State Taxes and Spatial Misallocation*

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Abstract

We study the impact of the state tax distribution on aggregate real income, welfare, and the distribution of economic activity across U.S. states. We build a spatial general-equilibrium model in which state governments use tax revenue to finance public services, and estimate firm and worker mobility elasticities and preferences for public services. We find that a revenue-neutral tax harmonization leads to a welfare gain of 0.7% and to a similar increase in real GDP. Additionally, state tax cuts lower own-state economic activity because of general-equilibrium effects on prices and public services, and impact other states differently due to trade linkages.

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1 Introduction

In 2012, U.S. states collected roughly $800 billion in tax revenue relying on very different tax structures. Across states, the 90-10 percentiles of the distributions of sales, average personal income, and corporate income tax rates were 7%-1%, 5%-0%, and 9%-0%, respectively. State tax reforms happen frequently – between 1978 and 2010, there were more than 300 modifications of some state tax rate by at least 0.5 percentage points – and are often subject to debate. Lower taxes are said to help create jobs or attract businesses to specific states,[1] but also to erode the provision of public services with little effect on employment.[2] In both academic and policy circles, proposals to harmonize tax rates are described as potentially beneficial because they could help curtail "beggar-thy-neighbor" scenarios.[3] Overall, there is little agreement about the implications of these policies.[4] In the light of recent research which emphasizes the negative impact of dispersion in distortions across economic units – across firms, as in Hsieh and Klenow (2007), or across cities, as in Desmet and Rossi-Hansberg (2013) – it is plausible to conjecture that dispersion in tax rates across states may lead to aggregate losses.

What are the impacts of eliminating dispersion in tax rates across U.S. states on aggregate real income and welfare? What are the effects of lowering taxes in one state on that state and on other states? These questions are difficult to tackle because many general-equilibrium forces are at work – changes in state taxes lead to reallocations of workers, firms, and trade flows across states, as well as to changes in the amount of public services provided by state governments – and to the best of our knowledge, no existing analysis has been able to answer them. To do so, we incorporate tools developed in recent trade and economic geography models into a general-equilibrium model that accounts for several types of spatial interactions among states and salient features of the U.S. state tax system. We estimate key parameters – elasticities of firm and worker mobility across states and preferences for public services – using equilibrium relationships implied by the model and data on the spatial distribution of economic activity and government finances across states from 1980-2010. Using the estimated model, we measure the effects of imposing counterfactual distributions of state tax rates.

In our model, workers decide where to locate based on each state's taxes, wage, cost of living, and amenity level. In turn, 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). Additionally, workers and firms hold, respectively, idiosyncratic preference and productivity draws across states, according to which they sort across states. The amenity and productivity levels of each state partly depend on government spending in

[1] E.g., see "Gov Kasich's Winning Proposal for Ohio: Lowering Income Taxes," *Forbes*, Arthur Laffer and Nicholas Drinkwater, May 15, 2015.

[2] E.g., see "Kansas' Ruinous Tax Cuts," *The New York Times*, Editorial Board, July 13, 2014.

[3] E.g., see Gordon (1983), Auerbach (2013), and, more recently, Wilson (2015).

[4] E.g., the March 24, 2015 poll of members of the IGM Economic Experts Panel of Chicago Booth on Local Tax Incentives illustrates the disagreement and uncertainty among economists on questions related to this topic: `http://www.igmchicago.org/igm-economic-experts-panel/poll-results?SurveyID=SV_9mead4nHknibSxn`.

public services. In our model, this spending is financed by the main taxes used by the states in the U.S.: sales, personal income, and corporate income taxes apportioned through both firm sales and factor usage.[5] 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-services' provision. Specifically, our model implies that state taxes impact the allocation of firms, workers, and goods through their effect on "adjusted fundamentals," defined as functions of actual state fundamentals (productivity, amenity, and trade costs), tax rates, and government spending. Given the level of government spending, higher income or sales taxes in one state are equivalent to a lower amenity level in that state, higher corporate taxes are equivalent to lower productivity, and sales-apportioned corporate tax rates are equivalent to trade costs. In general equilibrium, government spending varies with the size of each government's budget; as a result, changes in tax rates in one state impact the adjusted fundamentals of both the own state and other states.

To measure the effects of alternative state tax structures we need estimates of four key parameters: the elasticities of worker and firm mobility, and the weight of public services in worker preferences and firm productivity. We identify these parameters using equilibrium relationships from the model which characterize the location decisions of workers and firms, and a longitudinal dataset on the spatial distribution of workers and firms, state tax rates, and state government revenue from 1980-2010. Specifically, our model generates a worker-location equation that predicts each state's employment share as function of after-tax real wages and government spending, and a firm-location equation that predicts each state's share of establishments as function of after-tax market potential, factor prices, and government spending. The estimation strategy uses taxes in other states to instrument for each states' factor prices and government spending. We find a partial elasticity of state employment with respect to after-tax real wages of about 1, and with respect to government spending of about 0.2. Within our model, the ratio between these reduced-form coefficients identifies the preference for public services relative to private goods, and their level identifies the elasticity of worker mobility.[6]

The remaining parameters of the model (production technologies and state fundamentals) are calibrated such that the model exactly reproduces as an equilibrium outcome the distribution factor shares, wages, employment, and trade across states in 2007, the most recent year in which all the data we need is available. We verify that the estimated model correctly predicts the distribution of variables not targeted by the parametrization, such as the distribution of establishments, GDP, and shares of taxes in GDP. Using the estimated model, we measure the effects of replacing the 2007 distribution of state tax rates with counterfactual distributions.

Our main counterfactuals assess the impact of tax reforms that eliminate dispersion in tax rates

[5] Our baseline analysis focuses on these three types of taxes because they can be cleanly measured using statutory tax rates and account for the bulk of state tax revenue; see Section 2 for background on the U.S. tax system. In the counterfactuals, we entertain alternative ways of measuring these tax rates and also include local (sub-state) taxes.

[6] These estimates are in the range of existing work that has estimated similar specifications, such as Bound and Holzer (2000), Notowidigdo (2011), Suárez Serrato and Wingender (2011), Diamond (2015), and Suárez Serrato and Zidar (2014). See Section 4.3 for details.

across states. We define the spatial misallocation caused by the state tax distribution as the welfare and real-income gains (if they exist) that would result from eliminating the dispersion in each type of tax across states while keeping the size of state governments constant. We use two measures of government size: we undertake a revenue-neutral counterfactual by bringing each type of tax to a level such that the tax revenue collectively raised by all states is the same as in the initial scenario, and we also undertake a spending-neutral counterfactual by bringing each type of tax to a level such that the tax revenue collectively raised by all states can finance the same level of government spending in every state as in the initial scenario though cross-state transfers. Dispersion in tax rates across states can be shown to reduce real income and welfare under specific parametrizations that restrict some forces in the model, such as spatial externalities through home-market effects and government spending. However, the model that we bring to the data includes these forces, and therefore does not impose an answer to the question of whether eliminating tax dispersion must lead to real-income and welfare gains.

We find that a revenue-neutral harmonization of sales, income, and corporate taxes leads to aggregate real-income and welfare gains in the order of 0.7%, or roughly $100 billion in 2009, pointing to quantitatively important effects from dispersion in these taxes relative to their revenue share in GDP of about 4%. The spending-neutral elimination of tax dispersion leads to a 0.12% increase in welfare and to a similar increase in real GDP, also pointing to the existence of spatial misallocation. We inspect how these results vary under a range of alternative parametrizations and measures of state tax rates. We consider cases in which government spending has lower weight in worker preferences and productivity, and cases that allow for heterogeneity across states in workers' preferences for government spending. We continue to find gains from eliminating dispersion in income, sales, and corporate tax rates, including an extreme case that assigns zero weight to government spending in preferences and productivity; in that case, both revenue- and spending-neutral counterfactuals lead to welfare gains of 0.2%. We also compute counterfactuals under parametrizations corresponding to alternative estimation strategies and under different ways of measuring tax rates; e.g., adjusting corporate tax rates for state subsidies, using effective rates that account for local taxes, and incorporating progressivity in state and federal income tax schedules. We continue to find spatial misallocation of a similar magnitude to the benchmark across these cases.

We also use the estimated model to gauge the effects of other policies. Specifically, we measure the effects of lowering taxes by simulating a 1 percentage point reduction in the individual income tax in each state at a time. On average, this policy causes a loss of economic activity in the state enacting the tax change. General-equilibrium forces largely drive the effects: keeping goods prices, factor prices, and government spending constant, the tax reduction leads to an increase in economic activity in the state reducing taxes, but when these variables are allowed to adjust, activity in that state decreases. We find that this tax change leads to heterogeneous impacts across other states depending on the strength of trade linkages, with the states who export or import relatively more from the state lowering taxes experiencing a relatively smaller increase in economic

activity. We also explore the implications of the sales apportionment of corporate taxes; i.e., the fact that business profits are allocated to states proportionally to sales shares to compute the corporate tax rate.[7] In the model, the sales apportionment distorts sales decisions, leading firms to sell relatively more to states with lower sales apportionment. We find aggregate losses from fully apportioning corporate taxes through sales instead of employment. We identify a relevant role for trade in driving this result: moving away from sales apportionment implies smaller gains under no heterogeneity in trade linkages across states, suggesting a complementarity between trade frictions and the distortions caused by the sales apportionment.

The paper is related to a recent literature on quantitative economic-geography models including Ramondo et al. (2012), Redding (2012), Allen and Arkolakis (2014), Caliendo et al. (2014), Bartelme (2014), and Monte (2014).[8] Our 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. Specifically, our model combines a number of ingredients already present in these previous studies with a few new ones dictated by our research question.[9] The new ingredients include imperfect firm mobility (in the form of idiosyncratic productivity draws across states), a tax structure that encompasses the main taxes used by U.S. states, and a government sector that uses these taxes to finance public services valued by workers and firms. Relative to this literature, a central feature of our analysis is also the focus on policy variables that can be directly observed (the distribution of state taxes) and the estimation of key parameters (elasticities of firm and worker mobility and preferences for government spending) using changes over time and space in those policies and in economic activity.[10]

Our paper also contributes to the literature on the aggregate effects of misallocation. A common approach in the literature consists in measuring distortions across firms as an implied wedge between the observed and the model-implied undistorted allocation, as in Hsieh and Klenow (2007) and Restuccia and Rogerson (2008). A few papers adopt a similar strategy to analyze misallocation across geographic units, such as Desmet and Rossi-Hansberg (2013) across U.S. and Chinese cities, or Brandt et al. (2013) across Chinese provinces.[11] These wedges capture distortions that may be

[7] See the discussion in Section 2.1. There is substantial debate on state corporate tax apportionment policy (e.g., ITEP (2012) and Mazerov (2005)). Some (e.g., Zucman (2014)) have recently advocated moving towards a sales-based apportionment system for corporate taxation at a global scale.

[8] These papers have in common the introduction of labor mobility into quantitative trade models with CES preferences such as Eaton and Kortum (2002) or Anderson and Van Wincoop (2003).

[9] As in Redding (2012), workers in our model hold idiosyncratic preferences draws across location and there is an endogenous number of firms in each location determined through home-market effects; as in Caliendo et al. (2014), the model allows for heterogeneous production technologies across states and for trade in intermediate inputs, although for simplicity we abstract from the full set of input-output linkages across sectors that are included in their analysis; as in all these papers, congestion depends on decreasing returns to labor in a given location, in our case caused by the presence of immobile factors of production (land and structures). This congestion force is isomorphic to a non-traded or housing sector; see Allen and Arkolakis (2014).

[10] In this sense, our approach shares features with Caliendo and Parro (2014), who, in an international trade context, estimate trade elasticities using variation in tariffs. A few recent papers are also concerned with the impact of policies in models with labor mobility. Gaubert (2014) studies subsidies in a model with with heterogeneous firms and externalities from city size and Ossa (2015) studies the Nash equilibrium in state subsidies in a spatial model with home market effects.

[11] See also Hsieh and Moretti (2015), who use a Rosen-Roback model to measure the TFP effects associated with

due to multiple sources. Rather than inferring distortions from wedges, we focus on the spatial misallocation generated by one specific type of distortion (state taxes) that we can directly observe in the data, and we use the observed variation in this distortion to estimate key elasticities. While this literature typically focuses on the impact of distortions on TFP, we study the impact on real income and welfare because, in our setup, the distortions have the direct interpretation of taxes that are used to finance public services valued by workers.

Finally, our paper is also related to the public finance literature that has analyzed the general equilibrium effects of tax changes. For example, Shoven and Whalley (1972), Ballard et al. (1985), and Ballard et al. (1985) emphasize the importance of general equilibrium effects when analyzing large changes in policy. Also in a general equilibrium, Albouy (2009) and, more recently, Eeckhout and Guner (2014) study the distortions in the allocation of workers across U.S. cities caused by federal tax progressivity. The general-equilibrium effects implied by our analysis depend on the elasticities of firm and worker location with respect to taxes; evidence on the incidence 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 impact of local policies on business location.[12] Suárez Serrato and Zidar (2014) provide evidence on the impact of corporate taxes on worker and firm mobility, and Suárez Serrato and Wingender (2011) 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 or many states, such as tax harmonization, would impact outcomes in every state individually and in the U.S. economy through both partial- and general-equilibrium forces.

The rest of the paper is structured as follows. Section 2 describes the U.S. state tax system. Section 3 develops the model and describes general-equilibrium conditions. Section 4 presents the estimation. Section 5 shows the spatial-misallocation counterfactuals, Section 6 presents the additional counterfactuals. Section 7 concludes. Additional derivations and figures, details of the estimation, and data sources are shown in the appendix.

wage dispersion across U.S. cities. For any observed distribution of taxes, the quantitative economic-geography model that we adopt can rationalize the observed distribution of economic activity (wages, prices, employment, and trade) as an equilibrium outcome corresponding to some joint distribution of productivity, amenities, and trade costs. We do not introduce wedges in the model to save notation, but we note that, if introduced, they would not be separately identified from these fundamentals.

[12] 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 (1997) exploits foreign tax credit rules to show that investment responds to state corporate tax conditions, and Giroud and Rauh (2015) use establishment-level data to show that multi-state C-corporations reduce their activity on both the intensive and extensive margins 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.

2 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 amount 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 for the data discussed in this section.

2.1 Main State Taxes

Personal Income Tax Rates States tax the personal income of their residents. The base for personal income taxes includes both labor and capital income. In our benchmark analysis, we use a flat state income tax rate, and we then explore how our counterfactuals results change if we account for the progressivity of income taxes at both the state and federal levels.[13] We compute a single 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.[14] 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.

Corporate Income Tax Rates States also tax businesses. The tax base and tax rate on business depend on the legal form of the corporation. The tax base of C-corporations is national profits.[15] State tax authorities determine the share of a C-corporation's national profits allocated to their state using apportionment rules, which are based on 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.[16] 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

[13] 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 5.4.

[14] 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.

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

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

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 business as C-corporations.[17] 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 Rate 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.[18] 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.

2.2 Dispersion in Tax Rates and in Tax Revenue across States

Both the tax base and the tax rates vary considerably across states. 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. Panel (a) of Figure 1 shows the 2010 distribution of sales, income, corporate, and sales-apportioned corporate tax rates.[19] Each tax rate varies across states, corporate tax rates being the most dispersed. For each type of tax, there are at least four states with 0% rates. These differences in tax structures are associated with differences in tax revenue. 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% to 7% .

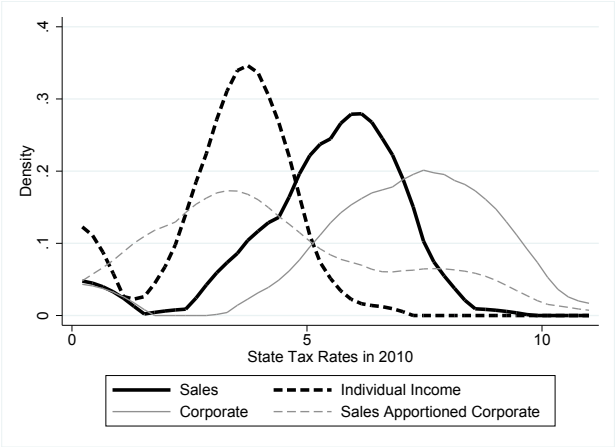
[17] C-corporations accounted for 66% percent of total business receipts in our baseline year of 2007 (PERAB, 2010).

[18] 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).

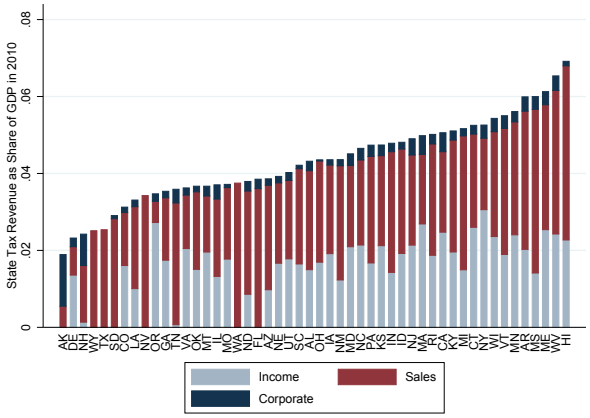
[19] The sales-apportioned corporate tax rate is the product of the sales apportionment factor (which is between 0 and 1) and the corporate rate; i.e., the variable $t_n^x = \theta_n^x t_n^{corp}$ defined in footnote 16.

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



Local (sub-state) governments also tax residents. Overall, state taxes amount to roughly 60% of state and local tax revenue combined.[20] 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. Our benchmark analysis excludes local taxes, but we also explore how our counterfactual results change if we use alternative measures of income, corporate and sales tax rates computed as the sum of the state and local tax rates, and also include property taxes.

2.3 Relationship Between State Taxes and Government Spending

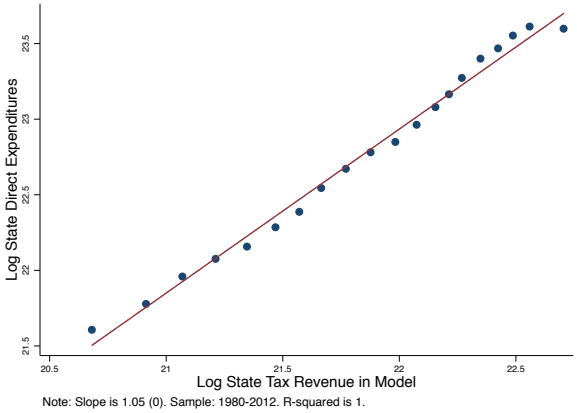
In 2012, direct expenditures by state governments added up to roughly 10% of GDP.[21] State governments typically have balanced budgets (Poterba, 1994), so we assume in our model that changes in state tax revenue translate to changes in state government spending. Figure 2 shows that there is indeed a high correlation between the tax revenue from the taxes we consider in the analysis (i.e., personal income, corporate income, and sales taxes) and direct state spending during 1980-2012 both within states over time and across states in any given year. Panel A shows the correlation with state fixed effects, and Panel B shows it with year fixed effects.

