 | 8.5 | 3.5 |
| WA | 0 | 6.5 | 0 | 0 |
| WI | 4.1 | 5 | 7.9 | 5.2 |
| WV | 4.8 | 6 | 8.7 | 3.6 |
| WY | 0 | 4 | 0 | 0 |

NOTES: This table shows state tax rates in 2007 for personal income, general sales, corporate, and sales-apportioned corporate taxes, which is the product of the statutory corporate tax rate and the state's sales apportionment weight. See the section 3.1 for details.

# B Appendix to Section 4 (Model)

## B.1 Firm Maximization

The first-order condition of (10) with respect the quantity sold to $n$ is:

$$\frac{\partial \pi_i^j}{\partial q_{ni}^j} = \left(1 - \bar{t}_i^j\right) \frac{\partial \tilde{\pi}_i^j}{\partial q_{ni}^j} - \frac{\partial \bar{t}_i^j}{\partial q_{ni}^j} \tilde{\pi}_i^j = 0, \tag{A.1}$$

where $\tilde{\pi}_i^j \equiv \sum_{n=1}^N x_{ni}^j - \frac{\tau_{ni} c_i}{z_i^j} q_{ni}^j$ are pre-tax profits, and where:

$$\frac{\partial \tilde{\pi}_i^j}{\partial q_{ni}^j} = \frac{\sigma - 1}{\sigma} E_n^{1/\sigma} P_n^{1-1/\sigma} \left(q_{ni}^j\right)^{-1/\sigma} - c_i \frac{\tau_{ni}}{z_i^j},$$
$$\frac{\partial \bar{t}_i^j}{\partial q_{ni}^j} = \frac{\sigma - 1}{\sigma} \left( t_n^x - \sum_{n'} t_{n'}^x s_{n'i}^j \right) \frac{p_{ni}^j}{x_i^j}.$$

Combining the last two expressions with (A.1) gives:

$$p_{ni}^j = \frac{1}{1 - \tilde{t}_{ni}^j \left(\tilde{\pi}_i^j / x_i^j\right)} \frac{\sigma}{\sigma - 1} \frac{\tau_{ni}}{z_i^j} c_i, \tag{A.2}$$

where

$$\tilde{t}_{ni}^j \equiv \frac{t_n^x - \sum_{n'} t_{n'}^x s_{n'i}^j}{1 - \bar{t}_i}. \tag{A.3}$$

Expressing pre-tax profits as $\tilde{\pi}_i^j \equiv \sum_{n=1}^N x_{ni}^j \left(1 - \frac{\tau_{ni}}{z_i^j} \frac{c_i}{p_{ni}^j}\right)$, replacing (A.2) and using that $\sum_i s_{ni}^j \tilde{t}_{ni}^j = 0$ yields $\tilde{\pi}_i^j = x_i^j / \sigma$. This implies

$$p_{ni}^j = \frac{\sigma}{\sigma - \tilde{t}_{ni}^j} \frac{\sigma}{\sigma - 1} \frac{\tau_{ni}}{z_i^j}. \tag{A.4}$$

Finally, note that export shares are independent of productivity, $z_i^j$:

$$s_{ni}^j = \frac{E_n \left(p_{ni}^j\right)^{1-\sigma}}{\sum_{n'=1}^N E_{n'} \left(p_{n'i}^j\right)^{1-\sigma}} = \frac{E_n \left(\frac{\sigma - \tilde{t}_{ni}^j}{\tau_{ni}}\right)^{\sigma - 1}}{\sum_{n'=1}^N E_{n'} \left(\frac{\sigma - \tilde{t}_{n'i}^j}{\tau_{n'i}}\right)^{1-\sigma}}. \tag{A.5}$$

Equations (A.3) and (A.5) for $n = 1, .., N$ define a system for $\left\{\tilde{t}_{ni}^j\right\}$ and $\left\{s_{ni}^j\right\}$ whose solution is independent from $z_i^j$. Therefore, $\tilde{t}_{ni}^j = \tilde{t}_{ni}$ and $s_{ni}^j = s_{ni}$ for all firms $j$ from $i$.

## B.2 Additional State-Level Variables

**Factor Payments** From the Cobb-Douglas technologies and CES demand, it follows that payments to intermediate inputs, labor and fixed factors in state $i$ are all constant fractions of $X_i$:

$$P_i I_i = (1 - \gamma_i) \frac{\sigma - 1}{\sigma} X_i, \tag{A.6}$$

$$w_i L_i = (1 - \beta_i) \gamma_i \frac{\sigma - 1}{\sigma} X_i, \tag{A.7}$$

$$r_i H_i = \beta_i \gamma_i \frac{\sigma - 1}{\sigma} X_i. \tag{A.8}$$

Similarly, aggregate pre-tax profits $\tilde{\Pi}_i$ are also proportional to sales:

$$\tilde{\Pi}_i = \frac{X_i}{\sigma}, \tag{A.9}$$

After-tax profits therefore are:

$$\Pi_i = \left(1 - \bar{t}_n\right) \frac{X_i}{\sigma}. \tag{A.10}$$

**Expenditure and Sales Shares** The share of aggregate expenditures in state $n$ on goods produced in state $i$ is

$$\lambda_{ni} = M_i \left( \frac{p_{ni}\left(\tilde{z}_i\right)}{P_n} \right)^{1-\sigma}, \tag{A.11}$$

where $p_{ni}(z)$ is the pricing function defined in (12).

We construct the sales shares $s_{ni}$, which are necessary to compute the corporate tax rate $\bar{t}_i$ in (11) and the pricing distortion $\tilde{t}_{ni}$ in (13), using the identity $s_{ni} = \lambda_{ni} P_n Q_n / X_i$, where $P_n Q_n$ is the aggregate expenditure on final goods in state $n$.

**GDP** Adding up (A.7), (A.8), and (A.9), GDP in state $n$ is

$$GDP_n = \left(\gamma_n(\sigma - 1) + 1\right) \tilde{\Pi}_n. \tag{A.12}$$

From (A.12) and A.9, aggregate real GDP in the counterfactual relative to the initial scenario is:

$$\widehat{GDP}^{real} = \sum_n \frac{\frac{\gamma_n(\sigma-1)+1}{(1-\beta_n)\gamma_n(\sigma-1)} \frac{w_n L_n}{P_n}}{\sum_{n'} \frac{\gamma_{n'}(\sigma-1)+1}{\left(1-\beta_{n'}\right)\gamma_{n'}(\sigma-1)} \frac{w_{n'} L_{n'}}{P_{n'}}} \frac{\widehat{w_n}\widehat{L_n}}{\widehat{P_n}}. \tag{A.13}$$

**Consumption** Adding up the expenditures of workers and capital-owners described in Section (4.3), the aggregate personal-consumption expenditure in state $n$ is

$$P_n C_n = P_n C_n^W + \frac{\left(1 - t_{fed}^y\right)\left(1 - t_n^y\right)}{1 + t_n^c} b_n \left(\Pi + R\right). \tag{A.14}$$

where $C_n^W = \left(1 - T_n\right) \frac{w_n L_n}{P_n}$ is the consumption of workers and $C_n^K = \frac{(1-t_{fed}^y)\left(1-t_n^y\right)}{1+t_n^c} \frac{b_n(\Pi+R)}{P_n}$ is the consumption of capital-owners. The value of consumption of workers and capital owners in the new counterfactual equilibrium relative to its initial value is:

$$\widehat{C^W} = \sum_n \left( \frac{\left(1 - T_n\right) \frac{w_n L_n}{P_n}}{\sum_{n'} \left(1 - T_{n'}\right) \frac{w_{n'} L_{n'}}{P_{n'}}} \right) \hat{C_n^W}. \tag{A.15}$$

$$\widehat{C^K} = \sum_n \left( \frac{\frac{1-t_n^y}{1+t_n^c} \frac{b_n}{P_n}}{\sum_{n'} \frac{1-t_n^y}{1+t_n^c} \frac{b_{n'}}{P_{n'}}} \right) \hat{C_n^K}. \tag{A.16}$$

**State Tax Revenue By Type of Tax** State government revenue from corporate, sales, and income taxes, is, respectively,

$$R_n^{corp} = t_n^x \sum_{n'} s_{nn'} \tilde{\Pi}_{n'} + t_n^l \tilde{\Pi}_n, \tag{A.17}$$

$$R_n^y = t_n^y (1 - t_{fed}^y) \left[ w_n L_n + b_n \left(\Pi + R\right) \right], \tag{A.18}$$

$$R_n^c = t_n^c P_n C_n. \tag{A.19}$$

The base for corporate tax profits are the pre-tax profits from every state, defined in (A.9), adjusted by the proper apportionment weights. Equation (A.18) shows that the base for state income taxes is the income of both workers and capital-owners who reside in $n$ net of federal income taxes; in that expression, $\Pi = \sum_i \Pi_i$ and $R = \sum_i r_i H_i$ are

national after-tax profits and returns to land and structures, respectively. The base for the sales tax in (A.19) is the total personal consumption expenditure of workers and capital owners, $P_n C_n$ defined in Equation (A.14).

**Taxes Paid to the Federal Government** Total taxes paid by residents of state $n$ to the federal government are:

$$T_{n,fed} = \left(t^y_{fed} + t^w_{fed}\right) w_n L_n + b_n t^y_{fed} \left(\Pi + R\right) + b_n t^{corp}_{fed} \sum_{n'} \tilde{\Pi}_{n'}. \tag{A.20}$$

The first term accounts for payroll and income taxes paid by workers, the second term is the income taxes paid by capital owners residing in $n$, and the last term is the corporate-tax payments made by corporations owned by residents of state $n$. We include federal taxes in the analysis because they change the effective impact of changes in state tax rates. However, we do not model the use of federal tax revenues: we just impose the assumption that federal spending does not affect the allocation of workers across states or over time.

**Trade Imbalances** Three reasons give rise to differences between aggregate expenditures $P_n Q_n$ and sales $X_n$ of state $n$, and therefore create trade imbalances. First, differences in the ownership rates $b_n$ lead to differences between the gross domestic product of state $n$, $GDP_n$, and the gross income of residents of state $n$, $GSI_n$. Second, differences in ownership rates $b_n$ and in sales-apportioned corporate taxes $t^x_n$ across states create differences between the corporate tax revenue raised by state $n$'s government ($R^{corp}_n$) and the corporate taxes paid by residents of state $n$ ($TP^{corp}_n$). Third, there may be differences between taxes paid by residents of state $n$ to the federal government ($T_{n,fed}$) and the expenditures made by the federal government in state $n$ in either transfers to the state government in $n$ ($T^{fed\to st}_n$) or purchases of the final good produced in state $n$ ($G_{n,fed}$). As a result, the trade imbalance in state $n$, defined as difference between expenditures and sales in that state, can be written as follows:[84]

$$P_n Q_n - X_n = \left(GSI_n - GDP_n\right) + \left(R^{corp}_n - TP^{corp}_n\right) + \left(P_n G_{n,fed} + T^{fed\to st}_n - T_{n,fed}\right). \tag{A.21}$$

Letting $R = \sum_n r_n H_n$ and $\tilde{\Pi} = \sum_n \tilde{\Pi}_n$ be the pre-tax returns to the national portfolio of fixed factors and firms , we can rewrite some of the components of (A.21) as follows:[85]

$$GSI_n = b_n \left(\tilde{\Pi} + R\right) + w_n L_n, \tag{A.22}$$

$$R^{corp}_n = \frac{1}{\sigma}\left(t^x_n P_n Q_n + t^l_n X_n\right), \tag{A.23}$$

$$TP^{corp}_n = b_n \sum_{n'} \left(\bar{t}_{n'} - t^{corp}_{fed}\right) \tilde{\Pi}_{n'}. \tag{A.24}$$

Replacing (A.12) and (A.22) to (A.24) into (A.21), and using (A.7) and (A.9) to express labor payments and pre-tax profits as function of sales, we obtain:

$$\frac{P_n Q_n}{X_n} = \frac{1}{\sigma - t^x_n}\left(\left(\sigma - 1\right)\left(1 - \beta_n \gamma_n\right) + t^l_n + \frac{P_n G_{n,fed} + T^{fed\to st}_n - T_{n,fed}}{\tilde{\Pi}_n} + \frac{b_n}{\tilde{\Pi}_n / \left(\Pi + R + t^{corp}_{fed}\tilde{\Pi}\right)}\right), \tag{A.25}$$

where, from (A.9) and (A.8), the denominator in the last term is:

$$\frac{\tilde{\Pi}_n}{\Pi + R + t^{corp}_{fed}\tilde{\Pi}} = \frac{X_n}{\sum_i \left(1 - t^l_n - \bar{t}_n + \beta_i \gamma_i \left(\sigma - 1\right)\right) X_i}. \tag{A.26}$$

Expression (A.25) is used in the calibration to back out the ownership shares $\{b_n\}$ from observed data on trade

[84] To reach this relationship, first impose goods market clearing (5) to obtain $P_n Q_n = P_n\left(C_n + G_{n,fed} + G_n + I_n\right)$. Then, note that personal-consumption expenditures can be written as $P_n C_n = GSI_n - \left(R^y_n + R^c_n + TP^{corp}_n\right) - T_{n,fed}$, where the terms between parentheses are tax payments made by residents of state $n$ to state governments and $T_{n,fed}$ are taxes paid to the federal government. Combining these two expressions and using the state's government budget constraint (17) gives $P_n Q_n = \left(GDP_n + P_n I_n\right) + \left(GSI_n - GDP_n\right) + \left(R^{corp}_n - TP^{corp}_n\right) + \left(P_n G_{n,fed} + T^{fed\to st}_n - T_{n,fed}\right)$. Adding and subtracting $GDP_n$ and noting that by definition $GDP_n = X_n - P_n I_n$ gives (A.21).

[85] (A.22) and (A.24) are by definition. For (A.23), combine (A.17) with (A.30) and (A.9).

imbalances. Specifically, it implies that the ownership shares can be expressed as a function of other parameters and observables as follows:[86]

$$b_n = \frac{\tilde{\Pi}_n}{\Pi + R + t_{fed}^{corp}\tilde{\Pi}} \left[ (\sigma - t_n^x) \left( \frac{P_n Q_n}{X_n} \right) - (\sigma - 1)(1 - \beta_n \gamma_n) - t_n^l \right]. \tag{A.27}$$

**Share of State Taxes and Spending in GDP** Replacing $P_n C_n$ from (A.14), $R_n^y$ from (A.18), and $R_n^{corp}$ from (A.23) into the government budget constraint (A.20), and then normalizing by GDP using (A.12), we reach

$$\frac{R_n}{GDP_n} = \frac{t_n^x \frac{P_n Q_n}{X_n} + t_n^l + \left(1 - t_{fed}^y\right) \frac{t_n^c + t_n^y}{1 + t_n^c} \frac{b_n}{\tilde{\Pi}_n/(\Pi + R)} + \left( \left(1 - t_{fed}^y\right) \frac{t_n^c + t_n^y}{1 + t_n^c} - \frac{t_n^c}{1 + t_n^c} t_{fed}^w \right) (1 - \beta_n) \gamma_n (\sigma - 1)}{\gamma_n (\sigma - 1) + 1}, \tag{A.28}$$

where $P_n Q_n / X_n$ is the share of state expenditure in aggregate sales (i.e., a measure of state trade deficit) derived in (A.25) . The state government budget constraint (17) then implies a share of state spending in GDP equal to $\left(1 + s_n^{fed \to st}\right) \frac{R_n}{GDP_n}$.