[20] Local governments rely more heavily on property taxes than income, corporate, and sales taxes. State taxes 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.

[21] Direct expenditures include all government expenditures other than intergovernmental transfers. The main direct-expenditure items include education, public welfare, hospitals, highways, police, correction, natural resources, parks and recreation, government administration, and utility expenditure.

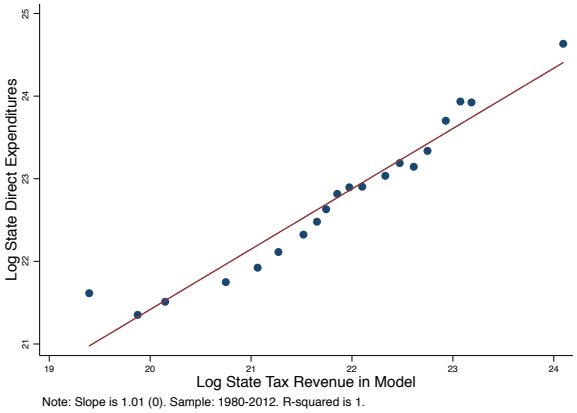
Figure 2: Comparing State Tax Revenue and Spending

(a) State Fixed Effects



Note: Slope is 1.05 (0). Sample: 1980-2012. R-squared is 1.

(b) Year Fixed Effects



Note: Slope is 1.01 (0). Sample: 1980-2012. R-squared is 1.

3 Quantitative Trade Model with State Taxes and Public Goods

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. We normalize $M = 1$ and $L = 1$, so that M_n and L_n are the fractions of firms and workers located in state n.

Each state n is characterized by 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. 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 of that state's amenity and of the productivity of firms that locate in that state. The federal government collects personal income taxes t_{fed}^y, payroll taxes t_{fed}^w, and corporate taxes t_{fed}^{corp}. Federal public spending is not valued by consumers or firms.[22]

[22] We could impose the alternative assumption that federal public spending shifts the utility of consumers independently from where they locate. In this case, our analysis would remain unchanged except that, in counterfactuals, there would be an additional aggregate welfare effect through the size of the federal budget.

3.1 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 σ,

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

where J_i denotes the set of varieties produced in state i and q_{ni}^j is the quantity of variety j from state i used 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 (equal to its price net of sales taxes) is

$$P_n = \left(\sum_i \int_{j \in J_i} \left(p_{ni}^j \right)^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}}. \tag{2}$$

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

$$q_i^j = z_i^j \left[\frac{1}{\gamma_i} \left(\frac{h^j}{\beta_i} \right)^{\beta_i} \left(\frac{l^j}{1-\beta_i} \right)^{1-\beta_i} \right]^{\gamma_i} \left(\frac{i^j}{1-\gamma_i} \right)^{1-\gamma_i}, \tag{3}$$

where γ_i is the value-added share in production of every firm in state i, and where $1-\beta_i$ 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 its relative price. Production functions are allowed to vary by state; this flexibility is needed to match the heterogeneity in shares of labor and intermediate inputs observed in the data.[23]

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

$$Q_n = C_n + I_n + G_n + G_n^{fed}. \tag{4}$$

3.2 Workers and Capital-Owners

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

[23] This heterogeneity in production function may be thought of as a way of modeling the 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 abstract from this margin in our analysis.

component is

$$v_n = u_n \left(\frac{G_n}{L_n^{\chi_W}} \right)^{\alpha_W} \left(\left(1 - T_n^L\right) \frac{w_n}{P_n} \right)^{1-\alpha_W}, \tag{5}$$

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

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

Equations (5) and (6) imply that workers have preferences over amenities and final goods. The amenities of state n have an endogenous part that depends on the amount of public spending and an exogenous part u_n. The endogenous part equals real government spending G_n normalized by $L_n^{\chi_W}$. The parameter χ_W captures rivalry in public goods and ranges from $\chi_W = 0$ (non-rival) to $\chi_W = 1$ (rival). The exogenous part captures both natural characteristics, like the weather, and the rate at which the government transforms real spending into services valued by consumers, i.e., the quality or the efficiency in the provision of government services. The quantity of final goods consumed by an individual equals after-tax wages, $((1 - t_{fed}^y)(1 - t_n^y) - t_{fed}^w)w_n$, normalized by the after-tax price, $(1 + t_n^c) P_n$.[24] As a result, real consumption equals the pre-tax wage, $\frac{w_n}{P_n}$, adjusted by income and sales taxes, $1 - T_n$. The parameter α_W captures the weight of state-provided amenities in preferences.

The idiosyncratic taste draw ϵ_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 that we have normalized the mass of workers to 1, the fraction of workers located in state n is

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

where

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

The term v is an harmonic average of the state-specific effects, v_n. 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 proportional to v; hence, we adopt it as our measure of worker welfare.[25]. In the counterfactuals, we also report the change in real consumption (of both mobile workers and immobile capital-owners) and real GDP; we present the corresponding expressions in Section 5.

A larger value of ε_W implies that the idiosyncratic taste draws are less dispersed across states;

[24] Note that state income taxes can be deducted from federal taxes. We abstract from the non-linearity of the federal income tax scheme in the benchmark analysis; empirically, we set the value of these taxes to the average effective federal rate paid by residents in that state and assume that state wage changes do not affect the effective federal income tax rate in each state. However, in section 5.4 we relax this assumption and allow for the federal rate to be a function of state wages. As the federal income tax schedule is defined on nominal wages, it may lead to spatial distortions, as analyzed by Albouy (2009).

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

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 that choose to locate there. From the definitions of v_n and L_n in (5) and (7), it follows that $\varepsilon_W (1-\alpha_W)$ is the partial elasticity of the fraction of workers who locate in state n with respect to after-tax real wages, $(1-T_n)\frac{w_n}{P_n}$, while $\varepsilon_W \alpha_W$ is the partial elasticity with respect to real government services per worker, $\frac{G_n}{L_n^{\chi_W}}$. We rely on these relationships to estimate $\{\varepsilon_W, \alpha_W\}$ in section (4.3).

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. Therefore, their income is $b_n(\Pi + R)$, where Π are national after-tax profits, R are the national returns to land and structures. We do not need to specify the number of capital owners located in each state n for our computations. We calibrate the ownership shares b_n to match the observed trade imbalances. Capital owners spend their income locally, and pay sales taxes on consumption and both federal and income taxes on their income.

3.3 Firms

A continuum of firms $j \in [0,1]$ decide in which state to locate and produce and how much to sell to every state. Each firm j produces a differentiated variety and is endowed with a vector of productivities $\left\{z_i^j\right\}_{i=1}^N$ across states. Firms are monopolistically competitive; when a firm j located in state i sets 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 in a given location, and then solve the location problem. We finally discuss some of the aggregation properties of our model, which are common with standard models of international trade such as Melitz (2003).

Profit Maximization given Firm Location If a firm j decides to locate in state i, its profits are

$$\pi_i\left(z_i^j\right) = \max_{\{q_{ni}\}}\left(1-\overline{t}_i^j\right)\left(\sum_{n=1}^N x_{ni}^j - \frac{c_i}{z_i^j}\sum_{n=1}^N \tau_{ni} q_{ni}^j\right), \tag{9}$$

where $\overline{t}_i^j$ is the corporate tax rate, $x_{ni}^j = P_n Q_n^{\frac{1}{\sigma}}(q_{ni}^j)^{1-\frac{1}{\sigma}}$ 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.[26]

All firms face corporate taxes apportioned through sales, payroll, and land and structures.[27] A

[26] Note that the definition of c_i incorporates that, unlike consumers, firms do not face the sales tax when purchasing the final good to be used as an intermediate. Note also that, because of iceberg trade costs, $\tau_{ni} q_{ni}^j$ units must be shipped from state i to n for q_{ni}^j varieties to arrive, where $\tau_{ni} > 1$, making $\sum_n \tau_{ni} q_{ni}^j = q_i^j$.

[27] This assumption implies that we treat all companies in the model 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. revenues. See our previous discussion in section 2.1. In Section 5, we perform a robustness check where corporate rates are adjusted by actual the share of C-corporations.

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 profit in corporate taxes apportioned through sales to state n . Firms located in i also pay t_i^l times pre-tax 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 is of firm j is:

$$\bar{t}_i^j = t_{fed}^{corp} + t_i^l + \sum_{n=1}^{N} t_n^x s_{ni}^j. \tag{10}$$

Due to the sales apportionment of corporate taxes, the decision of how much to sell to each state in 9 is not separable across states as in the standard CES maximization problem 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 base of the corporate tax are 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 its entire profits.

Despite this interaction in the sales decision, the firm problem retains convenient properties from the standard CES maximization problem which allows for aggregation; we describe these properties here and refer to Appendix (B.1) for derivations. Specifically, all firms set the same sales shares across destinations irrespective of their productivity, $s_{ni}^j = s_{ni}$ for all firms j located in i; from (10), 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 in state i is:

$$p_{ni}(z) = \tau_{ni} \frac{\sigma}{\sigma - \tilde{t}_{ni}} \frac{\sigma}{\sigma - 1} \frac{c_i}{z}, \tag{11}$$

where

$$\tilde{t}_{ni} \equiv \frac{t_n^x - \sum_{n'} t_{n'}^x s_{n'i}}{1 - \bar{t}_i}. \tag{12}$$

The term $\tilde{t}_{ni}$ is a pricing distortion created by heterogeneity in sales-apportioned corporate taxes. Under no dispersion in sales-apportioned corporate tax ($t_n^x = t^x$ for all n) we have that $\tilde{t}_{in} = 0$ for all i and n, in which case the pricing decision is the same as in the standard CES maximization problem. 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 corporate taxes apportioned through sales.

Firm Location Choice Firm-level productivity z_i^j can be decomposed into a term z_i^0 which is common to all firms that locate in i and a firm-state specific component ϵ_i^j: $z_i^j = z_i^0 \epsilon_i^j$. The common

component of productivity is:

$$z_i^0 = \left(\frac{G_i}{M_i^{\chi_F}}\right)^{\alpha_F} z_i^{1-\alpha_F}. \tag{13}$$

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 χ_F captures rivalry among firms in access to public goods. The exogenous part captures both natural characteristics that impact productivity, like natural-resource availability, and the rate at which the government transforms real spending into services valued by firms. Using 9, the profits of firm j when it locates in i can be expressed as the product of a common and an idiosyncratic component:

$$\pi_i\left(z_i^j\right) = \pi_i\left(z_i^0\right)\left(\epsilon_i^j\right)^{\sigma-1}. \tag{14}$$

The common component, $\pi_i\left(z_i^0\right)$, is defined as the profit of a firm with productivity equal to z_i^0 located in i.

Firm j decides to locate in state i if $i = \arg\max_{i'} \pi_{i'}(z_{i'}^j)$. The idiosyncratic component of productivity, ϵ_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 implies that firm-level profits, $\pi_i(z_i^j)$, are also Fréchet-distributed with shape parameter $\varepsilon_F/(\sigma-1) > 1$. 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

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

where

$$\bar{\pi} = \left(\sum_i \pi_i\left(z_i^0\right)^{\frac{\varepsilon_F}{\sigma-1}}\right)^{\frac{\sigma-1}{\varepsilon_F}}. \tag{16}$$

Equation (15) says that 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 other locations.[28] The distributional assumption on the idiosyncratic productivity draw implies that both the ex-ante profits of a firm before drawing $\left\{\epsilon_i^j\right\}_{i=1}^N$ and the average ex-post profits of firms located in any state are proportional $\bar{\pi}$.[29] A larger value of $\varepsilon_F/(\sigma-1)$ 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 optimally locate in that location.

[28] This structure has similar implications to standard monopolistic competition models with free entry, in the sense that in both types of models the number of firms by location is endogenous and proportional to sales. We discuss the contrast with models with free entry in more detail in Appendix B.3.

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

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 of each state i. This productivity level is endogenous and can be expressed as function of the number of firms that optimally choose to locate in each state i:[30]

$$\tilde{z}_i = z_i^0 M_i^{-\frac{1}{\varepsilon_F}}. \tag{17}$$

The productivity of the representative state-i firm is larger than the unconditional average of the distribution of productivity draws, $\tilde{z}_i/z_i^0 > 1$, 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.

Aggregation to the State Level State-i outcomes can be constructed as if there were M_i homogeneous firms, all with productivity $\tilde{z}_i$. Specifically, the share of aggregate expenditures in state n spent on goods produced in state i is

$$\lambda_{ni} = M_i \left(\frac{p_{ni}\left(\tilde{z}_i\right)}{P_n} \right)^{1-\sigma}, \tag{18}$$

where $p_{ni}\left(z\right)$ is the pricing function defined in (11). We can also construct the sales shares s_{ni}, which are necessary to compute the corporate tax rate $\bar{t}_i$ and the pricing distortion $\tilde{t}_{ni}$, using the identity $s_{ni} = \lambda_{ni} P_n Q_n / X_i$, where $P_n Q_n$ are aggregate expenditures on final goods in state n. By definition, aggregate sales in state i are:

$$X_i = \sum_n \lambda_{ni} P_n Q_n. \tag{19}$$

Because of Cobb-Douglas technologies and CES demand, it follows that aggregate payments to intermediate inputs, labor and fixed factors in state i are all constant fractions of X_i.[31] As a result, spatial interactions drive local effects: larger expenditures $P_n Q_n$ in state n act as a factor-demand shifter in state i through X_i depending on the intensity of the trade linkage λ_{ni}. Aggregate pre-tax profits $\tilde{\Pi}_i$ are also proportional to sales:

$$\tilde{\Pi}_i = \frac{X_i}{\sigma}, \tag{20}$$

implying aggregate profits equal to $\Pi_i = \left(1 - \bar{t}_n\right) X_i / \sigma$.

[30] By definition, $\tilde{z}_i = \left(\int_{j \in J_n} \left(z_i^j\right)^{\sigma-1} dj \right)^{\frac{1}{\sigma-1}}$. To reach (17), we use that the distributional assumption on the productivity draws implies average profits of $\pi\left(\tilde{z}_i\right) = \bar{\pi}$ in every state together with (15) and the relationship $\frac{\pi_i\left(z_i^0\right)}{\pi_n\left(\tilde{z}_i\right)} = \left(\frac{z_i^0}{\tilde{z}_i}\right)^{\sigma-1}$ implied by (14).

[31] See the expressions A.6 to A.8 in Appendix B.2.

3.4 State Government

State governments use their tax revenue R_n to finance their spending. Total government spending and revenue in state n is:

$$P_n G_n = R_n = R_n^{corp} + R_n^y + R_n^c, \tag{21}$$

where R_n^{corp}, R_n^c, and R_n^y , government revenue from corporate, sales, and income taxes respectively, are:

$$R_n^{corp} = t_n^x \sum_{n'} s_{nn'} \tilde{\Pi}_{n'} + t_n^l \tilde{\Pi}_n, \tag{22}$$

$$R_n^y = t_n^y \left(1 - t_{fed}^y\right) \left[w_n L_n + b_n \left(\Pi + R\right)\right], \tag{23}$$

$$R_n^c = t_n^c P_n C_n. \tag{24}$$

The base for corporate tax profits are the pre-tax profits from every state, defined in (20), adjusted by the proper apportionment weights. Equation (23) 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. The base for the sales tax in (24) is the total personal consumption expenditure of workers and capital owners, $P_n C_n$, defined in (A.11) in Appendix B.2.[32]

3.5 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 (2); ii) workers make consumption and location decisions optimally, as described in Section 3.2; iii) firms make production, sales, and location decisions optimally, as described in Section 3.3; iv) government budget constraints hold, as described in Section 3.4; v) goods markets clear in every location, i.e. (4) holds for all n; vi) the labor market clears in every state, i.e. labor supply (7) equals labor demand (A.7) for all n; vii) the land market clears in every location, i.e. (A.8) holds; and viii) the national labor market clears, i.e. $\sum_n L_n = 1$.

Adjusted Fundamentals As shown in Appendix B.4, we can reach a system that characterizes the general equilibrium solution for wages and employment in every state, $\{w_n, L_n\}_{n=1}^N$, and welfare, v, as function of the model's primitives. In this system, wages, employment and welfare are affected by state taxes $\left\{t_n^c, t_n^y, t_n^x, t_n^l\right\}_{n=1}^N$ only through their impact on the following "adjusted

[32] As we have mentioned, taxes are also collected by the federal government, and federal-government expenditures in state n, $P_n G_{n,fed}$, equal taxes levied by the federal government state n. Expression (A.14) in Appendix B.2 shows this expression explicitly.

fundamentals" in every state, $\left\{\tau_{in}^A, z_n^A, u_n^A\right\}_{n=1}^N$,

$$z_n^A = (1-\bar{t}_n)^{\frac{1}{\sigma-1}-\left(\frac{1}{\varepsilon_F}+\alpha_F\chi_F\right)}\left(\frac{P_nG_n}{GDP_n}\right)^{\alpha_F} * z_n^{1-\alpha_F}, \tag{25}$$

$$\tau_{in}^A = \frac{\sigma}{\sigma-\tilde{t}_{in}} * \tau_{in}, \tag{26}$$

$$u_n^A = (1-T_n)^{1-\alpha_W}\left(\frac{P_nG_n}{GDP_n}\right)^{\alpha_W} * u_n, \tag{27}$$

where $\frac{P_nG_n}{GDP_n}$ is state government spending, defined in (21), over state GDP. After some manipulations, we can express this share as

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

where $\frac{P_nQ_n}{X_n}$ is the share of state expenditures to sales (i.e., a measure of state trade deficit) shows in equation (A.19) in Appendix B.2.[33] In Section 4.4 we contrast the estimated model's prediction for this variable against the data.

The adjusted fundamentals are functions of the state fundamentals (productivity z_n, amenity u_n, and trade costs τ_{in}) , tax rates and government size. State taxes impact the adjusted fundamentals in state n through their effect on the price distortion $\left\{\tilde{t}_{in}\right\}_{i=1}^N$, the corporate tax rate $\bar{t}_n$, the keep-tax rate $1-T_n$, and government size relative to GDP.