## B.3 General-Equilibrium Conditions

We note that, using the definition of import shares in (A.11), imposing expression (3) for final-goods prices in every state is equivalent to imposing that expenditures shares in every state add up to 1.

$$\sum_n \lambda_{in} = 1 \text{ for all } i. \tag{A.29}$$

Additionally, by definition, aggregate sales by firms located in state $i$ are:

$$X_i = \sum_n \lambda_{ni} P_n Q_n. \tag{A.30}$$

This is equivalent to imposing that sales shares from every state add up to 1:

$$\sum_i s_{in} = 1 \text{ for all } n. \tag{A.31}$$

After several manipulations of the equilibrium conditions (available upon request), these shares can be expressed as function of employment shares, wages, aggregate variables, and parameters as follows:

$$\lambda_{in} = A_{in} \left( \frac{w_n}{\bar{\pi}} \right)^{1 - \kappa_1} L_n^{1 - \kappa_{2n}} \left( \frac{w_i}{\bar{\pi}} \right)^{\sigma - 1} L_i^{-\kappa_3}, \tag{A.32}$$

$$s_{in} = \lambda_{in} \frac{P_i Q_i}{X_i} \frac{(w_i/\bar{\pi}) L_i}{(w_n/\bar{\pi}) L_n} \frac{(1 - \beta_n) \gamma_n}{(1 - \beta_i) \gamma_i}, \tag{A.33}$$

where $A_{in}$ is given by

$$A_{in} = \left( \frac{H_n^{\beta_n \gamma_n} \Theta_{1n} z_n^A}{\frac{\sigma}{\sigma - 1} \tau_{in}^A} \frac{\left(\Theta_{2i} u_i^A\right)}{\left(\Theta_{2n} u_n^A\right)^{1 - \gamma_n + \alpha_F}} v^{\alpha_F - \gamma_n} \right)^{\sigma - 1}, \tag{A.34}$$

where $\left\{ z_n^A, \tau_{in}^A, u_n^A \right\}$ are defined in (19) to (21) in the text, and where $\{\Theta_{1n}, \Theta_{2n}\}$ are functions of parameters:

$$\Theta_{1n} = \left( \frac{1 - \beta_n}{\beta_n} \right)^{\beta_n \gamma_n} \left( \frac{1}{(1 - \beta_n) \gamma_n (\sigma - 1)} \right)^{\frac{1}{\sigma - 1} - \left( \frac{1}{\varepsilon_F} + \alpha_F \chi_F \right)} \left( \frac{\gamma_n (\sigma - 1) + 1}{(1 - \beta_n) \gamma_n (\sigma - 1)} \right)^{\alpha_F},$$

$$\Theta_{2n} = \left( \frac{\gamma_n (\sigma - 1) + 1}{(1 - \beta_n) \gamma_n (\sigma - 1)} \right)^{\alpha_W}.$$

[86] This expression assumes that transfers from the federal government to the state government in $n$ are entirely financed with federal taxes paid by residents of state $n$. We could undertake the analysis relaxing this assumption using data on the actual distribution of federal spending by state.

The parameters $\{\kappa_1, \kappa_{2n}, \kappa_3\}$ in (A.32) and (A.33) are given by:

$$\kappa_1 = (\sigma - 1)\left(\frac{1}{\varepsilon_F} + \alpha_F \chi_F + 1\right), \tag{A.35}$$

$$\kappa_{2n} = (\sigma - 1)\left[\left(\frac{1}{\varepsilon_F} - \alpha_F\left(1 - \chi_F\right) + \beta_n \gamma_n\right) - \left(1 - \gamma_n + \alpha_F\right)\left(\frac{1}{\varepsilon_W} - \alpha_W\left(1 - \chi_W\right)\right)\right], \tag{A.36}$$

$$\kappa_3 = (\sigma - 1)\left(\frac{1}{\varepsilon_W} - \left(1 - \chi_W\right)\alpha_W\right). \tag{A.37}$$

Equations (A.29) to (A.34), together with (9), (A.25), and (A.28) give the solution for import shares $\{\lambda_{in}\}$, export shares $\{s_{in}\}$, employment shares $\{L_n\}$, wages relative to average profits $\{w_n/\bar{\pi}\}$, government sizes $\{P_n G_n / GDP_n\}$, relative trade imbalances $\{P_n Q_n / X_n\}$, and utility $v$.[87] The endogenous variables not included in this system (e.g., the fraction of firms, $M_n$) can be recovered using the remaining equilibrium equations of the model.

## B.4 Uniqueness

Consider a special case of the model in which i) technologies are homogeneous across regions ($\beta_n = \beta$ and $\gamma_n = \gamma$ for all $n$); ii) there is no dispersion in sales-apportioned corporate taxes across states ($t_n^x = t^x$ for all $n$); and iii) there is no cross-ownership of assets across states. In this case, the adjusted amenities and productivities $u_n^A$ and $z_n^A$ defined in (21) and (19) are primitives (exogenous functions of fundamentals and own-state taxes). Define:

$$K_{in} = \tau_{in}^{1-\sigma},$$

$$\gamma_n = \overline{A}_n^{\sigma-1} w_n^{1-\kappa_1} L_n^{1-\kappa_2}, \tag{A.38}$$

$$\delta_i = \left(\frac{\overline{u}_i}{\overline{W}}\right)^{\sigma-1} w_i^{\sigma} L_i^{1-\kappa_3}, \tag{A.39}$$

where

$$\overline{A}_n = \frac{1}{\bar{\pi}^{\frac{\sigma-\kappa_1}{\sigma-1}}} \frac{\sigma}{\sigma-1} \frac{z_n^A}{\left(u_n^A\right)^{(1-\gamma)+\alpha_F}},$$

$$\overline{u}_i = \frac{u_i^A}{\left(\beta^L\right)^{\frac{1}{\sigma-1}}},$$

$$\overline{W} = v^{\gamma-\alpha_F}.$$

Using these definitions and the definition of import shares in (A.32), it follows that Conditions 1 to 3 of Allen et al. (2014) are satisfied. We must show that their condition 4' is also satisfied. First, combining the solution for $\{w_n, L_n\}$ from (A.38) and (A.39) with (A.7) gives

$$X_n = \frac{1}{\overline{\lambda}} B_n \gamma_n^{\frac{\sigma-(1-\kappa_3)}{\sigma(1-\kappa_2)-(1-\kappa_3)(1-\kappa_1)}} \delta_n^{\frac{\kappa_1-\kappa_2}{\sigma(1-\kappa_2)-(1-\kappa_3)(1-\kappa_1)}}$$

for a constant $B_n$ that is a function $\overline{A}_n$, $\overline{u}_n$, and parameters, and where $\overline{\lambda} = \overline{W}^{-\frac{(\kappa_1-\kappa_2)(\sigma-1)}{(1-\kappa_3)(\kappa_1-1)+(1-\kappa_2)\sigma}}$. Second, using that labor shares add up to 1, the solution for $w_n$ from (A.38) and (A.39), and (A.7) allows us to write $\overline{\lambda}^{1+a} = \sum_n C_n \gamma_n^d \delta_n^e$, for some constants $a$, $d$, and $e$ which are functions of $\sigma$, $\kappa_1$, $\kappa_2$ and $\kappa_3$. This satisfies Condition 4', so that we can apply their Corollary 2 to reach a uniqueness condition for the system of equations in $\{L_n, w_n, v\}$

[87] The terms $u_n^A$, $\tau_{in}^A$, and $z_n^A$ which enter in (A.34) are function of the export shares $\{s_{in}\}$ and government sizes $\{P_n G_n / GDP_n\}$. Government sizes and trade deficits also depend on the terms $\{\tilde{\Pi}_n, \tilde{\Pi}, \Pi + R\}$. These variables can be expressed as a function of export shares, labor compensation and parameters.

in (A.29) to (A.31):

$$\frac{\sigma-(1-\kappa_3)}{\sigma(1-\kappa_2)-(1-\kappa_3)(1-\kappa_1)}>1, \tag{A.40}$$

$$\frac{\kappa_1-\kappa_2}{\sigma(1-\kappa_2)-(1-\kappa_3)(1-\kappa_1)}>1, \tag{A.41}$$

where $\kappa_1$ to $\kappa_3$ are defined in (A.35) to (A.37). These steps hold taking as given the value of $\overline{\pi}$; since (the inverse of) $\overline{\pi}$ enters as a proportional shifter of wages, the condition applies to the solution of $\left\{L_n, \frac{w_n}{\overline{\pi}}, v\right\}$.

## B.5 General Equilibrium in Relative Changes

To perform counterfactuals, we solve for the changes in model outcomes as function of changes in taxes. Consider computing the effect of moving from the current distribution of state taxes, $\left\{t_n^y, t_n^c, t_n^x, t_n^l\right\}_{n=1}^N$ to a new distribution $\{(t_n^y)', (t_n^c)', (t_n^x)', (t_n^l)'\}_{n=1}^N$. Letting $\hat{x}=x'/x$ be the counterfactual value of $x$ relative to its initial value, we have that the changes in import shares, export shares, employment shares, and wages $\{\hat{\lambda_{in}}, \hat{s_{in}}, \hat{L_n}, \hat{w_n}\}_{n=1}^N$ as well as the welfare change $\hat{v}$ must be such that conditions (A.29) and (A.31) hold:

$$\sum_n \lambda_{in}\hat{\lambda_{in}}=1 \text{ for all } i, \tag{A.42}$$

$$\sum_i s_{in}\hat{s_{in}}=1 \text{ for all } n, \tag{A.43}$$

where, using (A.32) and (A.33),

$$\hat{\lambda_{in}}=\hat{A_{in}}\hat{w_n}^{1-\kappa_1}\hat{L}_n^{1-\kappa_{2n}}\hat{w_i}^{\sigma-1}\hat{L}_i^{-\kappa_3}, \tag{A.44}$$

$$\hat{s_{in}}=\hat{\lambda_{in}}\left(\frac{P_i\hat{Q}_i}{X_i}\right)\frac{\hat{w_i}\hat{L}_i}{\hat{w_n}\hat{L}_n}, \tag{A.45}$$

where using (A.34),

$$\hat{A}_{in}\propto\left(\frac{\hat{z_n^A}}{\hat{\tau_{in}^A}}\frac{\hat{u_i^A}}{\left(\hat{u_n^A}\right)^{(1-\gamma_n)+\alpha_F}}\hat{v}^{\alpha_F-\gamma_n}\right)^{\sigma-1}, \tag{A.46}$$

and where, from (19) to (21),

$$\hat{\tau_{in}^A}=\frac{\sigma-\tilde{t}_{in}}{\sigma-\left(\tilde{t}_{in}\right)'}, \tag{A.47}$$

$$\hat{z_n^A}=\left(\frac{1-(\bar{t}_n)'}{1-T_n}\right)^{\frac{1}{\sigma-1}-\left(\frac{1}{\varepsilon_F}+\alpha_F\chi_F\right)}\left(\frac{P_n\hat{G}_n}{GDP_n}\right)^{\alpha_F}, \tag{A.48}$$

$$\hat{u_n^A}=\left(\frac{1-T_n'}{1-T_n}\right)^{1-\alpha_W}\left(\frac{P_n\hat{G}_n}{GDP_n}\right)^{\alpha_W}. \tag{A.49}$$

Additionally, labor shares must add up to 1 :

$$\sum L_n\hat{L_n}=1. \tag{A.50}$$

The variables $\left\{\frac{P_n\hat{Q}_n}{X_n}, \frac{P_n\hat{G}_n}{GDP_n}, T_n', (\bar{t}_n)', \left(\tilde{t}_{in}\right)'\right\}_{n=1}^N$ can be expressed as function of the original taxes $\left\{t_n^y, t_n^c, t_n^x, t_n^l\right\}_{n=1}^N$, the new tax distribution $\{(t_n^y)', (t_n^c)', (t_n^x)', (t_n^l)'\}_{n=1}^N$, and the new export shares $\{\hat{s_{in}}s_{in}\}_{n,i=1}^N$ using (7), (11), (13), (A.25), and (A.28). Hence, these equations, together with (A.42) to (A.50), give the solution for $\left\{\hat{\lambda}_{in}, \hat{s}_{in}, \hat{L}_n, \hat{w}_n\right\}$ and $\hat{v}$.[88]

[88]Note that the new government sizes and trade deficits also depend on the new values of $\tilde{\Pi}$ and $\Pi+R$; these variables can be expressed as a function of initial conditions and changes in the endogenous variables, $\tilde{\Pi}'=(1/\sigma)\sum_i w_iL_i(\hat{w}_i\hat{L}_i)$ and $\Pi'+R'=(1/\sigma)\sum_i\left(1-(\bar{t}_i)'+\beta_i\gamma_i(\sigma-1)\right)w_iL_i(\hat{w}_i\hat{L}_i)$.

# C Appendix to Section 5 (Impact of Tax Dispersion in a Special Case)

**Proof of Proposition 1** Because goods are perfect substitutes ($\sigma \to \infty$) and there are no trade costs ($\tau_{in} = 1$ ) the production cost $c_n$ must be equalized across regions, and normalized to 1. This must also be the price of the final good produced everywhere,$P_n = 1$. Because firms are homogeneous ($\varepsilon_F \to \infty$), it follows from (16) that the summary statistic of the productivity distribution in $n$ equals the common-component of productivity, $\tilde{z}_n = z_n^0$. Using (A.6), total production in region $n$ is

$$\left(\frac{z_n^0}{\gamma_n}\right)^{1/\gamma_n}\left(\frac{H_n}{\beta_n}\right)^{\beta_n}\left(\frac{L_n}{1-\beta_n}\right)^{1-\beta_n}. \tag{A.51}$$

Under the assumptions of the proposition, the price of final good is the same across locations and may be chosen as numeraire; therefore, from (6), state-specific appeal is:

$$v_n = u_n\left(\frac{G_n}{L_n^{\chi_W}}\right)^{\alpha_{W,n}}\left(\left(1-T_n\right)w_n\right)^{1-\alpha_{W,n}}. \tag{A.52}$$

From (A.7), labor demand in state $n$ is given by the condition that wage equals the marginal product of labor, $w_n = MPL_n$, given by

$$MPL_n = Z_{n,0}L_n^{-\beta_n}, \tag{A.53}$$

where $Z_{n,0} = (1-\beta_n)^{1-\beta_n}\beta_n^{-\beta_n}\left(z_n^0/\gamma_n\right)^{1/\gamma_n}H_n^{\beta_n}$. Labor supply in $n$ follows from (8). Equating local labor demand and local labor supply gives the solution for employment in $n$,

$$L_n^*(v) = \left(\frac{\left(Z_n\left(1-T_n\right)\right)^{1-\alpha_{Wn}}}{v}\right)^{\frac{1}{1/\varepsilon_W+\alpha_{W,n}\chi_W+\left(1-\alpha_{W,n}\right)\beta_n}} \tag{A.54}$$

where $Z_n = Z_{n,0}\left(u_nG_n^{\alpha_W}\right)^{\frac{1}{1-\alpha_W}}$. Using (8) national labor-market clearing then gives the solution for worker welfare $v$ as the value where $H^*(v) \equiv \sum L_n^*(v) = 1$. Note that $H^*(v)$ is decreasing in $v$ so that there can only be a unique solution for $v$. Assume now that $\alpha_{W,n} = \alpha_W$ and $\beta_n = \beta$ for all $n$. Then, letting $\zeta = \frac{1-\alpha_W}{1/\varepsilon_W+\alpha_W\chi_W+(1-\alpha_W)\beta}$, the solution for worker welfare is:

$$v = \left(\sum\left(Z_n\left(1-T_n\right)\right)^{\zeta}\right)^{1/\varepsilon_W+\alpha_W\chi_W+(1-\alpha_W)\beta}. \tag{A.55}$$