Consider the effect of sales-apportioned corporate taxes, $\{t_n^x\}_{n=1}^N$. The taxes impact the adjusted trade costs in state n, τ_{in}^A, through the pricing distortion $\left\{\tilde{t}_{in}\right\}_{i=1}^N$. Because of this distortion, markups are higher to importing states with higher sales-apportioned corporate taxes t_i^x, and from states with higher average tax rates, $\bar{t}_n$. Hence, sales-apportioned corporate taxes are similar to trade costs: given government sizes and trade deficits, the equilibrium outcomes can be rationalized without sales-apportioned corporate taxes ($t_n^x = 0$ for all n) but with a different distribution of trade costs (equal to τ_{in}^A). To clarify the role of the remaining taxes, it is useful to focus on a case without pricing distortion ($t_n^x = t^x$ for all n) and without cross-ownership of assets across states.[34] In this case, the effective corporate tax is exogenous, $\bar{t}_n = t^x + t_n^l$, and government size relative to GDP in a state n, P_nG_n/GDP_n, becomes a function of state n taxes only. State taxes $\left\{t_n^c, t_n^y, t_n^l, t^x\right\}$ then affect the allocation exclusively through the adjusted productivities $\left\{z_n^A\right\}$ and the adjusted amenities $\left\{u_n^A\right\}$. Individual income and sales taxes are similar to amenities: given government sizes relative to GDP, the equilibrium outcomes can be rationalized with no individual income or sales taxes, but with a different distribution of amenities u_n (equal to the adjusted amenities u_n^A). In the same way, corporate taxes are similar to productivity: given government size relative to GDP, the equilibrium outcomes can be rationalized without corporate taxes, but with a different distribution of productivities (equal to z_n^A).

[33] To reach (28), first replace P_nC_n from (A.11), R_n^y from (23), and R_n^{corp} from (A.17) into the government budget constraint (A.14), and then normalize by GDP using (A.9).

[34] This corresponds to ownership rates $b_n = \left(\tilde{\Pi}_n + r_nH_n\right) / \left(\tilde{\Pi} + R\right)$.

Agglomeration Forces, Congestion Forces, and Uniqueness Our model features agglomeration forces through standard home market effects. Because of trade costs, workers (who consume final goods) and firms (who purchase intermediate inputs) have an incentive to locate near states with low price indexes and large markets; in turn, the price index decreases with the number of firms, and market size increases with the number of workers. It also features agglomeration through public-services: states with a larger number of firms and workers have higher tax revenue and spending; as long as $\chi_W < 1$ or $\chi_F < 1$, this means that larger market size leads to higher utility per worker (see (5)) or firm productivity (see (13)). At the same time, our model features congestion forces through the use of an immobile factor (land and structures) in production, leading to a higher cost of fixed factors when employment increases (as implied by (A.8) in Appendix (B.2)). It also features congestion through selection of heterogeneous firms, leading to lower average firm productivity when the number of firms increases (as implied by (17)).

Through the agglomeration forces, workers and firms tend to locate in the same state, whereas through the congestion forces, workers and firms tend to spread across different states. It is natural to ask whether the general equilibrium of our model is unique. Allen et al. (2014) establish conditions for existence and uniqueness of the general equilibrium 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.5 shows a uniqueness condition from Allen et al. (2014) applied to this context. The condition is satisfied by the parameter values estimated in Section 4, under which we compute the counterfactual results presented in Section 5.[35]

4 Data and Parametrization

This section describes our procedure to set values for the model parameters. Section 4.1 describes the data we use in this procedure. Section 4.2 describes the calibration of the technology parameters, state fundamentals, and ownership rates. These parameters are chosen so that the model exactly reproduces the distributions of employment, wages, labor and intermediate-inputs shares of income, bilateral sales, bilateral expenditure shares, and trade imbalances across states in a given year; we choose 2007 because this is the latest year in which all these data are available. In Section 4.3, we present the estimation of the labor and firm mobility elasticities and the weight of government spending in preferences and firm productivity. These parameters are estimated using a longitudinal dataset on the spatial distribution of workers and firms, taxes, and state government revenue from 1980-2010. Finally, in Section 4.4, we study cross-sectional predictions of the model for variables that are not targeted by the parametrization strategy described in sections 4.2 and 4.3.

[35] When computing the counterfactuals, we experiment with different starting values of our algorithm and find always the same results, suggesting that the system of equations has indeed a unique solution.

4.1 Data

For the calibration in Section 4.2, we need measures by state of employment L_n, wages w_n, total sales X_n, intermediate-input expenditures $P_n I_n$, and total expenditures $P_n Q_n$ for same given year. As detailed in Appendix F.2, these variables are drawn from the Economic Census of the United States. We also use a recently available dataset from the B.E.A. on Personal Consumption Expenditures to calculate a measure of consumption expenditures by state, $P_n C_n$. Finally, we use information on bilateral trade flows X_{ni} from the Commodity Flow Survey. All these variables correspond to the year 2007.

Since the model is cast in closed economy, we construct our measure of total sales in the model X_n by subtracting state exports to the rest of the world from the state total sales reported in the Census.[36] Intermediate-input expenditures $P_n I_n$ are constructed from the difference between state sales and GDP, and total expenditures $P_n Q_n$ are constructed by adding up personal consumption expenditures, intermediate-goods expenditures, and government expenditures. We also need bilateral sales shares s_{in} and expenditure shares λ_{in}. We define sales to the own state as the difference between total sales and trade flows to every other state, $X_{ii} = X_i - \sum_n X_{ni}$.[37] To calibrate the ownership rates we also need corporate tax rates, which are drawn from Suárez Serrato and Zidar (2014).

For the estimation described in 4.3, we need information for multiple states and years on number of workers and firms, hourly wage, total tax revenues, price indices, and tax rates. Because Economic Census data are available infrequently, we use data on the number of workers and establishments from County Business Patterns (CBP), which reports this information annually for the period 1977-2010. The number of workers and establishments reported in the CBP is similar to the census data in the years when both are available. We use the Current Population Survey to construct an hourly wage measure by state. We use regional price indexes 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 US Census, NBER TAXSIM, the Book of States, and Suárez Serrato and Zidar (2014), among other sources. State spending on public services $P_n G_n$ is set equal to tax revenue R_n, which is the sum of tax revenues in the model. The most recent year since which all the state tax rates that we consider are available in the data is 1978.[38] Therefore, for the estimation described in Section 4.3, we use data on all 50 U.S. states for the years 1978 to 2010.

4.2 Calibrated Parameters

Technologies We set the value-added share by state, γ_n, and the share of labor in value added, $1-\beta_n$, so that the intermediate-input and employment shares predicted by the model in equations

[36] 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.

[37] This definition is needed since data on sales from the Economic Census is for the entire economy, while trade data from the CFS are available for a subset of trade-related sectors. Specifically, the CFS includes the following industries: mining, manufacturing, wholesale trade, and select retail and services.

[38] Specifically, the data on sales taxes, personal income tax rates, and corporate taxes, are available in 1975-2012, 1977-2010, 1978-2012, respectively.

(20), (A.7) and (A.6) match their empirical counterparts.[39] On average across states, we get $\frac{1}{N}\sum_n 1-\gamma_n = 0.62$ and $\frac{1}{N}\sum_n 1-\beta_n = 0.68$. As a result, the outcomes of the parametrized model exactly match the distributions of intermediate-input and employment shares in income across states in 2007.

Fundamentals The general-equilibrium system of equations that characterizes the solution to the counterfactuals, described in Appendix B.6, is a function of the value of all fundamentals (endowments of land and structures H_n, productivities z_n, amenities u_n, and trade costs τ_{in}) for every state or pair of states. However, all these fundamentals only affect the outcomes from the counterfactuals through the composite A_{in} defined in (A.27) in Appendix B.4. In order to calibrate this composite, we match A_{in} to the function of expenditure shares, wages, and employment described in equation (A.25). We therefore do not need to separately identify the value of all fundamentals.[40] As a result, the outcomes of the parametrized model exactly match the distributions of bilateral expenditure shares, bilateral sales shares, wages, and employment across states in 2007.

Ownership Rates We set the ownership rates $\{b_n\}$ to match relative trade imbalances, defined as the ratio of expenditures to sales. Expression (A.21) in Appendix B.2 shows an expression that uniquely identifies b_n as a function of observables and technology parameters in state n, and the parameter σ. As a result, the outcomes of the parametrized model exactly match the distribution of trade imbalances across states in 2007.[41]

Other Parameters As shown in the next section, the firm- and labor mobility elasticities $\{\varepsilon_F, \varepsilon_W\}$ are not separately identified from the congestion parameters $\{\chi_W, \chi_F\}$. In the benchmark specification we set $\chi_W = 1$ and $\chi_F = 1$, corresponding to a case where government goods and services are rival, as in for example Wildasin (1991). We inspect how the counterfactual predictions change when we assign to χ_W and χ_F values between 0 and 1. The elasticity of substitution across varieties σ is set to 4, which corresponds to a central value for the demand elasticity across differentiated products from the international trade literature; see Head and Mayer (2013).

4.3 Estimated Parameters

Table 1 summarizes the values of our estimates of the remaining parameters. The labor supply elasticity, ε_W, and the share of public goods in preferences, α_W, are estimated using the labor-supply equation, as described in Section 4.3.1. The elasticity of firm mobility, ε_F, and the weight

[39] I.e.: $1-\gamma_n = \frac{\sigma}{\sigma-1}\frac{P_n I_n}{X_n}$ and $1-\beta_n = \frac{\sigma}{\sigma-1}\frac{w_n L_n}{\gamma_n X_n}$. To perform this calculation, we use the value of σ described below.

[40] This feature of our model is similar to the existing models of trade and economic geography discussed in the introduction to which our model is related. Dekle et al. (2008) show how to undertake counterfactuals with respect to trade costs without having to separately identify all the fundamentals.

[41] The ownership rates b_n that we obtain are positively correlated with the share of national dividend, interest, and rental income earned in state n in 2007. In particular, in the cross section of states in 2007, we estimate that $b_n = .14 + 1.36 SHARE_n$ where the standard errors for the intercept and slope are .018 and .28, respectively.

of government spending in productivity, α_F, are estimated using the firm-location equation, as described in Section 4.3.2 below. Both set of parameters are estimated using the longitudinal dataset on the spatial distribution of economic activity and government finances from 1980-2010 described in (4.1). Appendix section C.4 shows that our estimates for these parameters are in line with previous estimates which rely on different sources of variation, geography, and time dimension.[42]

Parameter	Notation	Value	Source
Labor supply elasticity	ε_W	1.49	Section 4.3.1
Share of public goods in preferences	α_W	0.17	
Firm mobility elasticity	ε_F	3.08	Section 4.3.2
Share of public goods in technology	α_F	0.04	

Table 1: Elasticities and Preference for Government Spending

4.3.1 Labor-Supply Elasticity and Share of Government Spending in Preferences

Combining the labor supply equation (7), the definition of the state effect (5), and the government budget constraint (21), we obtain the following expression for the share of labor located in state n at time t:

$$\ln(L_{nt}) = a_0 \ln(\tilde{w}_{nt}) + a_1 \ln\left(\tilde{R}_{nt}\right) + \psi_t^L + \xi_n^L + \nu_{nt}^L, \tag{29}$$

where $a_0 \equiv \varepsilon_W(1-\alpha_W)/(1+\chi_W\varepsilon_W\alpha_W)$ and $a_1 \equiv \varepsilon_W\alpha_W/(1+\chi_W\varepsilon_W\alpha_W)$ 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;[43] $\xi_n^L + \nu_{nt}^L \equiv \varepsilon_W/(1+\chi_W\varepsilon_W\alpha_W) * \ln(u_{nt})$ 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 in state n; and $\tilde{R}_{nt} = R_{nt}/P_{nt}$ is real government spending. Given identification of the reduced-form parameters a_0 and a_1, the preference for government spending is identified as $\alpha_W = a_1/(a_0+a_1)$. The parameters ε_W and χ_W are not separately identified; therefore, we present estimates for ε_W given values of $\chi_W \in \{0, 0.5, 1\}$.

Our model predicts that ordinary least squares (OLS) estimates of a_0 and a_1 are inconsistent due to the dependence of real wages and government spending in state n and year t on the unobserved amenities or government efficiency in the same state and year, which are accounted for in the term ν_{nt}^L.[44] Specifically, our model predicts amenities in a state to be negatively correlated with after-tax

[42] For γs and βs equal to the averages from the calibration, the resulting set of parameter estimates satisfies the sufficient conditions for uniqueness of the equilibrium shown in (A.33) and (A.34) in Appendix B.5. Changing one parameter at a time, we find that these sufficient conditions for uniqueness are violated if the elasticities of firm and labor mobility (ε_F and ε_W) or the importance of government spending for firms and workers (α_F and α_W) are sufficiently high, or if congestion in the provision of public goods (χ_W and χ_F) or if the elasticity of substitution σ are sufficiently low.

[43] We have normalized the total employment to 1. Time variation in aggregate labor supply leads to changes in v_t, hence this fixed effect captures changes in aggregate labor supply.

[44] The variable u_{nt} captures both changes in amenities and in the efficiency or quality of government spending in state n. That is, if we had an additional variable z_{nt}^G representing the efficiency or quality of government spending,

real wages and positively correlated with 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 the tax revenue and thus increases government spending. Our model thus predicts that the OLS estimate of a_0 are biased downwards, and the OLS estimate of a_1 are biased upwards.

Consequently, we estimate a_0 and a_1 using two different versions of a two-stage least squares (TSLS) estimator. In both versions, we account for the terms ψ_t^L and ξ_n^L using time and state dummies, respectively. In the first version, we instrument both the after-tax real wage and the real government spending in state n at period t using two vectors of tax rates: a vector of state-n taxes in period t, $\boldsymbol{Z}_{nt}^L \equiv (1 - T_{nt}, 1 - t_{nt}^{corp})$, and a vector of tax rates in states other than n at period t, $\boldsymbol{Z}_{nt}^{L*} \equiv (t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$. The components of the vector $\boldsymbol{Z}_{nt}^L$ are own taxes, including the worker keep-tax rates $1 - T_n$ defined in (6) (which account for state-n sales and income taxes) and the corporate keep-tax rates $1 - t_{nt}^{corp} \equiv 1 - \left(t_{nt}^x + t_{nt}^l\right)$. The components of vector $\boldsymbol{Z}_{nt}^{L*}$ are "external" taxes, defined as an inverse-distance to state n of sales, income, and sales-apportioned corporate tax rates from every state other than n:

$$t_{nt}^{*z} \equiv \sum_{i \neq n} \omega_{ni} t_{it}^z, \quad with \quad \omega_{ni} = \frac{\ln(dist_{ni})^{-1}}{\sum_{i' \neq n} \ln(dist_{ni'})^{-1}} \quad for \quad z = c, x, y. \tag{30}$$

Using standard asymptotics in panel data models, we assume that our panel data is fixed in the time dimension. In this case, the TSLS estimator that uses both $\boldsymbol{Z}_{nt}^L$ and $\boldsymbol{Z}_{nt}^{L*}$ as instruments for $\tilde{w}_{nt}$ and $\tilde{R}_{nt}$ assumes that ν_{nt}^L, which represents the amenity level and the quality or the efficiency of government spending in state n and period t, is mean independent of the functions of taxes included in either the vector $\boldsymbol{Z}_n^L$ or the vector $\boldsymbol{Z}_n^{L*}$in any time period, after controlling for year and state effects. Formally, $\mathbb{E}[\nu_{nt}^L | \boldsymbol{Z}_n^L, \boldsymbol{Z}_n^{L*}, \xi_n^L, \psi_t^L] = 0$, where $\boldsymbol{Z}_n^L = (\boldsymbol{Z}_{n1}^L, \ldots, \boldsymbol{Z}_{nt}^L, \ldots, \boldsymbol{Z}_{nT}^L)$ and analogously for $\boldsymbol{Z}_n^{L*}$.

An implication of this assumption is that income, sales and corporate tax rates in state n must affect state n employment shares only through their effect on real wages and the provision of public goods in that state. This assumption is not innocuous. If a state government tries to provide a given level of public goods, then an exogenous change in its efficiency would require a tax change. Similarly, changes in state amenities (e.g., droughts) may require state governments to change taxes (e.g., to pay for pipes to transfer water across the state). In either of these two cases, tax rates in state n contained in the vector $\boldsymbol{Z}_{nt}^L$ would react to changes in ν_{nt}^L and, therefore, the vector of instruments $\boldsymbol{Z}_{nt}^L$ would not be valid. In order to alleviate these concerns, we also present estimates from a TSLS estimator that exclusively relies on the vector of external taxes $\boldsymbol{Z}_{nt}^{L*}$ as instruments for $\tilde{w}_{nt}$ and $\tilde{R}_{nt}$. Under the assumption that changes in taxes in any state n will not react to idiosyncratic shocks to amenities or government efficiency in states other than n, excluding the vector $\boldsymbol{Z}_{nt}^L$ from the vector of instruments eliminates any possible bias in the TSLS estimates. Formally, the TSLS estimator that exclusively uses $\boldsymbol{Z}_{nt}^{L*}$ as instruments for $\tilde{w}_{nt}$ and $\tilde{R}_{nt}$ assumes

it would enter multiplicatively with u_{nt}.

that $\mathbb{E}[\nu_{nt}^L | \boldsymbol{Z}_n^{L*}, \xi_n^L, \psi_t^L] = 0$.

Appendix C.1 includes Table A.3 with the first-stage estimates and a discussion of the first-stage results. The estimation results appear in Table 2. Column (1) shows the OLS estimates, which indicate that higher levels of real government spending and after-tax real wages are correlated with higher supply of labor. Columns (2)-(3) show the TSLS estimates; column (2) uses own-state and external taxes as instruments, while column (3) uses only functions of external taxes as instruments. Compared to the TSLS estimates, the OLS estimates imply a lower elasticity of labor supply with respect to after-tax real wages and a larger one with respect to real government spending. This difference in estimates is consistent with amenities in any given state n being negatively correlated with after-tax real wages in n and positively correlated with real government spending in n. These two correlations have the sign predicted by our model, as described earlier in this section.

As indicated above, the orthogonality restriction needed for consistency of the TSLS is weaker in the case in which we exclusively rely on taxes in states other than n as instruments for the after-tax real wage and real government spending in state n . Therefore, we choose the specification in column (3) of Table 2 as our preferred specification. It implies a labor supply elasticity ε_W of roughly 1.5 and, given a value $\chi_W = 1$, a preference for government spending of 0.17. These results line up well with the existing literature which uses different shocks and settings (see appendix section C.4 for details).