Let $v'$ be welfare under a distribution of taxes where every tax rate is brought to the mean of the initial distribution, $T_n' = \overline{T} = \frac{1}{N}\sum T_n$ for all $n$. , $v' > v$ if

$$E\left[Z_n^{\zeta}\right]\left(E\left[1-T_n\right]\right)^{\zeta} > cov\left[Z_n^{\zeta},\left(1-T_n\right)^{\zeta}\right] + E\left[Z_n^{\zeta}\right]E\left[\left(1-T_n\right)^{\zeta}\right] \tag{A.56}$$

where $E$ and $cov$ denote the sample mean and covariance. This expression can be rearranged to reach

$$\frac{\mathbb{E}\left[1-T_n\right]^{\zeta} - \mathbb{E}\left[\left(1-T_n\right)^{\zeta}\right]}{sd\left(\left(1-T_n\right)^{\zeta}\right)} > cv\left(Z_n^{\zeta}\right)corr\left[Z_n^{\zeta},\left(1-T_n\right)^{\zeta}\right] \tag{A.57}$$

where $cv$ and $sd$ denote the coefficient of variation and the standard deviation. The results of parts i) and ii) follow by inspection of this last equation. Parts iii) and iv) follows from the examples and discussion in Section 5.

# D Appendix to Section 6.3 (Estimated Parameters)

## D.1 Construction of Covariates

To construct measures of market potential $MP_{nt}$, real government services $\tilde{R}_{nt}$ and unit costs $c_{nt}$, we need data

on prices. We use the consumer price index from the Bureau of Labor Statistics. This is the same price data that is used in the estimation of the labor equation to construct measures of real government spending and real wages.

Constructing unit costs also requires data on the price of structures $r_{nt}$, which is is not available at an annual frequency. Therefore, to construct an annual series of unit costs, we set the local price of structures equal to the local price index, resulting in the following measure of unit costs: $c_{nt} = \left(w_{nt}^{1-\beta_n} P_{nt}^{\beta_n}\right)^{\gamma_n} P_{nt}^{1-\gamma_n}$.[89]

We need information on sales shares both to build $\bar{t}_{nt}$ and the term $\{\tilde{t}_{n'nt}\}$ entering $MP_{nt}$. Annual data on trade flows across U.S. states does not exist; therefore, we set export shares equal to the average of the recorded export shares for the years 1993 and 1997, i.e., $s_{int} = 0.5 \times (s_{in,1993} + s_{in,1997})\ \forall t$. We also use the same information on export shares to construct a proxy for the term $\tau_{n'nt}$ entering the expression for $MP_{nt}$. Specifically, we set $\tau_{n'nt} = dist_{n'n}^{\zeta}$, where $\zeta = \frac{0.8}{\sigma - 1}$ and 0.8 is the point estimate of the elasticity of export shares with respect to distance, controlling for year, exporter and importer fixed effects.

We also need information on expenditures $P_{nt}Q_{nt}$ to build $MP_{nt}$. Since expenditures are not observed in every year, we follow the predictions of the model and construct a proxy for $P_{nt}Q_{nt}$ as a function of state GDP by combining equations (A.7), (A.12), and (A.25) to obtain

$$P_{nt}Q_{nt} = \frac{(\sigma - 1)(1 - \beta_n \gamma_n) + a_{nt} + t_n^l}{\sigma - t_n^x} \frac{\sigma}{\gamma_n (\sigma - 1) + 1} GDP_{nt}, \tag{A.58}$$

where $a_{nt} \equiv \frac{b_n}{\tilde{\Pi}_n / \left(\Pi + R + t_{fed}^{corp} \tilde{\Pi}\right)}$. State GDP is observed in every year, but $a_{nt}$ is not. Hence, to compute a yearly measure of $P_{nt}Q_{nt}$, we set its value to that observed in the calibration: $a_{nt} = a_{n,2007}$ for all $t$.[90]

## D.2 Construction of Instrument for Market Potential

We define the instrument $MP_{nt}^*$ as a variable that has a similar structure to market potential $MP_{nt}$ in (27), but $MP_{nt}^*$ differs from $MP_{nt}$ because we substitute the components $E_{nt}$, $P_{nt}$, and $\tilde{t}_{n'nt}$ that might potentially be correlated with $\nu_{nt}^M$ with functions of exogenous covariates that we respectively denote as $E_{nt}^*$, $P_{nt}^*$, and $\tilde{t}_{n'nt}^*$ :

$$MP_{nt}^* = \sum_{n' \neq n} E_{n't}^* \left( \frac{\tau_{n'nt}}{P_{n't}^*} \frac{\sigma}{\sigma - \tilde{t}_{n'nt}^*} \frac{\sigma}{\sigma - 1} \right)^{1-\sigma}. \tag{A.59}$$

To implement this expression, we need to construct measures of the variables $E_{nt}^*$, $P_{nt}^*$, and $\tilde{t}_{n'nt}^*$. We construct $E_{nt}^*$ using (A.58) with lagged GDP instead of period $t's$ GDP.[91] We set $P_{n,t}^* = 1 + t_{n,t}^c$. We construct $\tilde{t}_{n'nt}^*$ using the expression for $\tilde{t}_{ni}$ in (13) evaluated at hypothetical export shares defined as relative inverse log distances: $s_{int}^* = \frac{\ln(dist_{in})^{-1}}{\sum_{i \neq n} \ln(dist_{in})^{-1} + 1}\ \forall t, i \neq n$ and $s_{iit}^* = \frac{1}{\sum_{i \neq n} \ln(dist_{in})^{-1} + 1}\ \forall t$.

[89] Projecting the decadal data on rental prices $r_{nt}$ on wages and local price indices, $w_{nt}$ and $P_{nt}$, and using the projection estimates in combination with annual data on $w_{nt}$ and $P_{nt}$ to compute predicted rental prices, $\hat{r}_{nt}$, and predicted unit costs, $c_{nt} = (w_{nt}^{1-\beta_n} \hat{r}_{nt}^{\beta_n})^{\gamma_n} P_{nt}^{1-\gamma_n}$, produces similar estimates of the structural parameters $\varepsilon_F$ and $\alpha_F$.

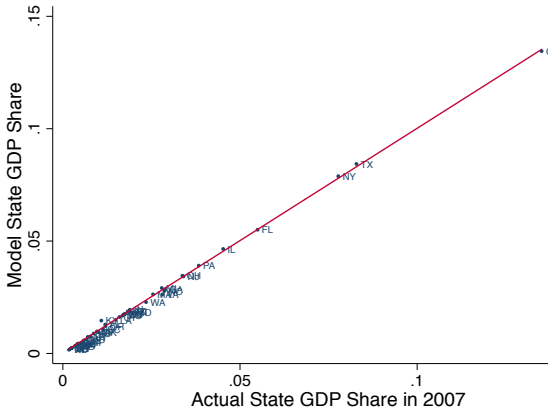
[90] Using an alternate definition of $P_{nt}Q_{nt}$, i.e. $P_{nt}Q_{nt} = constant * GDP_{nt}$ where the constant is an OLS estimate of the derivative of total expenditures with respect to GDP in those years in which we observe both components, yields very similar results.

[91] I.e., $E_{nt}^* = \frac{(\sigma-1)(1-\beta_n\gamma_n)+a_{nt}+t_n^l}{\sigma - t_n^x} \frac{\sigma}{\gamma_n(\sigma-1)+1} GDP_{n,t-1}$. A sufficient condition for an instrument that depends on lagged GDP to be exogenous is that the error term in equation (A.59) is independent over time.

## D.3 Appendix Figure to Section 6.4 (Over-Identification Checks)

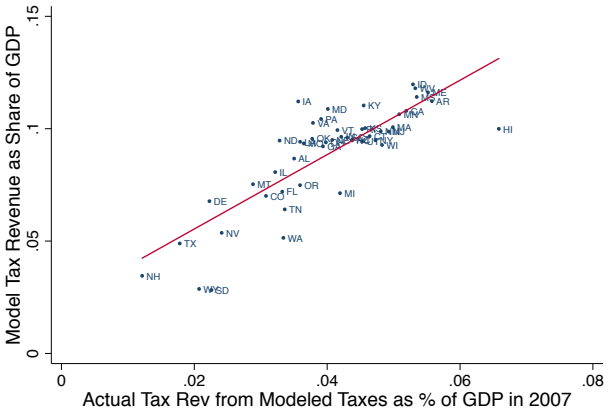
Figure A.2: Over-identifying Moments: Model vs Data

(a) State GDP Share



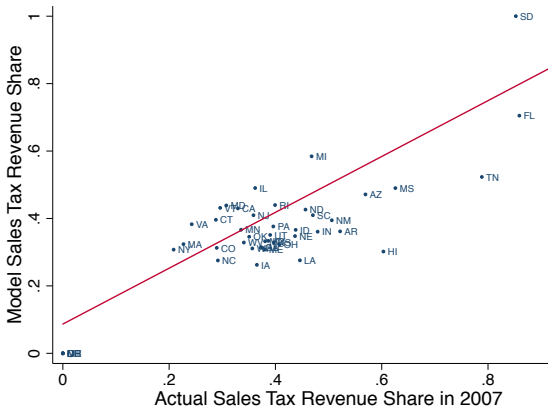

Note: Slope is 1 (0). R-squared is 1.

(b) State Tax Revenue as Share of GDP



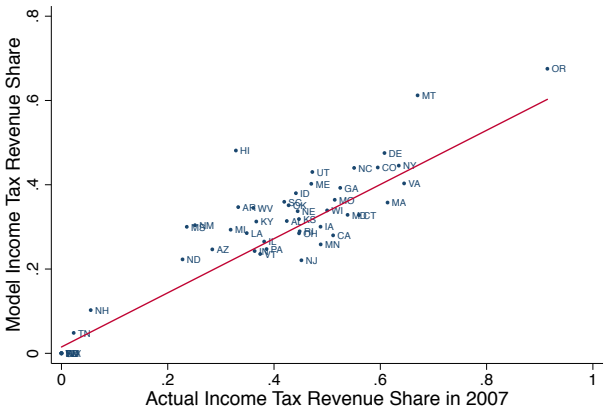

Note: Slope is 1.65 (.14). R-squared is .74.

(c) Sales Tax Revenue Share



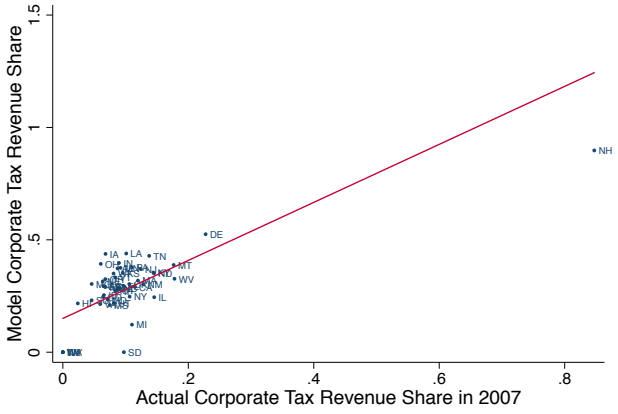

Note: Slope is .83 (.05). R-squared is .85.

(d) Income Tax Revenue Share




Note: Slope is .64 (.03). R-squared is .88.

(e) Corporate Tax Revenue Share




Note: Slope is 1.29 (.21). R-squared is .45.

## D.4 Comparison with Existing Estimates

Researchers have previously estimated regressions similar to (23) and (26) using sources of variation different from ours to identify the labor and firm mobility elasticities. Table A.3 compares our estimates of $\varepsilon_W$, $\alpha_W$, $\varepsilon_F$, and $\alpha_F$ to those that we would have constructed if we had used estimates of the elasticity of labor and firms with respect to after-tax wages and public expenditure from six recent studies. The parameter that is most often estimated is the elasticity of labor with respect to real wages; this previous literature implies estimates of $\varepsilon_W$ with mean value of 1.79. Our benchmark numbers of $\varepsilon_W = 1.24$ ($\chi_W = 0$) and $\varepsilon_W = 1.57$ ($\chi_W = 1$) reported in the first row of Table 1 are within the range of these estimates. Our estimate of $\varepsilon_F$ is between the firm-mobility parameters reported in Suárez Serrato and Zidar (2015) and Giroud and Rauh (2015).

Concerning $\alpha_W$ and $\alpha_F$, there is substantial evidence that public expenditures have amenity and productivity value for workers and firms, respectively, which is consistent with $\alpha_W > 0$ and $\alpha_F > 0$. Some studies infer positive amenity value for government spending from land rents,[92] while others focus on the productivity effects of large investment projects.[93] However, very few papers estimate specifications similar to (23) and (26). The estimates of the effects of variation in federal spending at the local level from Suárez Serrato and Wingender (2014) imply $\alpha_F = 0.10$ and $\alpha_W = 0.26$.

Of course, all these comparisons are imperfect due to differences in the source of variation, geography, and time dimension; for example, all of these studies use smaller geographic units than states. Additionally, not all specifications include the same covariates as our estimating equations (23) and (26). These differences notwithstanding, our structural parameters are close to those in the literature.

[92] E.g., Bradbury et al. (2001) show that local areas in Massachusetts with lower increases in government spending had lower house prices, and Cellini et al. (2010) show that public infrastructure spending on school facilities raised local housing values in California. Their estimates imply a willingness to pay \$1.50 or more for each dollar of capital spending. Chay and Greenstone (2005) and Black (1999) also provide evidence of amenity value from government regulations on air quality and from school quality, respectively.

[93] Kline and Moretti (2014) find that infrastructure investments in by the Tennessee Valley Authority resulted in large and direct productivity increases, yielding benefits that exceeded the costs of the program. Fernald (1999) also provides evidence that road-building increases productivity, especially in vehicle-intensive industries. Haughwout (2002) shows evidence from a large sample of US cities that "public capital provides significant productivity and consumption benefits" for both firms and workers.

Table A.3: Structural Parameters Implied by Similar Studies

| Paper | Estimates | Implied Values of | | | | Source of Variation (Shock) | Level of Variation |
|---|---|---|---|---|---|---|---|
| | | $\varepsilon_W$ | $\alpha_W$ | $\varepsilon_F$ | $\alpha_F$ | | |
| Bound and Holzer (2000) | $a_0 = 1.20$[a] | 1.16 | | | | Bartik | MSA (1980's) |
| Notowidigdo (2013) | $a_0 = 3.47$[b] | 2.44 | | | | Bartik | MSA (1980-2000) |
| Suárez Serrato and Wingender (2014) | $a_0 = 1.58$[c] | 1.44 | | | | Bartik and Census Instrument | County Group (1980-2009) |
| | $a_0 = 2.9$, $a_1 = 1.02$, $b_1 = 0.26$[d] | 1.94 | 0.26 | | 0.10 | | |
| Diamond (2015) | $a_0 = 3.10$[e] | 2.29 | | | | Bartik | MSA (1980-2000) |
| Suárez Serrato and Zidar (2015) | $a_0 = 1.28$[f] | 1.23 | | | | Bartik | County Group (1980-2009) |
| | $a_0 = 2.63$, $b_0 = 3.35$[g] | 2.06 | | 5.33 | | Business Tax | |
| Giroud and Rauh (2015) | $b_0 = 0.40$[h] | | | 1.34 | | Corporate Tax | Firm-Level (1977-2011) |

This table reports the values of our structural parameters implied by estimates of specifications similar to (23) and (26) found in the previous literature. Whenever needed, we assume the values used in our baseline parametrization of $\sigma = 4$, $\chi_W = 1$, $\chi_F = 1$, and $\alpha_W = 0.17$ in recovering structural parameters. When the effects are only reported separately for skilled and unskilled workers we use a share of skilled workers of 33% to average the effects.