Table 2: TSLS Estimates of Local Labor Supply Parameters

	(1) OLS	(2) All IVs	(3) External IVs
$\ln(\tilde{w}_{nt})$	0.4***	1.0***	1.0***
	(0.1)	(0.2)	(0.3)
$\ln \tilde{R}_{nt}$	0.4***	0.3***	0.2
	(0.0)	(0.1)	(0.1)
Structural Parameters			
ε_W for $\chi_W = 0$	.79***	1.31***	1.24***
	(.07)	(.24)	(.33)
ε_W for $\chi_W = .5$	1.07***	1.5***	1.36***
	(.08)	(.27)	(.38)
ε_W for $\chi_W = 1$	1.66***	1.76***	1.49***
	(.13)	(.35)	(.45)
α_W	.53***	.26***	.17*
	(.04)	(.07)	(.09)

NOTES: This table shows the 2SLS estimates for labor supply. The dependent variable in each column is log state employment $\log L_{nt}$. The data are at the state year level. Each column has 712 observations due to incomplete coverage of price data. 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 BLS that is available for a subset of states which collectively amount to roughly 80 percent of total US population. Every specification includes state and year fixed effects. Robust standard errors clustered by state are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

4.3.2 Firm-Mobility Elasticity and Share of Government Spending in Productivity

Combining the firm-location equation (15) with the definition of profits in (16), the pricing equation (11), and the definition of productivity in (13), we obtain

$$\ln M_{nt} = b_0 \ln\left(\left(1-\bar{t}_n\right) MP_{nt}\right) + b_1 \ln(\tilde{R}_{nt}) + b_2 \ln c_{nt} + \psi_t^M + \xi_n^M + \nu_{nt}^M, \tag{31}$$

where $b_0 \equiv \left(\varepsilon_F/\left(\sigma-1\right)\right)/\left(1+\chi_F\alpha_F\left(\sigma-1\right)\right)$, $b_1 \equiv \varepsilon_F\alpha_F/\left(1+\chi_F\alpha_F\left(\sigma-1\right)\right)$, and $b_2 \equiv -\alpha_F b_1$; ψ_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, $\ln(z_{nt})$.[45] The term MP_{nt} is the market potential of state n in year t,

$$MP_{nt} = \sum_{n'} E_{n't}\left(\frac{\tau_{n'nt}}{P_{n't}}\frac{\sigma}{\sigma-\tilde{t}_{n'nt}}\frac{\sigma}{\sigma-1}\right)^{1-\sigma}, \tag{32}$$

where $E_{n't} \equiv P_{n't}Q_{n't}$ are aggregate expenditures in state n' and unit costs are given by $c_{nt} = (w_{nt}^{1-\beta_n} r_{nt}^{\beta_n})^{\gamma_n} P_{nt}^{1-\gamma_n}$. Details on how we construct measures of all the covariates entering the right-hand side of equation (32) are contained in Appendix C.2.

Our model predicts that estimates of $\{\varepsilon_F, \alpha_F\}$ in (31) resulting from a GMM estimator that relies on the right-hand side variables in equation (31) as instruments are biased due to the dependence of after-tax market potential, government spending, and unit costs on unobserved productivity, as captured by the component ν_{nt}^M. Therefore, we implement instead a GMM estimator that uses as instruments a vector of state and year effects, tax rates in both state n and in other states, and a shifter for market potential. Specifically, we use own-state corporate keep-tax rates $\boldsymbol{Z}_{nt}^M \equiv 1 - t_{nt}^{corp} - t_{fed,t}^{corp}$, a vector $\boldsymbol{Z}_{nt}^{M*} \equiv (t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$ of external taxes already defined (30), and an exogenous shifter MP_{nt}^* of the market potential term defined in equation (A.45). The exogenous shifter of market potential has a similar structure to market potential MP_{nt} in (32), but differs from it in that we substitute the components E_{nt}, P_{nt}, and $\tilde{t}_{n'nt}$ that might potentially be correlated with ν_{nt}^M with functions of exogenous covariates that we respectively denote as E_{nt}^*, P_{nt}^*, and $\tilde{t}_{n'nt}^*$. Appendix C.2 presents the precise definitions of MP_{nt}^*, E_{nt}^*, P_{nt}^*, and $\tilde{t}_{n'nt}^*$.

Using standard asymptotics in panel data models, we assume that our panel data is fixed in the time dimension. The GMM estimator that uses $\boldsymbol{Z}_{nt}^M$, $\boldsymbol{Z}_{nt}^{M*}$, and MP_{nt}^* as instruments assumes that ν_{nt}^M, which represents the productivity level and the quality or the efficiency of government spending in state n and period t, is mean independent of the functions of taxes included in $\boldsymbol{Z}_{nt}^M$, $\boldsymbol{Z}_{nt}^{M*}$, and MP_{nt}^* in any time period, after controlling for year and state effects. Formally, $\mathbb{E}[\nu_{nt}^M | \boldsymbol{Z}_n^M, \boldsymbol{Z}_n^{M*}, MP_n^*, \xi_n^M, \psi_t^M] = 0$, where $\boldsymbol{Z}_n^M = (\boldsymbol{Z}_{n1}^M, \ldots, \boldsymbol{Z}_{nt}^M, \ldots, \boldsymbol{Z}_{nT}^M)$ and analogously for $\boldsymbol{Z}_n^{M*}$and MP_n^*. An implication of this assumption is that corporate tax rates in state n must affect that state's number of establishments only through their effect on the real government spending, unit production costs, and market potential of that state. The orthogonality conditions necessary for consistency of our GMM estimator are weaker when we only rely on state fixed effects, year

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

fixed effects, and the vectors $\boldsymbol{Z}_{nt}^{M*}$ and MP_{nt}^{*} to construct moments. In this case, the resulting GMM estimates are consistent even if corporate taxes in state n react to changes in the unobserved productivity of state n, as captured in the composite ν_{nt}^{M}.

The inclusion of the variable MP_{nt}^{*} in the vector of instruments employed to compute our GMM estimator implies that additional orthogonality restrictions are needed for consistency of our estimator. The additional assumptions depend on the exact set of variables used to construct MP_{nt}^{*} in equation (A.45); i.e, they depend on the exact definition of E_{nt}^{*}, P_{nt}^{*}, and $\tilde{t}_{n'nt}^{*}$. As described in AppendixC.2, we use functions of lagged state-n GDP to construct E_{nt}^{*}, functions of state-n sales taxes to construct P_{nt}^{*}, and functions of bilateral distance and tax differences to construct $\tilde{t}_{n'nt}^{*}$. In order to test the robustness of our results, we compute estimates that rely on alternative definitions of MP_{n}^{*}. For more details and results, see Appendix C.2 and Table A.5.

Table 3: GMM Estimates of Firm Mobility Parameters

	A. All IVs		B. External IVs	
	Fix $\sigma = 4$	Fix $\sigma = 5$	Fix $\sigma = 4$	Fix $\sigma = 5$
	(1)	(2)	(3)	(4)
$\chi_F = 0$				
ε_F	2.4***	3.04***	2.75***	3.49***
	(.4)	(.56)	(.46)	(.66)
α_F	.1	.08	.04	.03
	(.09)	(.08)	(.09)	(.08)
$\chi_F = 0.5$				
ε_F	2.77***	3.5***	2.91***	3.68***
	(.54)	(.81)	(.58)	(.87)
α_F	.1	.08	.04	.03
	(.09)	(.08)	(.09)	(.08)
$\chi_F = 1$				
ε_F	3.13***	3.96***	3.08***	3.87***
	(.82)	(1.25)	(.9)	(1.3)
α_F	.1	.08	.04	.03
	(.09)	(.08)	(.09)	(.08)

NOTES: This table shows the GMM estimates for firm mobility parameters. The dependent variable is log state establishments $\ln M_{nt}$. The data are at the state-year level. Each column has 661 observations due to incomplete coverage of price and other data. 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 US population. After-tax market potential is based on s_{int}^{dist} and the instrument for market potential is MP_{nt}^{*}, which excludes own state components and is described in more detail in the text. Every specification includes state and year fixed effects. Robust standard errors clustered by state are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

Table 3 presents the GMM estimates. Columns (1) and (2) show the results using the vector of instruments $(Z_{nt}^{M}, Z_{nt}^{M*}, MP_{nt}^{*})$, and columns (3) and (4) show the results using only the vector of

external instruments $(Z_{nt}^{M*}, MP_{nt}^{*})$. The estimates that rely on the later vector of instruments are consistent even in the case in which states react to productivity shocks by changing their corporate tax rate; therefore, we choose the specification in column (3) as our preferred specification. It yields estimates $\varepsilon_F = 3.08$ (1.04) and $\alpha_F = 0.04$ (0.09) corresponding to the pair $(\sigma, \chi_F) = (4, 1)$. These estimates are broadly consistent with estimates from different settings (see appendix section C.4 for details).

4.4 Over-Identification Checks

We verify the implications of the estimated model for moments not targeted by the parametrization. First, Panels (a) and (b) of Figure A.2 in Appendix C.3 compare the model implications for the share of state n in national GDP and in the total number of establishments against the data in 2007. Both line up almost perfectly, which reflects that, in the data, both state GDP and number of establishments across states are roughly proportional to sales, as our model predicts.[46]

Second, we verify the implications for the share of government revenue in state GDP (see equation (28)). Having a sense of whether the model implies a reasonable government share of GDP is important because changes in this variable as a result of changes in taxes are a potentially important force determining welfare. Panel (c) of Figure A.2 compares the model-implied share of government revenue in GDP with its empirical counterpart; we see a clear positive correlation between both, although the model tends to predict somewhat larger shares of government revenue in GDP than in the data.

Third, panels (d) to (f) of Figure A.2 contrast the model-implied share in tax revenue for each type of tax against the the actual shares observed in the data.[47] 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 corporate tax rates for the share of C-corporations.

[46] From (A.9) in Appendix B.2, the share of state n in national GDP in the model is $\frac{GDP_n}{GDP} = \frac{\left(\frac{\gamma_n(\sigma-1)+1}{\sigma}\right)X_n}{\sum_{n'}\left(\frac{\gamma_{n'}(\sigma-1)+1}{\sigma}\right)X_{n'}}$, and from (A.22), the share of establishments of state n is proportional that state's share of after-tax profits: $M_n = \frac{\Pi_n}{\Pi} = \frac{(1-\bar{t}_n)\frac{X_n}{\sigma}}{\sum_{n'}(1-\bar{t}_{n'})\frac{X_{n'}}{\sigma}}$.

[47] The revenue shares are constructed in the data using the same variables as in the model, e.g., panel (d) corresponding to the sales tax shows $\frac{R_n^c}{R_n} = \frac{R_n^c}{T_n^c + T_n^y + R_n^{corp}}$ in the model and in the data.

5 Measuring the Spatial Misallocation from State Taxes

We move to studying the impacts of imposing counterfactual distribution of state taxes. In this section we measure the aggregate impact of eliminating dispersion in tax rates across states. We replace the distribution of state taxes in 2007 with counterfactual distributions which feature no dispersion across states in some or all taxes, keeping every other parameter and federal taxes constant. Tables A.2 and A.1 show the 2007 state and federal tax rates used as baseline in the counterfactuals. Appendix B.6 shows the system of equations used to compute the counterfactual changes in endogenous variables. Before implementing these counterfactuals, a few considerations are in order.

Aggregate Welfare Measures We compute changes in two aggregate-welfare measures. First, we compute the change in welfare for the representative U.S. worker. Combining (7) and (8), worker welfare in the counterfactual scenario relative to its initial value is

$$\widehat{v} = \left(\sum_n L_{n,2007} \widehat{v}_n^{\varepsilon_W} \right)^{\frac{1}{\varepsilon_W}}, \tag{33}$$

where, from (5), $\widehat{v}_n$ depends on the change in after-tax real wages and real government spending in state n .[48] This expression shows that the change in welfare is a employment-weighted average of the changes in each state's appeal, as captured by the v_n's. This measure excludes the gains or losses accruing to firms and fixed factors. Therefore, as a second aggregate measure, we also consider the change in the aggregate real income of all factors. Aggregate real income is defined as the aggregation of real state GDP's: $GDP^{real} = \sum_n GDP_n/P_n$. Equation (A.10) in Appendix B.2 shows the expression for real GDP in the counterfactual relative to the initial scenario.

Impact of Tax Dispersion on Real Income and Welfare In specific parametrizations of our model, dispersion in tax rates across states can be shown to reduce real income and welfare. This is the case, for example, if there are no trade costs, no trade imbalances, government spending does not change with taxes, workers are perfectly mobile, the number of firms in each state is exogenously fixed, and there is no dispersion in amenities.[49] However, more generally, it is theoretically unclear whether eliminating tax dispersion improves welfare and real income. First, keeping government spending constant, unobserved amenities imply that real income is not maximized under homogeneous taxes. Second, as we have already mentioned, our model features agglomeration forces through home-market effects, whereby the returns to locating in a state are an increasing function of the number of workers and firms located in close-by states. Additionally, when government spending is allowed to change with taxes, the number of workers located in each state impacts the

[48] Specifically, $\widehat{v}_n = \left(\frac{1-T_n'}{1-T_{n,2007}} \frac{\hat{w}_n}{\hat{P}_n} \right)^{1-\alpha_W} \left(\frac{\widehat{G}_n}{\widehat{L}_n^{\chi_W}} \right)^{\alpha_W}$.

[49] In that case, the production side of our model collapses to the structure in Hsieh and Klenow (2007), with dispersion in tax rates across states in our model playing a similar role to dispersion in wedges across firms in theirs.

provision of public services in the own state and in other states through each state's government budget constraint. Because of these spatial externalities, the market allocation is not generically efficient and, therefore, distortions that make the equilibrium different from the market allocation are not generally welfare and real-income reducing. As a result, our model does not impose an answer for whether eliminating tax dispersion leads to welfare gains.

Definition of Spatial Misallocation Taxes impact aggregate outcomes through two channels: the allocation of resources across regions, and the allocation of spending between the government and the private sectors. Because our focus is on the first channel, we engineer an elimination of tax dispersion such that the second channel is not present. Specifically, we define the spatial misallocation caused by the state tax distribution as the welfare and real-income gains (if they exist) that would result from eliminating the observed dispersion in tax rates across states in a way that keeps government size constant. We use two measures of state government size. We undertake a revenue-neutral counterfactual by bringing each tax to a percentile of its distribution such that the aggregate tax revenue collectively raised by all states is the same as in the initial scenario; i.e., in the counterfactual, $\sum_{n=1}^{N} R'_n = \sum_{n=1}^{N} P_n G_n$, where R'_n is the tax revenue of state n in the counterfactual scenario. We also undertake a spending-neutral counterfactual by bringing each tax to a percentile of its distribution such that the aggregate tax revenue collectively raised by all states allows each state to keep government spending constant at its initial level though a system of cross-state transfers; i.e., in the counterfactual, $\sum_{n=1}^{N} R'_n = \sum_{n=1}^{N} P'_n G_n$, and $G'_n = G_n$ for all n. In both counterfactuals, dispersion tax rates across states is eliminated by bringing taxes to some percentile of their initial distribution; in the revenue-neutral counterfactual, there is a redistribution of real government spending from initially high-tax states to initially low-tax states, while in the spending-neutral counterfactual real government spending is kept constant in all states.

5.1 Benchmark

Table 4 presents the results for the spatial-misallocation counterfactual using the benchmark parametrization and definitions of tax rates. The first row shows the results for the case in which we eliminate the dispersion in all taxes simultaneously; the remaining rows show the results for the elimination of the dispersion in one type of tax at a time. The columns labeled "S-neutral" show the results from the spending-neutral counterfactual described above, and the columns labeled "R-neutral" show the results from the revenue-neutral counterfactual described above.[50] We note that the direct welfare effect of these tax changes, defined as their impact on worker welfare keeping prices, government spending, and employment constant at their initial values, is negligible: because some tax rates increase and others decrease, the real consumption does not change at the initial

[50] When dispersion in all taxes is eliminated, the revenue-neutral counterfactuals is implemented if each tax rate is brought to the 43th percentile of their respective distributions. Eliminating dispersion only in income, sales, or corporate taxes is revenue-neutral when the corresponding tax rate is brought to the 28th, 53th, or 54th percentile of its distribution across states, respectively. These percentiles also implement the spending-neutral counterfactual.

prices.[51]

Keeping government spending constant in every state, the elimination of dispersion in all taxes leads to a welfare gain of 0.12%, pointing to the existence of distortionary effects from heterogeneity in taxes. The welfares gains are 0.69% in the revenue-neutral counterfactual, with similar gains in terms of real GDP.[52] We also compute changes in real consumption of workers and capital-owners; in the revenue-neutral counterfactual, when dispersion in all taxes is eliminated the real consumption of workers increases by 0.3% and consumption of capital owners increases by 0.4%.[53] We recall that these gains correspond to revenue- or spending- neutral changes in taxes whose aggregate tax revenue only adds up to 4% of GDP. Therefore, the results point to considerably distortionary effects from tax dispersion relative to the initial levels of tax revenue in GDP.

Table 4: Removing Tax Dispersion: Benchmark

Counterfactual	Welfare		Real GDP	
	S-neutral	R-neutral	S-neutral	R-neutral
All state taxes	0.12%	0.69%	0.11%	0.65%
Income Taxes	0.13%	0.49%	0.02%	0.29%
Sales Taxes	0.01%	-0.08%	0.00%	-0.06%
Corporate Taxes	0.08%	0.55%	0.09%	0.51%

Adjusted Fundamentals Figure A.3 shows the distributions of the endogenous components of the adjusted productivities z_n^A amenities u_n^A, and trade costs τ_{ni}^A (see (25)-(26)) for the estimated model and when tax dispersion is removed. Eliminating tax dispersion strongly reduces dispersion in the adjusted productivity and eliminates dispersion in adjusted trade costs. It also leads to a leftward shift in the adjusted amenities.[54] Since we expect reductions in adjusted amenities to lead to lower welfare, the welfare and GDP gains from eliminating tax dispersion must be associated with the reductions in dispersion in the adjusted fundamentals and not with changes in the levels of their distributions.

Role of Trade Frictions To explore the implications of trade costs, we re-compute the revenue-neutral elimination of dispersion in all taxes starting from a different parametrization that does,

[51] We construct the direct welfare effect by evaluating (33) at the state-specific effects $\widehat{v}_n^{direct} = \left(\left(1-T_n'\right)/\left(1-T_{n,2007}\right)\right)^{1-\alpha_W}$ instead of the full $\widehat{v}_n$ effects defined in footnote 48.

[52] We also undertake an alternative counterfactual where, for each type of tax, we replace the tax rate in every state with its average across states. In this case, the welfare and real-income gains are 0.79% and 0.60%, respectively. We note that, while this counterfactual happens to be nearly revenue-neutral, the direct effect from this tax change keeping prices, government spending, and employment constant at their initial values is 0.24%; i.e., while some tax rates increase and others decrease, the change in the distribution is such that consumers end up paying lower taxes at the initial prices, leading to higher welfare.

[53] (A.12) and (A.13) in Appendix B.2 show the expressions used to compute the change in aggregate real consumption.

[54] For the case of the trade-cost adjustment, the counterfactual distribution is degenerate at 1. Eliminating tax dispersion does not eliminate dispersion in the adjustments to productivity and amenities because government spending over GDP, $P_n G_n / GDP_n$, is part of these adjustment but varies with the technology parameters of each state – see equation (28).

instead of matching the actual distribution of bilateral spending and sales shares across states as in the benchmark parametrization (see Section 4.2), matches counterfactual symmetric spending and sales shares.[55] In the absence of corporate taxes, these symmetric shares would be the equilibrium outcomes if there were no trade costs. Hence, this parametrization explores how our counterfactual results would differ in an environment in which trade costs are smaller. We find the welfare gain from the revenue-neutral elimination of tax dispersion to be larger (1.01%) in this case, pointing to a complementarity between reducing tax dispersion and eliminating barriers to trade.

5.2 Heterogeneous Preferences for Government Spending Across States

The benchmark model assumes that the preference for government spending α_W is the same across states. We consider how allowing for heterogeneity across states in workers' preferences for government services affects our results. This assumption can be interpreted through a complementarity of state-specific features and government services. For instance, spending in state parks will have a higher value in states that are rich in natural amenities.

We use two measures of heterogeneous preferences. First, we explore the possibility that differences in the average political ideology of the residents in a state have predictive power for the differences across state in the preference for government spending. 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-level elections. We estimate estimate the parameters ε_W, α_0 and α_1 following a similar procedure to Section 4.3.1 and describe this procedure and the results in Appendix D.2.[56] This measure yields estimates of $\alpha_{W,n}$ between 0.161 and 0.175.

We construct a second measure of heterogeneous preferences that uses the ratio of government spending to GDP to proxy for $\alpha_{W,n}$, as in Michaillat and Saez (2015); i.e. $\alpha_{W,n}^{R/GDP} = R_n/GDP_n$. This approach takes the stand that there might be multiple reasons why workers in different states might have different preferences for public goods (e.g., differences in skill level, differences in state characteristics that make every worker prefer a larger provision of public goods in one state than in another) and that most of the reasons might be unobservable to researchers but that, no matter what these reasons are, they are reflected in the observed ratio of government spending to GDP. To isolate the effect of dispersion in α's, we rescale the distribution of $\alpha_{W,n}^{R/GDP}$ so that the mean of its distribution coincides with the benchmark value of 0.17. This measure yields estimates of $\alpha_{W,n}$ between 0.147 and 0.218.

Table 5 reports the results from the spending-neutral and revenue-neutral counterfactuals that bring all taxes to the same percentile under each of these alternatives measures, and compares them with the benchmark. The first measure of heterogeneous $\alpha_{W,n}$ produces similar welfare and real-income effects as our benchmark. For the second measure, we observe that allowing for

[55] I.e., we use the artificial spending shares $\lambda_{ni} = \frac{X_i}{\sum_{i'} X_{i'}}$ for all n and sales shares $s_{ni} = \frac{P_n Q_n}{\sum_{n'} P_{n'} Q_{n'}}$ for all i.

[56] We find $\hat{\alpha}_0 = .17$ (0.07) and $\hat{\alpha_1} = -.003$ (0.025), which implies that states with higher Republican party vote have smaller preference for government spending. However, the estimate implies that the political index POL_n has small predictive power to explain heterogeneity in preferences for public goods across states.

heterogeneity across states moderately reduces the revenue-neutral welfare effects (to 0.49% from the 0.69% benchmark), but has not impact on the predictions for real-income or spending-neutral effects of tax dispersion.

Table 5: Removing Tax Dispersion Under Heterogeneous Preferences Across States

Counterfactual	Welfare		Real GDP	
	S-neutral	R-neutral	S-neutral	R-neutral
Benchmark	0.12%	0.69%	0.11%	0.65%
Political Heterogeneity	0.12%	0.67%	0.13%	0.65%
Revenue/GDP	0.11%	0.49%	0.11%	0.65%

5.3 Lower Weights of Government Spending in Preferences and Productivity

We explore the role of the weight of public spending in preferences and productivity in shaping the results. Table 6 reports the results for α_W and α_F between the benchmark estimates and zero. Halving the values of both parameters also halves the real-income and welfare effects in the revenue-neutral counterfactual, but does not affect the predictions from the spending-neutral counterfactual. The table also includes the case with zero weight of government spending in preferences and productivity. This is an extreme parametrization since, as we have argued in Appendix section C.4, the existing evidence points towards the existence of some positive effects of government spending on preferences or productivity. Still, we observe that spatial misallocation continues to be present under this extreme parametrization, and the welfare effects are of the same magnitude as in benchmark for the spending-neutral counterfactual.

Table 6: Removing Tax Dispersion under Lower Preferences for Government Spending

Counterfactual	Welfare		Real GDP	
	S-neutral	R-neutral	S-neutral	R-neutral
Benchmark	0.12%	0.69%	0.11%	0.65%
Lower α's by 25%	0.14%	0.49%	0.11%	0.47%
Lower α's by 50%	0.15%	0.34%	0.11%	0.32%
Lower α's by 75%	0.17%	0.24%	0.11%	0.20%
$\alpha_W = \alpha_F = 0$	0.19%	0.19%	0.11%	0.11%

5.4 Progressive Income Taxes

Our benchmark analysis uses a flat state income tax, but in practice most states have a progressive income tax. We explore how our counterfactuals results vary if we account for the progressivity of income taxes. We implement three changes in the definition of taxes in our benchmark: we take into account of 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 for the period 1980-2010 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 groups and average tax rates. We use OLS to estimate the parameters of the linear projection $t^{y}_{n2007}(y) = a_n + b_n y + \varepsilon_n$ and, using the estimates $\left\{\hat{a}_n, \hat{b}_n\right\}_n$, we construct the income tax rate that a worker of state n earning wage w_n must pay in our model as $t^{y,prog}_{n}(w_n) = \hat{a}_n + \hat{b}_n w_n$. We follow the same procedure using information on federal income tax rates, and construct a federal income tax rate in state n in our model as $t^{y,prog}_{fed}(w_n) = \hat{a}_{fed} + \hat{b}_{fed} w_n$.[57] The introduction of these progressive tax schedules in our model generalize our benchmark results by allowing state income tax rates to change as a result of changes in state nominal wages. 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 average income tax rate that the progressive tax schedule in state n imposes (i.e., the income tax rate for the highest income bracket).[58]

Table 7 reports the results. The first line shows the outcome eliminating of tax dispersion when the only departure from the benchmark is that federal income taxes are allowed to be progressive, the second line allows for progressivity in state income taxes, and the third line does so in the context of progressive federal and state income taxes.[59] The results show that accounting for tax progressivity increases the welfare gains from both spending- and revenue-neutral tax harmonization.[60] The spending-neutral effects on real GDP do not change with the introduction of income tax progressivity.

Table 7: Removing Tax Dispersion under Progressive Income Taxes

Counterfactual	Welfare		Real GDP	
	S-neutral	R-neutral	S-neutral	R-neutral
Benchmark	0.12%	0.69%	0.11%	0.65%
Federal Progressive Only	0.14%	1.62%	0.11%	1.24%
State Progressive Only	0.40%	1.27%	0.11%	0.84%
State and Federal Progressive	0.45%	1.58%	0.11%	1.01%

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

[58] 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%.

[59] Under state tax progressivity, we implement the revenue- and spending- neutral counterfactuals by eliminating dispersion in the intercepts and slopes of each state schedule, $\left\{\hat{a}_n, \hat{b}_n\right\}_{n=1}^{N}$, as well as the remaining tax rates (sales and corporate).

[60] In the revenue-neutral case,latter case, the bulk of the increase in spatial misallocation lies in the introduction of progressive federal income taxes. This is consistent with results in Albouy (2009), who studied misallocation across U.S. cities due to federal income taxes.

5.5 Alternative Definitions of Tax Rates

TableA.9 in Appendix D.4 reports the results of the revenue- and spending- neutral elimination in dispersion in all taxes in the benchmark case and under 3 alternative ways of defining tax rates:

Corporate Taxes Adjusted for Subsidies Some states grant subsidies to firms through reductions in their corporate tax liabilities. These subsidies effectively modify the effective corporate tax rate that firms face. In order 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. As in Ossa (2015), we use data from the New York Times subsidy database. Collectively, state subsidies granted to firms amounted to $16 billion in 2012, which is substantial relative to the $40 billion in corporate tax revenue in 2012. However, we find that this adjustment reduces spatial misallocation very slightly.

Corporate Taxes Adjusted by share of C-Corporations In our benchmark model, all firms pay state corporate taxes on their profits and their owners pay income taxes on the remaining after-tax profits, corresponding to the tax treatment of business defined as C-corporations. Pass-through businesses (S-corporations, partnerships and sole proprietorships) do not pay corporate taxes, and only personal income taxes are paid when the profits originated by their activity is distributed. To account for pass-through businesses, we scale down the statutory corporate tax rate used in our benchmark analysis and obtain a new rate by multiplying the statutory corporate tax by the share of employment in C-corporations in each state in 2010 relative to the total employment in that state.[61] This adjustment reduces the welfare and real-income effects of misallocation due to smaller effective corporate rates.

Adding Local Taxes In our benchmark analysis we include only the main state taxes. However, the spatial distribution of economic activity is potentially affected not only by state taxes but also by taxes that are determined at a sub-state level. To account for local taxes, we modify our benchmark analysis in two dimensions: we introduce property taxes, which tax the value of the fixed factor of production used by firms, H_n, and we scale up the income, sales and corporate tax rates of a given state n to incorporate information on the local rates for each of these three types of taxes.[62] We find considerably larger welfare and real-GDP gains from revenue-neutral tax harmonization

[61] Data on the share of employment in C-corporations by state is obtained from the County Business Patterns.

[62] For property taxes, we use the 1970-2000 U.S. Censuses as well as the 2009 American Community Survey to obtain an estimate of the average property tax liability at the state level. In particular, we use self-reported measures of property taxes, which include both state and local contributions, as well as self-reported home values and use the ratio of average property tax liabilities to home values as our estimated property tax rate. For the income, sales and corporate tax rates, we scale our benchmark tax rates by the ratio of state plus local aggregated tax revenue to state-only tax revenue for each of these three types of taxes. In particular, $t_n^{c,state+local} = (rev_n^{c,s+l}/rev_n^{c,s})t_n^c$, $t_n^{y,state+local} = (rev_n^{y,s+l}/rev_n^{y,s})t_n^y$, $t_n^{corp,state+local} = (rev_n^{corp,s+l}/rev_n^{corp,s})t_n^{corp}$, where $rev_n^{x,s+l}$ denotes the tax revenue from the type of tax x collected both by the government of state n and all the local institutions located in n, and $rev_n^{x,s}$ denotes the tax revenue from the type of tax $x$collected exclusively by the state government. As $rev_n^{x,s+l} > rev_n^{x,s}$, this adjustment scales up the state tax rates used in our analysis.

relative to the benchmark due to larger initial dispersion in state+local taxes than in state taxes; however, the spending-neutral misallocation is reduced, leading negative welfare effect.

5.6 Other Parametrizations

Our benchmark parametrization sets the value $\sigma = 4$ and assumes that the congestion parameters χ_W and χ_F equal 1. Table A.8 in Appendix D.3 reports the results for $\sigma = 5$ and for different congestion levels between 0 and 1. In each case, we use the corresponding reduced-form estimates of our benchmark estimation strategy based on external IV's in tables 2 and 3.[63] The last row uses the structural parameters corresponding to the all-IV's estimation strategy from these two tables. The results from spending-neutral counterfactuals change little across all these parametrizations. In the revenue-neutral case, misallocation decreases somewhat under larger σ, and is non-monotone with the congestion parameters. The all-IV's estimation strategy delivers considerably larger welfare and real-income effects in the revenue-neutral counterfactual, largely due to the higher value of the preference for government spending implied by this estimate.

6 Other Policies

6.1 Changes in Tax Rates in a Single State

Now, we tackle the question: What are the effects of tax changes in one state on this same state and on other states? To answer this question we simulate a 1 percentage point reduction in the income tax of each state in our data.[64] Each counterfactual is run twice: keeping government spending exogenously constant, and allowing it to change according to each state budget's constraint. Table 8 reports average percentage changes in employment, number of firms, real wage, real GDP, and real government spending across counterfactuals on the state enacting the tax change ("Own") and on average on other states ("Rest of the U.S.").

Table 8: State-by-state Reduction in Income Tax by 1 Percentage Point

Average Change in	G Constant		Total Effect	
	Own	Rest of U.S.	Own	Rest of U.S.
Aggregate Welfare	0.02%		-0.05%	
Employment	0.70%	-0.01%	-2.32%	0.04%
Firms	1.12%	-0.02%	-1.46%	0.02%
Real Wage	-0.37%	0.01%	-0.57%	-0.02%
Real GDP	0.33%	-0.01%	-2.88%	0.02%
Real Government Spending	0%	0%	-13.36%	0.01%

[63] In the cases in which the theoretical $\varepsilon_F > \sigma - 1$ condition is violated, we re-estimate the α_F imposing the restriction that $\varepsilon_F > \sigma - 1$. This approach results in estimates of α_F between 0.03 and 0.05, which are similar to the unconstrained estimates.

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

Keeping government spending constant, reducing income taxes increases welfare of the representative U.S. worker. From (27), higher tax keep rates, i.e., $1 - T_n$, are similar to an increase in amenities, which raises the number of workers in the state lowering taxes in detriment of the rest of the U.S. This increase in labor supply reduces the wage in the own state. Firms are also attracted to the state lowering taxes, leading to an increase in the set of varieties produced in own state. This increase in varieties partially offsets the real-wage decline through a reduction in the price index. After-tax real wages and rents increase; the combined effect of factor inflow and higher prices boost GDP, which increases in real terms; in the rest of the U.S., the effects on real wages and GDP are flipped due to the reallocation of workers. However, when government spending adjusts in every state to satisfy each states' government budget constraint, government revenue in the state lowering income taxes falls. This reduction in tax revenue reduces the provision of public goods to the own state, which in turn reduces both labor supply and labor demand. As a result, the previous outcomes are undone: both employment and real GDP fall in the state lowering taxes, and the welfare of the representative U.S. worker decreases.

General-Equilibrium Effects on the Own State How important are general-equilibrium effects in driving the employment impact on the state reducing income taxes? The estimated parameters summarized in Table 1 imply that the average change in employment in the own state can be decomposed as follows:[65]

$$\overline{\ln\left(\hat{L}_n\right)} = \underbrace{0.99 * \overline{\ln\left(\frac{1-T'_n}{1-T_{n,2007}}\right)}}_{1.08\%} + \underbrace{0.99 * \overline{\ln\left(\hat{w}_n/\hat{P}_n\right)}}_{-0.56\%} + \underbrace{0.20 * \overline{\ln\left(\hat{G}_n\right)}}_{-2.97\%} - \underbrace{1.18 * \overline{\ln\left(\hat{v}\right)}}_{-0.06\%}, \qquad (34)$$

where the bar over each variable denotes an average across the 49 experiments, each corresponding to a reduction in the income tax in a different state n. The first term in the right-hand side of (34) is the direct effect from the tax change keeping all general-equilibrium variables constant; given the estimate of a_0 in (29) and the average change in worker keep tax rates, it leads on average to an increase in employment.[66] However, in general equilibrium, the reduction in real wages and in the provision of public goods more than offsets the positive direct effect of the increase in the keep-tax rate, leading to an overall fall in employment, with a large part of the reversal being driven by the change in government spending.

Heterogeneous Impact Across States In states other than the state changing taxes, economic activity responds through general-equilibrium effects in heterogeneous ways. We illustrate this by focusing on the reduction in the income tax in one large state, California. Figure A.4 in Appendix E.1 shows the heterogeneous response across states in terms of real wages, real GDP, employment,

[65] To reach this expression we use (5) and the labor supply equation (7).

[66] Note that this is different from 0.7% change in own employment in the G-constant counterfactual reported in the table because that number includes both the direct effect and general-equilibrium effects through prices and aggregate welfare, i.e., the second and fourth components in the right-hand side of (34).

and number of firms. When government spending is kept constant, employment in California grows and it shrinks in every other state, but the negative employment effect is milder in states closer to California. The effects are reversed when government spending adjusts: economic activity in California shrinks, while states in the East Coast gain more in terms of employment and number of firms relative to states with stronger trade links with California. This heterogeneity across states is caused by heterogeneity in the economic linkages between California and every other state, which enter the quantification through the data on spending and sales shares. Figure A.5 in Appendix E.1 shows the employment change by state when government spending is allowed to adjust as function of each state's share of sales to CA (left panel) and share of spending in goods coming from CA (right panel). Employment increases relatively less in states that rely more on California as either an export market or a source of imported products. Figure A.6 in Appendix E.1 reproduces the same figure averaging across all counterfactuals, and it implies that the pattern in Figure A.5 is indeed representative of what happens when a typical U.S. state reduces the income tax in our model.[67]

6.2 Counterfactual Apportionment of Corporate Taxes

To conclude, we consider the implications of changing apportionment rules. According to some views, payroll-based apportionment tends to be more distortionary than sales-based apportionment.[68] Table A.10 in Appendix E.2 reports the effects from moving to either 0%, 50%, or 100% apportionment in every state. As shown in Table A.2, most states use sales apportionment rates of 33% or 50%. The direct effect of these changes is zero. However, moving to no sales apportionment increases welfare by 0.22%, while moving fully into sales apportionment reduces welfare. In our model, sales apportionment may cause larger distortions because it impacts both the adjusted productivities in (25) and the adjusted trade costs in (26), while payroll-based apportionment only impacts the adjusted productivities. A way to assess the extra role of the trade-cost distortion is to repeat the exercise under a parametrization that assumes frictionless trade, in which sales and spending shares are assumed to be independent from the identity of the exporter. In that case, we find a considerably smaller welfare gains from moving away from sales apportionment. Moreover, we see that the part of the welfare change corresponding to changes in government spending only ($\hat{v}^{Gonly}$) is essentially the same regardless of trade costs, implying that the differential welfare impact of trade frictions is due to reallocations.

[67] We highlight that these heterogeneous effects are entirely driven by heterogeneity in trade linkages. Our model does not include heterogeneity in other types of linkages across states. A natural extension that could be considered is to allow for some form of heterogeneity in labor mobility across states, making it easier for workers to move into nearby states than into faraway states. This force can be introduced in our model by allowing for spatial correlation in the idiosyncratic amenity draws, as in Diamond (2015).

[68] Because of their expected distortionary effects, some propose shifting away from income- and into sales-based state tax state systems. For example, see Auerbach (2013), Zucman (2014), and Auerbach and Devereux (2015) for a discussion of these ideas.

7 Conclusion

In this paper, we studied the impacts of the distribution of taxes across states on aggregate real income, welfare, and the spatial distribution of economic activity in the U.S. economy. We constructed a general-equilibrium model that draws on tools from recent trade and economic geography models and complements them by including salient features of the U.S. state tax structure. We estimated elasticities of firm and labor mobility, as well as the weight of state government spending in worker preferences and productivity, using data on economic activity and state finances from 1980-2010. Using the estimated model, we measured the general-equilibrium impact of some reforms typically put forth in public policy debates.