[a] For both college and non-college groups, we first construct $a_0$ from Table 3 in Bound and Holzer (2000) by taking the ratio of the effects on Population and Total Hours. We then average the effect by the college share above.

[b] This parameter comes from Table 3 in Notowidigdo (2013) and results from taking the ratio of columns (1) and (6). Note that these specifications also control for quadratic effects. We employ marginal effects around 0.

[c] This number is directly reported in Suárez Serrato and Wingender (2014) in Table 9.

[d] The parameters $a_0$ and $a_1$ come from Table 10 in Suárez Serrato and Wingender (2014) by manipulating the structural parameters as follows: $a_0 = 1/\sigma^i$ and $a_0 = \psi^i/\sigma^i$ for each skill group. The parameter $b_1$ comes from using the effect of spending on firm location (see Footnote 41) and by noting that this effect is equal to $1 - (\kappa_i^{GS} + (1 - \kappa_i^{GS})/(1 - \alpha_i))\frac{\partial W^i}{\partial F}$ in Suárez Serrato and Wingender (2014). The parameters $\alpha^i$,$\kappa_i^{GS}$, and $\frac{\partial W^i}{\partial F}$ are reported in Tables 9 and 10 by skill group in Suárez Serrato and Wingender (2014). We then average these effects by the college share above.

[e] Diamond (2015) reports the effect on wage on population by skill group in Table 3. We then average these effects by the college share above. Note that Diamond (2015) also controls for state of origin which leads to a larger effect of population on wages than in other similar papers, especially for the low skill population.

[f] We construct $a_0$ from Table 6, Panel (c) in Suárez Serrato and Zidar (2015) by taking the ratio of the effects on Population and Wages.

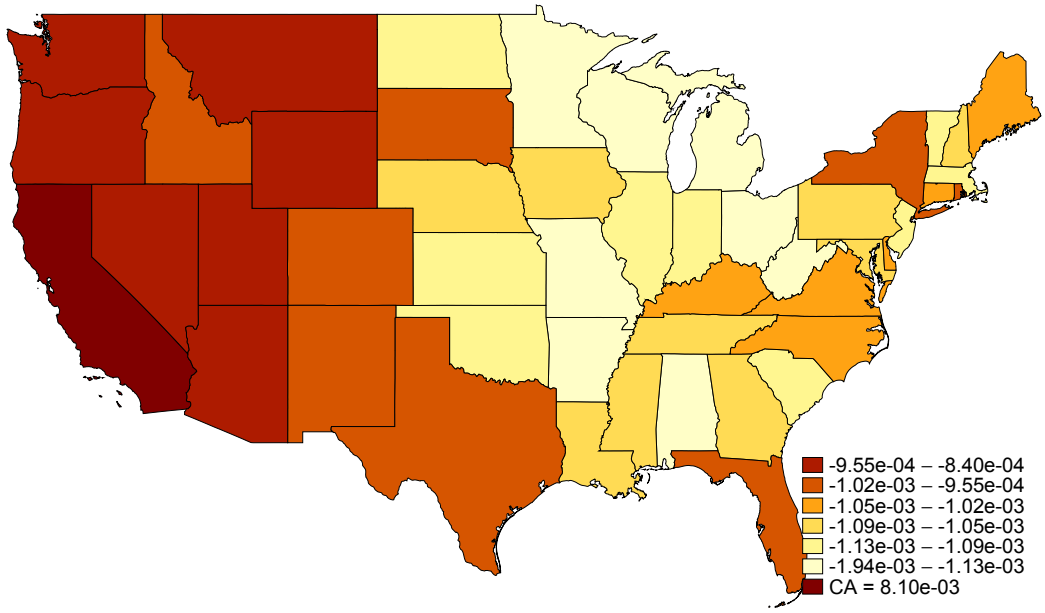
[g] We construct $a_0$ from Table 6, Panel (c) in Suárez Serrato and Zidar (2015) by taking the ratio of the effects on Population and Wages. $b_0$ is reported in Table 6, Panel (c).

[h] Giroud and Rauh (2015) report an elasticity of number of establishment with respect to corporate taxes of 0.4.

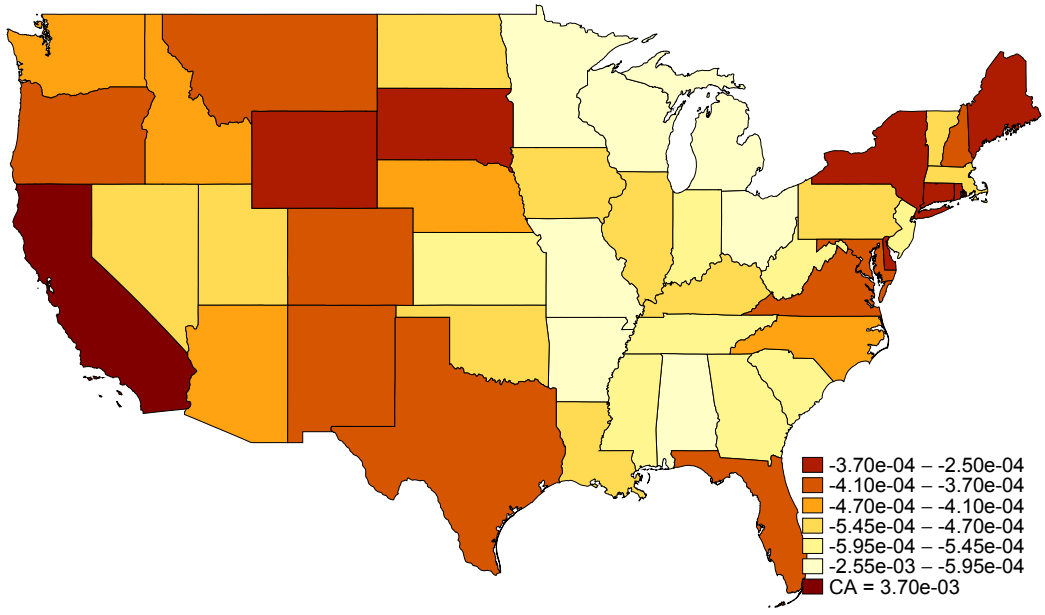
# E Appendix to Section 7 (Measuring Spatial Misallocation)

## E.1 Appendix Figure to Section 7.2 (Change in Tax in One State)

Figure A.3: Lowering Income Tax in California by 1 Percent Point




(a) Change in Employment




(b) Change in Number of Firms

# F Data Sources

In this section we describe the data used in sections 3.1, 6, and 7.

## F.1 Government Finances

- State revenue from sales, income and corporate taxes taxes ($R_n^c$, $R_n^y$, $R_n^{corp}$): Source: U.S. Census Bureau – Governments Division; Dataset: Historical State Tax Collections; Variables: corporate, individual, and general sales taxes, which are CorpNetIncomeTaxT41, IndividualIncomeTaxT40, TotalGenSalesTaxT09. We also collect TotalTaxes, which include the three types we measure as well as fuels taxes, select sales taxes, and a few other miscellaneous and minor sources of tax revenue.

- State direct expenditures: Source: U.S. Census Bureau – Governments Division; Dataset: State Government Finances; Variable: direct expenditures.

- State individual income tax rate $t_n^y$: Source: NBER TAXSIM; Dataset: Marginal and Average Tax Rates and Elasticities for the US, using a fixed 1984 (but in/deflated) sample of taxpayers; Variable: Average effective state tax rate on income, "st_avg", by state and year. Note: the fixed sample corresponds to actual 1984 tax returns. The features of the tax code taken into account by NBER TAXSIM include maximum and minimum taxes, alternative taxes, partial inclusion of social security, earned income credit, phaseouts of the standard deduction and lowest bracket rate. State tax liabilities are calculated using the data from the federal return. All items on the return are adjusted for inflation, so differences across tax years only reflect changes in tax laws.