Our results suggest quantitatively important effects on aggregate real income and welfare (in the order of 0.7%) from a revenue-neutral harmonization of sales, income, and corporate taxes relative to the revenue share of these taxes in GDP (4%). In our model, these effects are entirely driven by reallocations of workers, firms, and trade across states. The results also highlight the importance of general-equilibrium forces in driving the own-state effects of tax changes, and of trade frictions in driving both the spillovers from tax changes in one state to other states, and the impacts of tax policies, such as the apportionment rules of corporate taxes, which are often the subject of public-policy debate.

The paper contributes to the ongoing debate about the impacts of the state tax structure in the U.S., but has also implications for similar debates taking place within the European Union.[69] We also believe that a similar approach that combines a quantitative spatial equilibrium model with an estimation of key parameters using data on tax rates could be used to tackle questions related to taxation rules of multinational corporations.[70] These questions are left for future research.

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[69] E.g., see "Tax Harmonization in Europe: Moving Forward," *VOX*, Agnes Benassy-Quere, Alan Trannoy, and Guntram Wolff, July 22, 2014, and Bettendorf et al. (2010).

[70] E.g., see "Taxing the foreign profits of multinational firms," *VOX*, Michael Deveraux, Clements Fuest, and Ben Lockwood, June 12, 2015, and Auerbach and Devereux (2015)

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Appendices for Online Publication

A Appendix to Section 2 (Background)

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

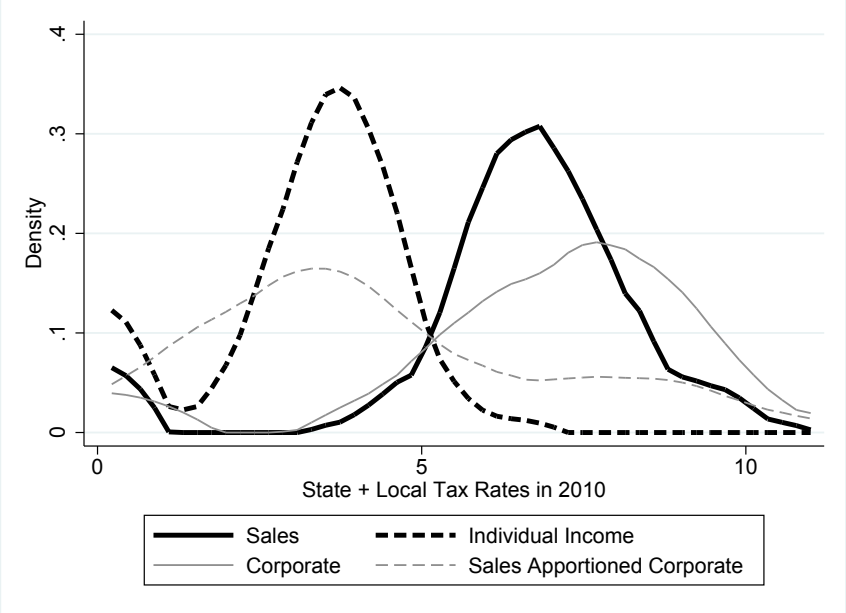


Table A.1: Federal Tax Rates from 2007

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 baseline federal tax rates in 2007 for personal income taxes, corporate taxes, and payroll taxes. The income tax rate in is the average effective federal tax rate from NBER's TAXSIM across all states in 2007. The rate that we use in the counterfactuals from NBER TAXSIM, however, varies slightly across states due to tax deductabilty. Variation in state tax rates results in variation in the after-deductbability effective federal tax rate. The TAXSIM data that we use provides the effective federal tax rate on personal income after accounting for deductabiltity. The corporate tax rate is the average effective corporate tax rate. We divide total tax liability (including tax credits) by net 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 employeer 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 baseline state tax rates in 2007 for personal income taxes, general sales taxes, statutory corporate taxes, 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 2.1 for details.

B Appendix to Section 3 (Model)

B.1 Firm Maximization

The first-order condition of (9) 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 from for 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:

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

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

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

GDP Adding up (A.7), (A.8), and (20), GDP in state n is

$$GDP_n = \left(\gamma_n (\sigma - 1) + 1\right) \tilde{\Pi}_n, \tag{A.9}$$

From (A.9) and 20, aggregate real GDP in the counterfactual relative to the initial scenario is:

$$\widehat{GDP}^{real} = \sum_n \frac{\frac{\gamma_n(\sigma-1)+1}{(1-\beta_n)\gamma_n(\sigma-1)}\frac{w_n L_n}{P_n}}{\sum_{n'}\frac{\gamma_{n'}(\sigma-1)+1}{(1-\beta_{n'})\gamma_{n'}(\sigma-1)}\frac{w_{n'}L_{n'}}{P_{n'}}}\frac{\widehat{w_n}\widehat{L_n}}{\widehat{P_n}}. \tag{A.10}$$

Consumption Adding up the expenditures of workers and capital-owners described in Section (3.2), the aggregate personal-consumption expenditure in state n is

$$P_n C_n = P_n C_n^W + \frac{\left(1-t_{fed}^y\right)\left(1-t_n^y\right)}{1+t_n^c} b_n \left(\Pi + R\right). \tag{A.11}$$

where $C_n^W = (1-T_n)\frac{w_n L_n}{P_n}$ 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 equilibrium relative to its initial value in the counterfactuals is computed using the following expressions:

$$\widehat{C^W} = \sum_n \left(\frac{\left(1-T_n\right)\frac{w_n L_n}{P_n}}{\sum_{n'}\left(1-T_{n'}\right)\frac{w_{n'}L_{n'}}{P_{n'}}}\right)\hat{C_n^W}. \tag{A.12}$$

$$\widehat{C^K} = \sum_n \left(\frac{\frac{1-t_n^y}{1+t_n^c}\frac{b_n}{P_n}}{\sum_{n'}\frac{1-t_n^y}{1+t_n^c}\frac{b_{n'}}{P_{n'}}}\right)\hat{C_n^K}. \tag{A.13}$$

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

$$P_n G_{n,fed} = \left(t_{fed}^y + t_{fed}^w\right) w_n L_n + b_n t_{fed}^y \left(\Pi + R\right) + b_n t_{fed}^{corp} \sum_{n'} \tilde{\Pi}_{n'}. \tag{A.14}$$

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 on state revenue. However, we do not model the use of federal revenues, which is consistent with assuming that federal spending does not affect the allocation of workers across states or over time.

Trade Imbalances Aggregate expenditures $P_n Q_n$ and sales X_n of state n may differ for two reasons. 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_n^x across states create differences between the corporate tax revenue raised by state n's government (R_n^{corp}) and the corporate taxes paid by residents of state n (TP_n^{corp}). As a result, the trade imbalance in state n, defined as difference between expenditures and sales in that state, can be written as follows:[71]

$$P_n Q_n - X_n = (GSI_n - GDP_n) + (R_n^{corp} - TP_n^{corp}), \tag{A.15}$$

where GSI_n is gross state income (the returns to the factors of production owned by residents of state n) and $TP_n^{corp}$are corporate taxes paid by capital owners residing in state n. Letting $R = \sum_n r_n H_n$ and $\tilde{\Pi} = \sum_n \tilde{\Pi}_n$ be the returns to the national portfolio of fixed factors and firms before taxes, we can write each of components of (A.15)

[71] To reach this relationship, first impose goods market clearing (4) 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 $P_n C_n = GSI_n - (R_n^y + R_n^c + TP_n^{corp}) - P_n G_{n,fed}$, where the terms between parentheses are tax payments made by residents of state n to state governments and $P_n G_{n,fed}$ are taxes paid to the federal government. Combining these two expressions and using the state's government budget constraint (21) gives $P_n Q_n = (GDP_n + P_n I_n) + (GSI_n - GDP_n) + (R_n - TP_n)$. Adding and subtracting GDP_n and noting that by definition $GDP_n = X_n - P_n I_n$ gives (A.15).

besides GDP as follows:[72]

$$GSI_n = b_n \left(\tilde{\Pi} + R \right) + w_n L_n, \tag{A.16}$$

$$R_n^{corp} = \frac{1}{\sigma} \left(t_n^x P_n Q_n + t_n^l X_n \right), \tag{A.17}$$

$$TP_n^{corp} = b_n \sum_{n'} \left(\bar{t}_{n'} - t_{fed}^{corp} \right) \tilde{\Pi}_{n'}. \tag{A.18}$$

Replacing (A.9) and (A.16) to (A.18) into (A.15), and using (A.7) and (20) to express labor payments and pre-tax profits as function of sales, we obtain:

$$\frac{P_n Q_n}{X_n} = \frac{1}{\sigma - t_n^x} \left((\sigma - 1)(1 - \beta_n \gamma_n) + t_n^l + \frac{b_n}{\tilde{\Pi}_n / \left(\Pi + R + t_{fed}^{corp} \tilde{\Pi} \right)} \right). \tag{A.19}$$

where, from (20) and (A.8), the denominator in the last term is:

$$\frac{\tilde{\Pi}_n}{\Pi + R + t_{fed}^{corp} \tilde{\Pi}} = \frac{X_n}{\sum_i \left(1 - t_n^l - \bar{t}_n + \beta_i \gamma_i (\sigma - 1) \right) X_i}. \tag{A.20}$$

Expression (A.19) is used in the calibration to back out the ownership shares b_n from observed data on trade imbalances. Specifically, it implies that the ownership shares can be expressed as function of other parameters and observables as follows:

$$b_n = \frac{\tilde{\Pi}_n}{\Pi + R + t_{fed}^{corp} \tilde{\Pi}} \left[(\sigma - t_n^x) \left(\frac{P_n Q_n}{X_n} \right) - (\sigma - 1)(1 - \beta_n \gamma_n) - t_n^l \right]. \tag{A.21}$$

B.3 Contrast with Models with Free Entry

Our structure has similar implications to standard monopolistic competition models with free entry, in the sense that in both types of models the number of firms by location is endogenous and proportional to sales. Specifically, the distributional assumption on the productivity draws implies that average profits are $\pi_i(\tilde{z}_i) = \bar{\pi}$ in every state. From (20) it follows that the number of firms in state i can be expressed as:

$$M_i = \frac{1 - \bar{t}_i}{\bar{\pi}} \frac{X_i}{\sigma}. \tag{A.22}$$

This condition determines the number of firms in each region similarly to a standard free-entry condition in monopolistic competition models such as Krugman (1980), where the number of firms is proportional to sales.[73] We pursue our strategy for three reasons: first, it gives the model additional flexibility to match patterns of firm mobility with respect to taxes through ε_F, and we estimate this parameter in Section 4.3; second, it is similar to existing work which has estimated elasticities of firm location with respect to taxes in the public-finance literature such as Suárez Serrato and Zidar (2014); third, it allows us to treat mobility of workers and firms symmetrically.[74]

[72] (A.16) and (A.18) are by definition. For (A.17), combine (22) with (19) and (20).

[73] Under free-entry of homogeneous firms with fixed cost equal to f_i nominated in units of factor and inputs bundle, the number of firms in state i in our model would adopt a very similar form: $M_i = \frac{1 - \bar{t}_i}{c_i f_i} \frac{X_i}{\sigma}$.

[74] The cost of not using the free-entry model is that changes in taxes do not affect the total number of firms in the economy. We note, however, that in both models the fraction of firms in each state is determined independently from the total number of firms (here normalized to 1); as such, the aggregate-entry margin would not affect the part of welfare changes that corresponds to the spatial distribution of economic activity which is the focus of our analysis. However, it would be possible to carry out our analysis using the free-entry model to assess this additional margin.

B.4 General-Equilibrium Conditions

We note that, using the definition of import shares in 18 , imposing expression (2) for final-goods prices in every state is equivalent to imposing that expenditures shares in every state add up to 1.

$$\sum_n \lambda_{in} = 1 \text{ for all } i; \tag{A.23}$$

Additionally, condition 19, which determines aggregate sales from i, is equivalent to imposing s that sales shares from every state add up to 1:

$$\sum_i s_{in} = 1 \text{ for all } n. \tag{A.24}$$

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

$$\lambda_{in} = A_{in} \left(\frac{w_n}{\bar{\pi}}\right)^{1-\kappa_1} L_n^{1-\kappa_{2n}} \left(\frac{w_i}{\bar{\pi}}\right)^{\sigma-1} L_i^{-\kappa_3}, \tag{A.25}$$

$$s_{in} = \lambda_{in} \frac{P_i Q_i}{X_i} \frac{(w_i/\bar{\pi})\, L_i}{(w_n/\bar{\pi})\, L_n} \frac{(1-\beta_n)\,\gamma_n}{(1-\beta_i)\,\gamma_i}, \tag{A.26}$$

where A_{in} in λ_{in} is given by

$$A_{in} = \left(\frac{H_n^{\beta_n \gamma_n} \Theta_{1n} z_n^A}{\frac{\sigma}{\sigma-1} \tau_{in}^A} \frac{\left(\Theta_{2i} u_i^A\right)}{\left(\Theta_{2n} u_n^A\right)^{1-\gamma_n+\alpha_F}} v^{\alpha_F - \gamma_n} \right)^{\sigma-1}, \tag{A.27}$$

where $\left\{z_n^A, \tau_{in}^A, u_n^A\right\}$ are defined in (25) to (27) in the text, and where $\{\Theta_{1n}, \Theta_{2n}\}$ are functions of parameters:

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

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

The parameters $\{\kappa_1, \kappa_{2n}, \kappa_3\}$ in (A.25) and (A.26) are given by:

$$\kappa_1 = (\sigma-1)\left(\frac{1}{\varepsilon_F} + \alpha_F\chi_F + 1\right), \tag{A.28}$$

$$\kappa_{2n} = (\sigma-1)\left[\left(\frac{1}{\varepsilon_F} - \alpha_F\,(1-\chi_F) + \beta_n\gamma_n\right) - (1-\gamma_n+\alpha_F)\left(\frac{1}{\varepsilon_W} - \alpha_W\,(1-\chi_W)\right)\right], \tag{A.29}$$

$$\kappa_3 = (\sigma-1)\left(\frac{1}{\varepsilon_W} - (1-\chi_W)\,\alpha_W\right). \tag{A.30}$$

Equations (A.23) to (A.27), together with (8), (A.19), and (28) give the solution for import shares $\{\lambda_{in}\}$, export shares $\{s_{in}\}$, employment shares $\{L_n\}$, wages relative to average profits $\left\{\frac{w_n}{\bar{\pi}}\right\}$, government sizes $\left\{\frac{P_n G_n}{GDP_n}\right\}$, relative trade imbalances $\left\{\frac{P_n Q_n}{X_n}\right\}$, and utility v.[75] The endogenous variables not included in this system (e.g., the fraction of firms, M_n) can be recovered using the remaining equations of the model and its solution.

B.5 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)

[75] The terms u_n^A, τ_{in}^A, and z_n^A which enter in (A.27) are function of the export shares $\{s_{in}\}$ and government sizes $\left\{\frac{P_n G_n}{GDP_n}\right\}$. Government sizes and trade deficits also depend on the terms $\left\{\tilde{\Pi}_n, \tilde{\Pi}, \Pi + R\right\}$. These variables can be expressed as function of export shares, labor compensation and parameters only.

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 (27) and (25) are primitives (exogenous functions of fundamentals and own-state taxes). Define:

$$K_{in} = \tau_{in}^{1-\sigma},$$
$$\gamma_n = \overline{A}_n^{\sigma-1} w_n^{1-\kappa_1} L_n^{1-\kappa_2}, \tag{A.31}$$
$$\delta_i = \left(\frac{\overline{u}_i}{\overline{W}}\right)^{\sigma-1} w_i^{\sigma} L_i^{1-\kappa_3}, \tag{A.32}$$

where

$$\overline{A}_n = \frac{1}{\overline{\pi}^{\frac{\sigma-\kappa_1}{\sigma-1}}} \frac{\sigma}{\sigma-1} \frac{z_n^A}{(u_n^A)^{(1-\gamma)+\alpha_F}},$$
$$\overline{u}_i = \frac{u_i^A}{(\beta^L)^{\frac{1}{\sigma-1}}},$$
$$\overline{W} = v^{\gamma-\alpha_F}.$$

Using these definitions, from the definition of import shares in (A.25) it follows that Conditions 1 to 3 of Allen et al. (2014) are satisfied. To show that their condition 4' is also satisfied, we follow steps similar to their Online Appendix B.4. First, combining the solution for $\{w_n, L_n\}$ from (A.31) and (A.32) 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.31) and (A.32), 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 σ, κ_1, κ_2 and κ_3. This satisfies Condition 4', so that we can apply Corollary 2 from their paper to reach a uniqueness condition for the system of equations in $\{L_n, w_n, v\}$ in (A.23) to (A.24):

$$\frac{\sigma-(1-\kappa_3)}{\sigma(1-\kappa_2)-(1-\kappa_3)(1-\kappa_1)} > 1, \tag{A.33}$$
$$\frac{\kappa_1-\kappa_2}{\sigma(1-\kappa_2)-(1-\kappa_3)(1-\kappa_1)} > 1, \tag{A.34}$$

where κ_1 to κ_3 are defined in (A.28) to (A.30). 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.6 General Equilibrium in Relative Changes

To perform counterfactuals, we solve for the solution to model outcomes in changes as function of changes in taxes.Consider, in this context, 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 $\left\{(t_n^y)', (t_n^c)', (t_n^x)', (t_n^l)'\right\}_{n=1}^N$. Letting $\hat{x} = \frac{x'}{x}$ be the counterfactual value of x relative to its initial value, we have that the the changes in import shares, export shares, employment shares, and wages $\left\{\hat{\lambda_{in}}, \hat{s_{in}}, \hat{L_n}, \hat{w_n}\right\}_{n=1}^N$ as well as the welfare change $\hat{v}$ must be such that conditions (A.23) and (A.24) hold:

$$\sum_n \lambda_{in} \hat{\lambda_{in}} = 1 \text{ for all } i, \tag{A.35}$$
$$\sum_i s_{in} \hat{s_{in}} = 1 \text{ for all } n, \tag{A.36}$$

where, using (A.25) and (A.26) and normalizing $\hat{\bar{\pi}} = 1$,

$$\hat{\lambda_{in}} = \hat{A_{in}} \hat{w_n}^{1-\kappa_1} \hat{L}_n^{1-\kappa_{2n}} \hat{w_i}^{\sigma-1} \hat{L}_i^{-\kappa_3} \tag{A.37}$$

$$\hat{s_{in}} = \hat{\lambda_{in}} \left(\frac{\hat{P_i Q_i}}{X_i} \right) \frac{\hat{w}_i \hat{L}_i}{\hat{w}_n \hat{L}_n} \tag{A.38}$$

and where using (A.27)

$$\hat{A}_{in} \propto \left(\frac{\hat{z_n^A}}{\hat{\tau_{in}^A}} \frac{\hat{u_i^A}}{\left(\hat{u_n^A}\right)^{(1-\gamma_n)+\alpha_F}} \hat{v}^{\alpha_F - \gamma_n} \right)^{\sigma-1} \tag{A.39}$$

and where, from (26) to (27),

$$\hat{\tau_{in}^A} = \frac{\sigma - \tilde{t}_{in}}{\sigma - \left(\tilde{t}_{in}\right)'}, \tag{A.40}$$

$$\hat{z_n^A} = \left(\frac{1 - (\bar{t}_n)'}{1 - T_n} \right)^{\frac{1}{\sigma-1} - \left(\frac{1}{\varepsilon_F} + \alpha_F \chi_F\right)} \left(\frac{\hat{P_n G_n}}{GDP_n} \right)^{\alpha_F}, \tag{A.41}$$

$$\hat{u_n^A} = \left(\frac{1 - T_n'}{1 - T_n} \right)^{1-\alpha_W} \left(\frac{\hat{P_n G_n}}{GDP_n} \right)^{\alpha_W} \tag{A.42}$$

Additionally, labor shares must add up to 1 :

$$\sum \hat{L_n L_n} = 1. \tag{A.43}$$

The variables $\left\{ \frac{\hat{P_n Q_n}}{X_n}, \frac{\hat{P_n G_n}}{GDP_n}, T_n', \left(\bar{t}_n\right)', \left(\tilde{t}_{in}\right)' \right\}_{n=1}^{N}$ can expressed as function of the original taxes $\left\{t_n^y, t_n^c, t_n^x, t_n^l\right\}$ the new distribution $\left\{ \left(t_n^y\right)', \left(t_n^c\right)', \left(t_n^x\right)', \left(t_n^l\right)' \right\}$, and the new export shares $\{\hat{s_{in}} s_{in}\}$ using (A.19), (28), (6), (10), and (12). Hence, these equations, together with (A.35) to (27), give the solution for $\left\{ \hat{\lambda_{in}}, \hat{s_{in}}, \hat{L_n}, \hat{w_n} \right\}$ and $\hat{v}$.[76]

C Appendix to Section 4.3 (Estimated Parameters)

C.1 Appendix to Section 4.3.1 (Labor-Supply Elasticity)

Table A.3 provides the first-stage estimates from the labor-supply estimation. Columns (1) and (2) show the first stage for after-tax real wages, and columns (3) and (4) show it for real government services $\tilde{R}_{nt}$. The odd-numbered columns use both the own-state as well as external sales taxes as instruments, and the even-numbered columns use the external tax rates only. The coefficient on $\ln(1 - T_{nt})$ reflects offsetting forces. Holding everything else constant, after-tax real wages are higher when keep-rates are higher, but the pre-tax real wage might also react to changes in income taxes due to the effect of these taxes on both labor supply and demand. The positive sign on that coefficient shows that the first force dominates. The negative coefficient on the term $1 - t_{nt}^{corp}$ reflects that higher corporate keep tax rates tend to be associated with lower after-tax real wages. The coefficients on external taxes indicate that being "close" to high sales tax (and high sales-apportioned corporate tax) states tends to be associated with lower after-tax real wages. Real government services tend to be lower when the personal-income keep shares $(1 - T_{nt})$ are high (in other terms, higher income tax rates are correlated with a higher level of government services) and when the state is "close" to high income tax states. Overall, the F-statistics of the joint significance of the instruments conditional on state and year fixed effects are large.

[76] 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 function of initial conditions and changes in the endogenous variables, $\tilde{\Pi}' = \sum_i \frac{w_i L_i \left(\hat{w_i} \hat{L_i}\right)}{\sigma}$ and $\Pi' + R' = \sum_i \left(1 - (\bar{t}_i)' + \beta_i \gamma_i (\sigma - 1)\right) \frac{w_i L_i \left(\hat{w_i} \hat{L_i}\right)}{\sigma}$.

Table A.3: First Stage of Labor-Supply Equation

	$\ln(\tilde{w}_{nt})$		$\ln(\tilde{R}_{nt})$	
	(1)	(2)	(3)	(4)
$\ln(1-T_{nt})$	1.0*		-7.2***	
	(0.6)		(2.2)	
$\ln Z_{nt}^{corp}$	-1.0***		-0.1	
	(0.2)		(0.5)	
$\ln t_{nt}^{*c}$	2.4**	4.1***	12.6***	-0.0
	(1.1)	(0.6)	(3.8)	(1.9)
$\ln t_{nt}^{*y}$	0.4	0.5	-6.5***	-8.1***
	(0.4)	(0.5)	(1.3)	(1.3)
$\ln t_{nt}^{*x}$	0.7***	-0.1	0.3	0.6
	(0.3)	(0.2)	(0.7)	(0.7)
Observations	796	796	796	796
F-stat:	17.49	18.35	12.15	13.64

NOTES: This table shows the first stage estimates for labor supply. The dependent variables are after-tax real wages and real government expenditures in columns (1)-(2) and (3)-(4), respectively. The data are at the state year level. 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 US population. Every specification includes state and year fixed effects. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

Table A.4: GMM Estimates of Labor Mobility Parameters

	A. All IVs	B. External IVs
	(1)	(2)
$\chi_W = 0$		
ε_W	1.31***	1.24***
	(.23)	(.32)
α_W	.26***	.17*
	(.07)	(.09)
$\chi_W = 0.5$		
ε_W	1.57***	1.39***
	(.33)	(.42)
α_W	.26***	.17*
	(.07)	(.09)
$\chi_W = 1$		
ε_W	1.97***	1.57***
	(.56)	(.58)
α_W	.26***	.17*
	(.07)	(.09)

NOTES: This table shows the GMM estimates for labor mobility parameters. The dependent variable is log state employment $\ln L_{nt}$. The data are at the state-year level. Each column has 712 observations due to incomplete coverage of price and other data. 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 US population. Every specification includes state and year fixed effects. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

C.2 Appendix to Section 4.3.2 (Firm-Mobility Elasticity)

C.2.1 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[77] 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 to equal the local price index, resulting in the following measure of unit costs: $c_{nt} = \left(w_{nt}^{1-\beta_n} P_{nt}^{\beta_n}\right)^{\gamma_n} P_{nt}^{1-\gamma_n}$.[78]

We need information on export shares both to build $\bar{t}_{nt}$ and the term $\{\tilde{t}_{n'nt}\}$ entering the expression for MP_{nt}. There does not exist annual data on trade flows across U.S. states; therefore, we set export shares equal to the average of the recorded export shares for the years 1993 and 1997, i.e., $s_{int} = \frac{s_{in,1993}+s_{in,1997}}{2}$ $\forall t$. 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.9), and (A.19) to obtain

$$E_{nt} = \frac{(\sigma-1)(1-\beta_n\gamma_n) + a_{nt} + t_n^l}{\sigma - t_n^x} \frac{\sigma}{\gamma_n(\sigma-1)+1} GDP_{nt}, \tag{A.44}$$

where $a_{nt} = D_{nt}(\sigma-1) - (\sigma-1)(1-\beta_n\gamma_n) - t_{nt}^l$, where D_{nt} denotes the deficit of $n$in t. State GDP is observed in every year, but a_{nt} is not. Hence, to compute a yearly measure of E_{nt}, we set its value to that observed in the calibration: $a_{nt} = a_{n,2007}$ for all t.[79]

C.2.2 Construction of Instrument for Market Potential and Robustness Checks

We define the instrument MP_{nt}^* by constructing a variable that has a similar structure to market potential MP_{nt} in (32), but differs from it in that we substitute the components E_{nt}, P_{nt}, and $\tilde{t}_{n'nt}$ that might potentially be correlated with ν_{nt}^M with functions of exogenous covariates that we respectively denote as E_{nt}^*, P_{nt}^*, and $\tilde{t}_{n'nt}^*$:

$$MP_{nt}^* = \sum_{n'\neq n} E_{n't}^* \left(\frac{\tau_{n'nt}}{P_{n't}^*} \frac{\sigma}{\sigma - \tilde{t}_{n'nt}^*} \frac{\sigma}{\sigma-1}\right)^{1-\sigma}, \tag{A.45}$$

In order to implement this expression, we need to construct measure of the variables E_{nt}^*, P_{nt}^*, and $\tilde{t}_{n'nt}^*$. We construct E_{nt}^* using (A.44) with lagged GDP instead of period $t's$ GDP.[80] Additionally, we set $P_{n,t}^* = 1 + t_{n,t}^c$, and we construct $\tilde{t}_{n'nt}^*$ using the expression for $\tilde{t}_{ni}$ in (12) 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 $s_{iit}^* = \frac{1}{\sum_{i\neq n}\ln(dist_{in})^{-1}+1}$ $\forall t$.

We explore alternate ways to define the variable MP_{nt}^* in Table A.5. Besides a measure of MP_{nt}^* , the first four columns additionally use both own-state and external taxes and the last four columns only add the external instruments included in the vector Z_{nt}^M. For each set of instruments, the first two columns, i.e., columns (1), (2), (5)

[77] 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.

[78] 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, $c_{nt} = \left(w_{nt}^{1-\beta_n}\hat{r}_{nt}^{\beta_n}\right)^{\gamma_n} P_{nt}^{1-\gamma_n}$, produces similar estimates of the structural parameters ε_F and α_F.

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

[80] 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.45) is independent over time.

and (6), use a measure of MP^*_{nt} that differs from that described above in that P^*_{nt} is set to equal 1. The results are very similar to those obtained in the baseline definition of MP^*_{nt} , using $P^*_{n,t} = 1 + t^c_{n,t}$. Columns (3), (4), (7)and (8) present estimates that use a measure of MP^*_{nt} in which, for the construction of the terms $\tilde{t}^*_{n'nt}$, we construct hypothetical export shares s^*_{in} using average export shares over two periods that precede those used to construct MP_{nt}, $\bar{s}_{in} = \frac{s_{in,1993}+s_{in,1997}}{2}$. Each of these approaches produces similar estimates of the parameters.

Table A.5: Robustness of Firm Mobility Parameters

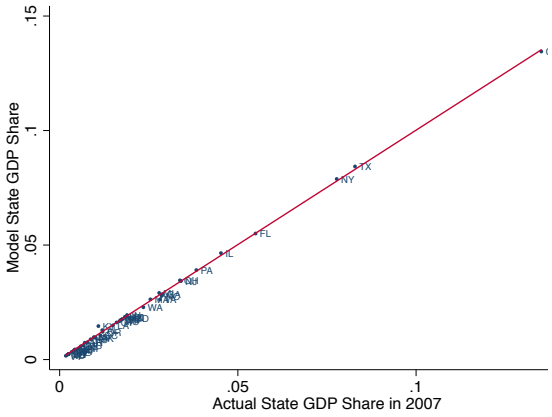
	A. All IVs				B. External IVs			
	Using $P^*_{nt} = 1$		Using $\bar{s}_{in}$		Using $P^*_{nt} = 1$		Using $\bar{s}_{in}$	
	Fix $\sigma = 4$	Fix $\sigma = 5$	Fix $\sigma = 4$	Fix $\sigma = 5$	Fix $\sigma = 4$	Fix $\sigma = 5$	Fix $\sigma = 4$	Fix $\sigma = 5$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\chi_F = 0$								
ε_F	2.44***	3.11***	2.29***	2.92***	2.79***	3.57***	2.75***	3.44***
	(.41)	(.58)	(.36)	(.53)	(.47)	(.67)	(.46)	(.66)
α_F	.1	.07	.06	.04	.04	.03	.04	.02
	(.09)	(.08)	(.09)	(.09)	(.09)	(.08)	(.09)	(.09)
$\chi_F = 0.5$								
ε_F	2.81***	3.56***	2.51***	3.18***	2.96***	3.76***	2.9***	3.6***
	(.54)	(.8)	(.49)	(.77)	(.62)	(.92)	(.61)	(.89)
α_F	.1	.07	.06	.04	.04	.03	.04	.02
	(.09)	(.08)	(.09)	(.09)	(.09)	(.08)	(.09)	(.09)
$\chi_F = 1$								
ε_F	3.17***	4.02***	2.73***	3.43***	3.13***	3.95***	3.05***	3.76***
	(.8)	(1.25)	(.73)	(1.18)	(.92)	(1.35)	(.9)	(1.33)
α_F	.1	.07	.06	.04	.04	.03	.04	.02
	(.09)	(.08)	(.09)	(.09)	(.09)	(.08)	(.09)	(.08)

NOTES: This table shows the GMM estimates for firm mobility parameters using alternate definitions of the instrument for market potential MP^*_{nt}. The dependent variable is log state establishments $\ln M_{nt}$. The data are at the state-year level. Each column has 661 observations due to incomplete coverage of price and other data. 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 US population. Every specification includes state and year fixed effects. Each specification in the first four columns uses all instruments in $\boldsymbol{Z}^M_{nt}$. Each specification in the last four columns, which are labeled external instruments, do not use the own-state tax instruments in $\boldsymbol{Z}^M_{nt}$. Robust standard errors clustered by state are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

C.3 Appendix Figure to Section 4.4 (Over-Identification Checks)

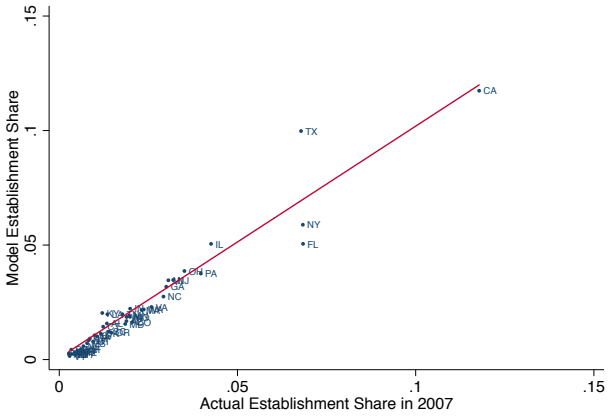
Figure A.2: Over-identifying Moments: Model vs Data

(a) State GDP Share



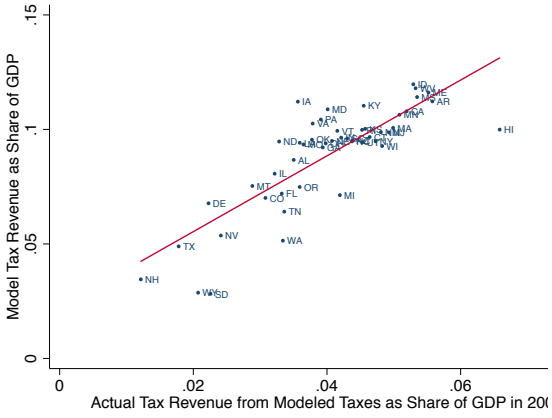
Note: Slope is 1 (0). R-squared is 1.

(b) Share of Establishments



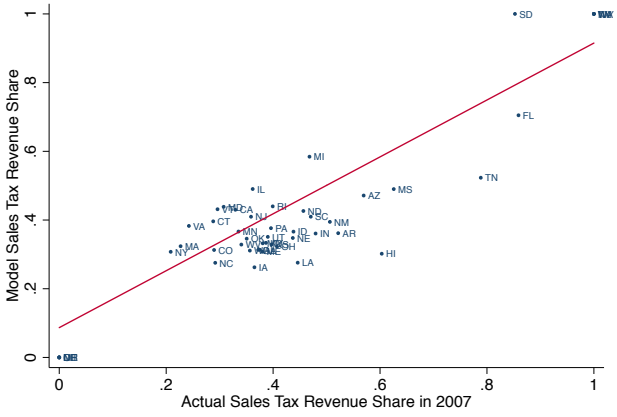
Note: Slope is 1.01 (.04). R-squared is .92.

(c) State Tax Revenue as Share of GDP



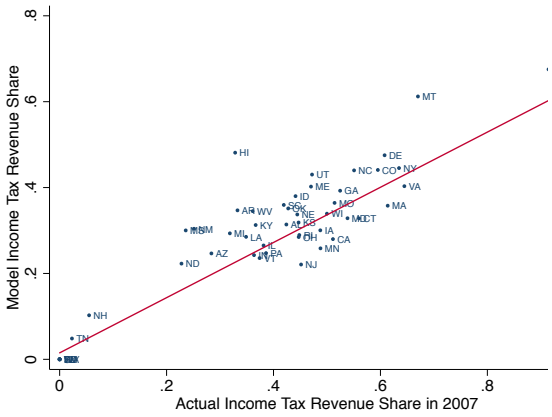
Note: Slope is 1.65 (.14). R-squared is .74.

(d) Sales Tax Revenue Share



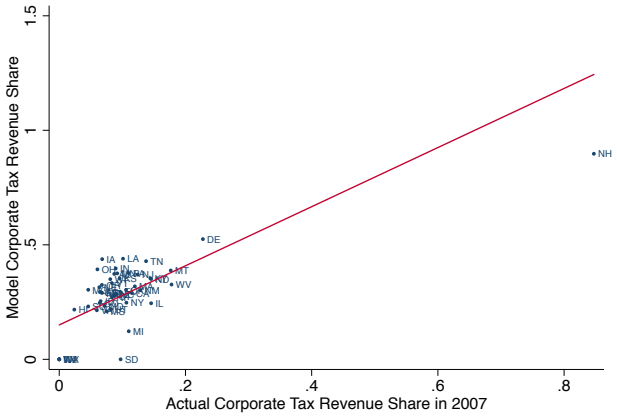
Note: Slope is .83 (.05). R-squared is .85.

(e) Income Tax Revenue Share



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

(f) Corporate Tax Revenue Share



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

C.4 Comparison with Existing Estimates

Previous researchers have estimated regressions similar to (29) and (31) using different sources of variation to identify the corresponding labor and firm mobility elasticities. Table A.6 compares our estimates of ε_W, α_W, ε_F, α_F to those that we would have constructed using estimates 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 ε_W with mean value of 1.73. Our benchmark number of $\varepsilon_W = 1.49$ is within the range of these estimates. The firm-mobility parameter is only reported in Suárez Serrato and Zidar (2014), and corresponds to $\varepsilon_F = 5.33$.[81]

In terms of α_W and α_F, there is substantial evidence that public expenditures has amenity and productivity value for workers and firms, which is consistent with $\alpha_W > 0$ and $\alpha_F > 0$ in our framework. Some studies infer positive amenity value for government spending from land rents,[82] while others focus on the productivity effects of large investment projects.[83] However, very few papers estimate specifications similar to (29) and (31). The estimates of the effects of variation in federal spending at the local level from Suárez Serrato and Wingender (2011) 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 (29) and (31). These differences notwithstanding, our structural parameters are close to those in the literature.

[81] Note that Suárez Serrato and Zidar (2014) focus on variation across local areas rather than across states, resulting in a higher amount of mobility.

[82] 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.