- State sales tax rate $t_n^c$: Source: Book of the States; Dataset: Table 7.10 State Excise Tax Rates; Variable: General sales and gross receipts tax (percent).

- State corporate tax rate and apportionment data for $t_n^x$ and $t_n^l$: Source: Suárez Serrato and Zidar (2015).

- Effective Federal Corporate Tax Rate $t_{fed}^{corp}$: Source: IRS, Statistics of Income; Dataset: Corporation Income Tax Returns (historical); Variable: Effective Corporate Tax Rate = Total Income Tax/ Net Income (less Deficit); i.e., the effective rate is row 83 divided by row 77.

- Federal Individual Income Tax Rate $t_{fed}^y$: Source: NBER TAXSIM; Dataset: Marginal and Average Tax Rates and Elasticities for the US, using a fixed 1984 (but in/deflated) sample of taxpayers; Variable: Average effective federal tax rate on income, "fed_avg", by state and year.

- Federal Payroll Tax Rate $t_{fed}^w$: Source: Congressional Budget Office; Dataset: Average Federal Tax Rates in 2007; Variable: Average Payroll Tax Rates. See Table A.2 for the average in 2007 and additional details in the table notes.

- Corporate taxes adjusted for subsidies (for Section 7.6.1): We use data from the New York Times Subsidy database to compute state corporate tax rates net of subsidies, which amounted to $16 billion in 2012.[94] We first calculate an effective corporate tax rate by state by dividing corporate tax revenues by total pre-tax profits, which are given in A.12 by $\tilde{\Pi}_n = GDP_n / (\gamma_n(\sigma - 1) + 1)$. Since these effective rates are smaller than statutory tax rates, we adjust them by the ratio of statutory corporate rates to effective corporate rates in order to match the statutory rates. We next compute a subsidy rate by dividing state subsidies by the same tax base as above, and further multiply this ratio by the same adjustment factor as above. The net-of-subsidy, effective corporate tax rate is then the difference between the adjusted effective corporate rate and the adjusted subsidy rate.

[94] http://www.nytimes.com/interactive/2012/12/01/us/government-incentives.html?_r=0

- Ratio of State and Local to State tax revenue for sales, income, and corporate tax $\frac{R_n^{StandLocal,j}}{R_n^{State,j}}$ $\forall j \in \{y, c, corp\}$: Source: U.S. Census Bureau – Governments Division; Dataset: State and Local Government Finances; Variable: State and Local Revenue; State Revenue (Note that sales taxes uses the general sales tax category)

- We derive the following variables from the primary sources listed above (for Figure A.1):

  - State and Local corporate tax rate: $t_n^{corp,s+l} = t_n^{corp} \times \frac{R_n^{StandLocal,corp}}{R_n^{State,corp}}$.
  - State and Local sales tax rate $t_n^{c,s+l} = t_n^{c} \times \frac{R_n^{StandLocal,c}}{R_n^{State,c}}$, where the sales revenue used is general sales tax revenue.
  - State and Local income tax rate $t_n^{y,s+l} = t_n^{y} \times \frac{R_n^{StandLocal,y}}{R_n^{State,y}}$.

## F.2 Calibration (Section 6.2) and Over-Identification Checks (Section 6.4)

- Number of Workers $L_n$: Source: 2007 Economic Census of the United States; Dataset: EC0700A1 - All sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007; Variable: Number of paid employees for pay period including March 12

- Wages $w_n$: Source: 2007 Economic Census of the United States; Dataset: EC0700A1 - All sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007; Variable: Annual Payroll / Number of paid employees

- Total sales $X_n^{Total}$: Source: 2007 Economic Census of the United States; Dataset: EC0700A1 - All sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007; Variable: Employer value of sales, shipments, receipts, revenue, or business done

- International Exports $Exports_t^{ROW}$: Source: US Department of Commerce International Trade Administration; Dataset: TradeStats Express - State Export Data; Variable: Exports of NAICS Total All Merchandise to World

- Consumption expenditures $P_nC_n$: Source: U.S. Department of Commerce – Bureau of Economic Analysis (BEA) Regional Data; Dataset: Personal Consumption Expenditures by State; Variable: Personal consumption expenditures

- State GDP $GDP_n$: Source: U.S. Department of Commerce – Bureau of Economic Analysis (BEA) Regional Data; Dataset: GSP NAICS ALL and and GSP SIC ALL; Variable: Gross Domestic Product by State

- Value of Bilateral Trade flow $X_{ni}$: Source: U.S. Census Bureau; Dataset: Commodity Flow Survey; Variable: Value

- Number of Establishments $M_n$: Source: 2007 Economic Census of the United States; Dataset: EC0700A1 - All sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007; Variable: Number of employer establishments

- We derive the following variables from the primary sources listed above:

  - Value of Intermediate Inputs: $P_nI_n = X_n - GDP_n$
  - Total state spending and revenue: $P_nG_n = R_n = T_n^c + T_n^y + R_n^{corp}$.
  - Sales from state $n$: $X_n = X_n^{Total} - Exports_n^{ROW}$.
  - Sales to the own state: $X_{ii} = X_i - \sum_n X_{ni}$.
  - Share of sales from $n$ to state $i$: $s_{in} = \frac{X_{in}}{\sum_{i'} X_{i'n}}$.
  - Share of expenditures in $i$ from state $n$: $\lambda_{in} = \frac{X_{in}}{\sum_{n'} X_{in'}}$.

## F.3 Estimation (Section 6.3)

The variables used for estimation are different from those used for the calibration due to data availability. In computing both the calibrated parameters and the counterfactuals, we use the Economic Census measures for wages and employment; the reason being that we collect the sales data from the Economic Census as well. However, the Economic Census is available less frequently than the following data sources, which we use for estimation.

- Number of Workers $L_n$: Source: U.S. Census Bureau; Dataset: County Business Patterns (CBP); Variable: Total Mid-March Employees with Noise; Data cleaning: Used the mid-point of employment categories for industry-state-year cells that withheld employment levels for disclosure reasons and then sum by state year.

- Number of Establishments $M_n$: Source: U.S. Census Bureau; Dataset: County Business Patterns (CBP); Variable: Total Number of Establishments

- Wages from CPS $w_n^{CPS}$: Source: IPUMS; Dataset: March Current Population Survey (CPS); Definition: we run the following regression, $\log wage_{int} = \mu_{nt} + \epsilon_{int}$ where $i$ is individual, $n$ is state, and $t$ is year, and then use $\mu_{nt}$ as our measure of average log wages; Variable Construction: Our measure of individual log wages, $\log wage_{int}$, is computed by dividing annual wages by the estimated total hours worked in the year, given by multiplying usual hours worked per week by the number of weeks worked. The CPI99 variable is used to adjust for inflation by putting all wages in 1999 dollars; Sample: Our sample is restricted to civilian adults between the ages of 18 and 64 who are in the labor force and employed. In order to be included in our sample, an individual had to be working at least 35 weeks in the calendar year and with a usual work week of at least 30 hours per week. We also drop individuals who report earning business or farm income. We drop imputed values from marital status, employment status, and hours worked. Top-coded values for years prior to and including 1995 are multiplied by 1.5.

- Rental prices $r_n$: Source: IPUMS; Dataset: American Community Survey (ACS); Variable: Mean rent; Sample: Adjusted for top coding by multiplying by 1.5 where appropriate

- Price Index $P_n = P_n^{BLS}$; Source: Bureau of Labor Statistics (BLS); Dataset: Consumer Price Index; Variable: Consumer Price Index - All Urban Consumers; Note: Not available for all states. We used population data to allocate city price indexes in cases when a state contained multiple cities with CPI data (e.g. LA and San Francisco for CA's price index)