[83] Kline and Moretti (2014) find that infrastructure investments in 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.6: Structural Parameters Implied by Similar Studies

Paper	Estimates	Implied Values of				Source of Variation (Shock)	Level of Variation
		ε_W	α_W	ε_F	α_F		
Bound and Holzer (2000)	$a_0 = 1.20^a$	1.16				Bartik	MSA (1980's)
Notowidigdo (2011)	$a_0 = 3.47^b$	2.44				Bartik	MSA (1980-2000)
Suárez Serrato and Wingender (2011)	$a_0 = 1.58^c$	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 (2014)	$a_0 = 1.28^f$	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 from the literature of specifications similar to (29) and (31). 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 (2011) 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 (2011) in Table 9.

[d] The parameters a_0 and a_1 come from Table 10 in Suárez Serrato and Wingender (2011) 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 noting in Equation A.22 that the effect of spending on firm location equals that of labor demand 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 (2011). The parameters α^i,κ_i^{GS}, and $\frac{\partial W^i}{\partial F}$ are reported in Tables 9 and 10 by skill group in Suárez Serrato and Wingender (2011). 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 (2014) 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 (2014) by taking the ratio of the effects on Population and Wages. b_0 is reported in Table 6, Panel (c).

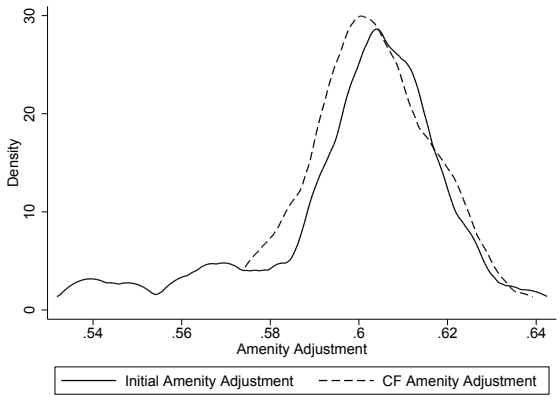
[h] Giroud and Rauh (2015) report an elasticity of number of establishment with respect to corporate taxes of 0.4.

D Appendix to Section 5 (Spatial Misallocation)

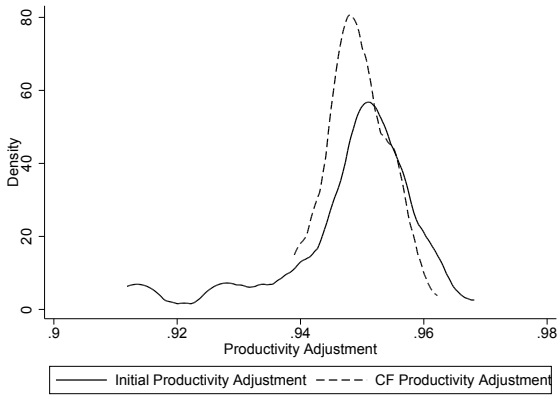
D.1 Appendix Figure to Section 5.1 (Benchmark)

Figure A.3: Removing Tax Dispersion: Adjustment to the Fundamentals

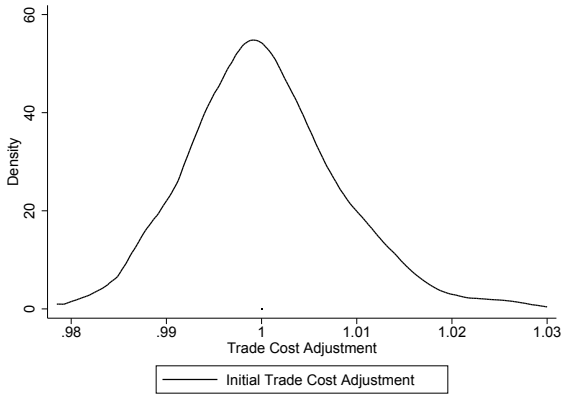
(a) Amenity Adjustment



(b) Productivity Adjustment



(c) Trade Cost Adjustment



Notes: panels (a), (b) and (c) show, respectively, the distributions of $(1-T_n)^{1-\alpha_W}\,\Gamma_n^{\alpha_W}$, $(1-\bar{t}_n)^{\frac{1}{\sigma-1}-\left(\frac{1}{\varepsilon_F}+\alpha_F\chi_F\right)}\,\Gamma_n^{\alpha_F}$, and $\frac{\sigma}{\sigma-\tilde{t}_{in}}$ which enter in the adjusted fundamentals in (26) to (27) under the initial parametrization and in the counterfactual without tax dispersion. In Panel (c), the counterfactual distribution is degenerate at 1 because $\tilde{t}_{in}=0$ for all i,n.

D.2 Appendix to Section 5.2 (Heterogeneous Preferences for Government Spending)

For this counterfactual 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). In order to estimate α_0 and α_1, we re-write the estimating labor-supply equation 29 substituting the term α_W by the function $\alpha_0 + \alpha_1 POL_n$. Now, the reduced-form parameters a_0 and a_1 in 29 vary across states:

$$a_{0,n} \equiv \frac{\varepsilon_W \left(1 - (\alpha_0 + \alpha_1 POL_n)\right)}{1 + \chi_W \varepsilon_W \left(\alpha_0 + \alpha_1 POL_n\right)} \text{ and } a_{1,n} = \frac{\varepsilon_W \left(\alpha_0 + \alpha_1 POL_n\right)}{1 + \chi_W \varepsilon_W \left(\alpha_0 + \alpha_1 POL_n\right)}.$$

Under the assumption that POL_n is independent of the amenity shocks in state n and the exogeneity assumptions described in Section 4.3.1, we use a GMM estimator to consistently estimate the parameters ε_W, α_0 and α_1. Table A.7 shows the results. Under the external-IV's and $\chi_W = 1$ specification we find $\hat{\alpha_0} = .17$ (0.07) and $\hat{\alpha_1} = -.003$ (0.025).

Table A.7: GMM Estimates of Heterogeneous Labor Mobility Parameters

	A. All IVs	B. External IVs
	(1)	(2)
$\chi_W = 0$		
α_{W0}	.24***	.16*
	(.07)	(.09)
α_{W1}	.015	.006
	(.018)	(.043)
$\chi_W = 0.5$		
α_{W0}	.26***	.17**
	(.07)	(.08)
α_{W1}	.011	-.001
	(.014)	(.031)
$\chi_W = 1$		
α_{W0}	.27***	.17**
	(.07)	(.07)
α_{W1}	.008	-.003
	(.012)	(.025)

NOTES: This table shows the GMM estimates for heterogeneous labor mobility parameters. The dependent variable is log state employment $\ln L_{nt}$. The data are at the state-year level. Each column has 712 observations due to incomplete coverage of price and other data. 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 US population. Every specification includes state and year fixed effects. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

D.3 Appendix Table To Section 5.6 (Alternative Parametrizations)

Table A.8: Removing Tax Dispersion under Alternative Parametrizations

Counterfactual	Welfare		Real GDP	
	S-neutral	R-neutral	S-neutral	R-neutral
Benchmark	0.12%	0.69%	0.11%	0.65%
Higher demand elasticity	0.08%	0.59%	0.07%	0.44%
Medium congestion	0.12%	0.78%	0.11%	0.88%
No congestion	0.13%	0.63%	0.10%	0.64%
All IV's	0.09%	2.35%	0.13%	2.66%

D.4 Appendix Table To Section 5.5 (Alternative Tax Rates)

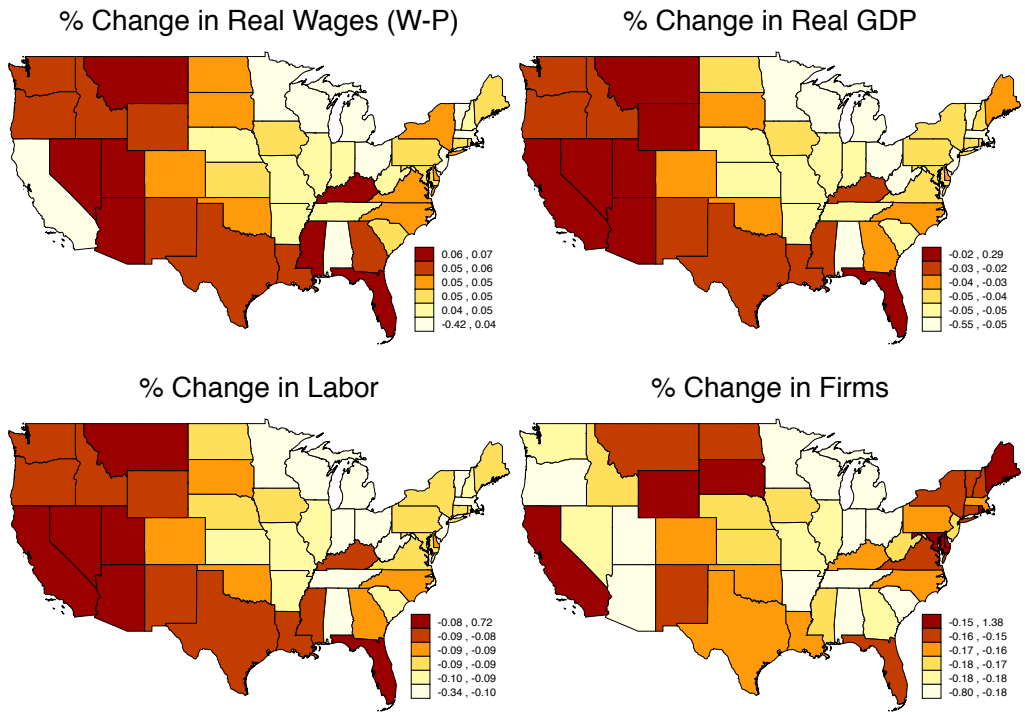
Table A.9: Removing Tax Dispersion under Alternative Definitions of Tax Rates

Counterfactual	Welfare		Real GDP	
	S-neutral	R-neutral	S-neutral	R-neutral
Benchmark	0.12%	0.69%	0.11%	0.65%
Corporate Taxes Adjusted for Tax Subsidies	0.10%	0.61%	0.09%	0.64%
Corporate Taxes Adjusted for Share of C-Corps	0.06%	0.42%	0.04%	0.32%
State+Local Taxes	-0.09%	1.23%	0.06%	0.91%

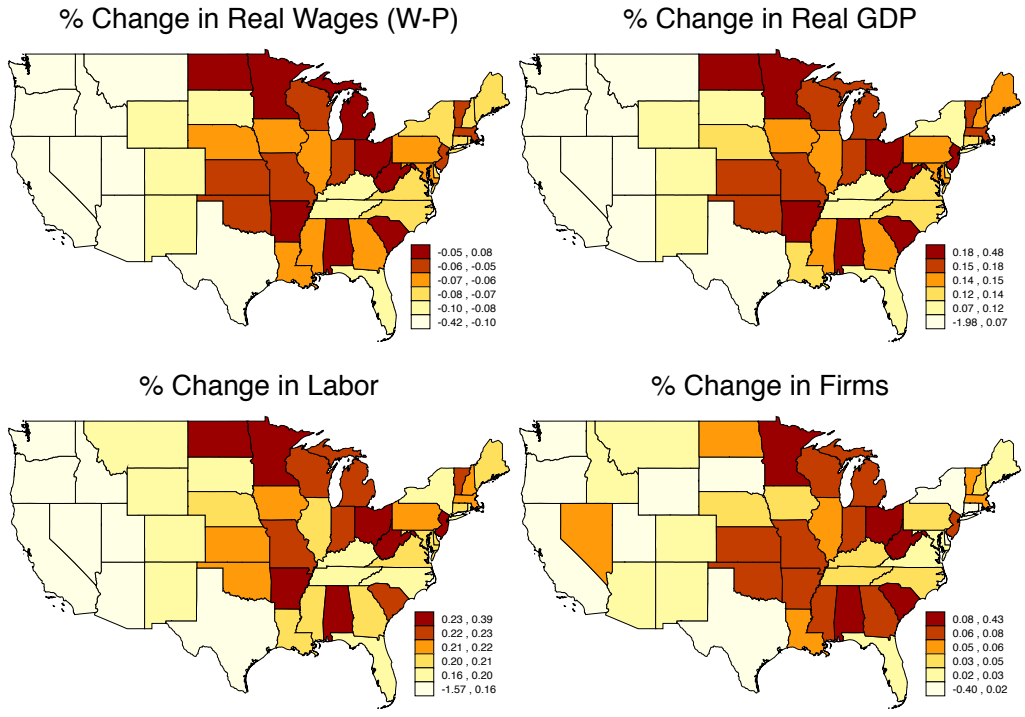
E Appendix to Section 6 (Other Policies)

E.1 Appendix Figures to Section 6.1 (Tax Changes in a Single State)

Figure A.4: Lowering Income Tax in California by 1 Percent Point



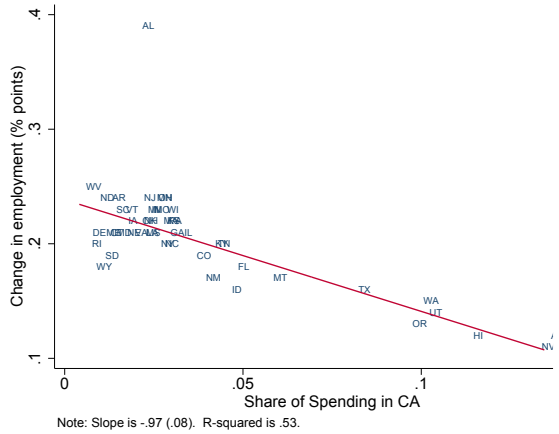
(a) Holding Government Spending Constant



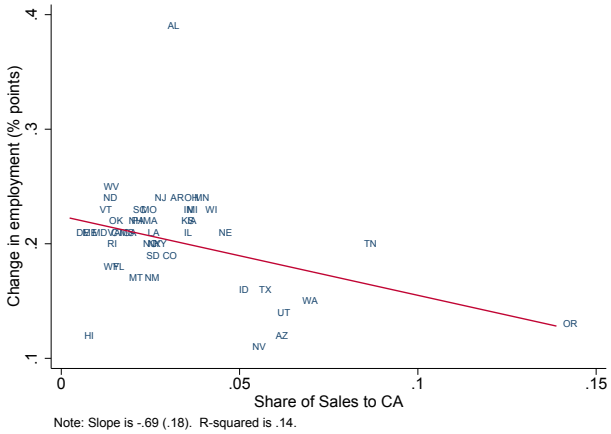
(b) Total Effect

Figure A.5: Lowering Income Tax in California by 1 Percent Point

(a) Employment Changes and Spending Shares



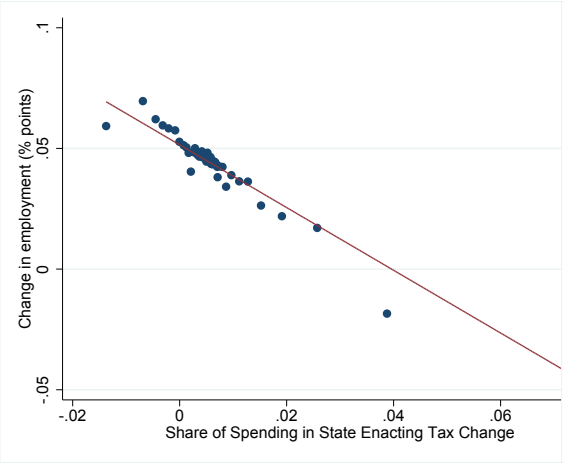
(b) Employment Changes and Sales Shares



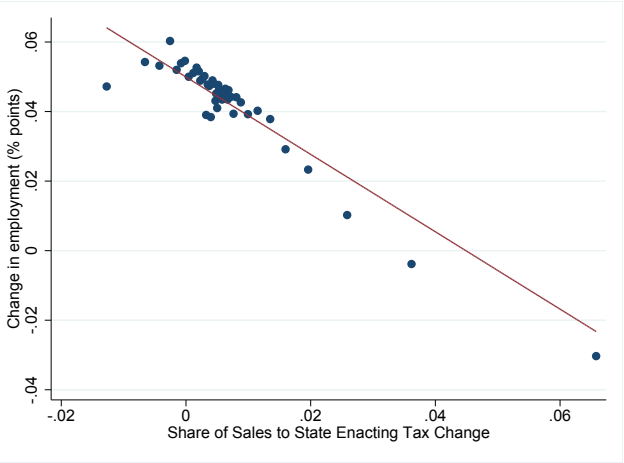
Note: Left panel shows the change in employment by state when there is a 1 percentage point reduction in income taxes in California against California's share in each state spending. California is excluded from the graph. Regression slope is -0.97 (robust s.e.=0.08). Right panel shows the change in employment by state when there is a 1 percentage point reduction in income taxes in California against California share of each state's sales. California is excluded from the graph. Regression slope is -0.69 (robust s.e.=0.18).

Figure A.6: Lowering Income Taxes by 1 Percent Point State by State

(a) Employment Changes and Spending Shares



(b) Employment Changes and Sales Shares



Note: we run 49 counterfactuals consisting of a 1-percent reduction in income taxes for each of the 49 states in our analysis. The figures show the average change in employment for 50 quantiles of the distribution of spending shares in the state enacting the tax change (left panel) and of sales shares to the state enacting the tax change (right panel) controlling for the identity of the state enacting the tax change. The state enacting the tax change is excluded from the figure. Regression slope is -1.29 (robust s.e.=0.03) in the left panel and -1.11 (robust s.e.=0.04) in the right panel.

E.2 Appendix Table to Section 6.2 (Counterfactual Apportionment)

Table A.10: Sales Apportionment of Corporate Income

Sales	Welfare Change				Real	Real Consumption	
Apportionment	Direct	G-constant	Total	Low Trade Costs	GDP	Workers	Capital
0%	0.00%	0.05%	0.22%	0.08%	0.14%	0.15%	-0.01%
50%	0.00%	0.01%	0.05%	0.04%	0.10%	0.05%	0.00%
100%	0.00%	-0.03%	-0.11%	-0.01%	-0.20%	-0.04%	0.00%

F Data Sources

In this subsection we discussed the data used in section 2.1 with motivating evidence, section 4 with the parametrization, and section 5 with the counterfactuals.

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 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.

- 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 (2014)

- 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

- 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:

  - 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 4.2) and Over-Identification Checks (Section 4.4)

- 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: $X_n = X_n^{Total} - Exports_n^{ROW}$.
  - Expenditures: $P_nQ_n = P_nC_n + P_nI_n + P_nG_n + P_nG_n^{fed}$
  - Sales to the own state: $X_{ii} = X_i - \sum_n X_{ni}$.
  - Sales share: $s_{in} = \frac{X_{in}}{\sum_{i'} X_{i'n}}$.
  - Expenditure share: $\lambda_{in} = \frac{X_{in}}{\sum_{n'} X_{in'}}$.

F.3 Estimation (Section 4.3)

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 available 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 μ_{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)