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 a similar increase in real GDP. Additionally, state tax cuts lower own-state economic activity and impact other states differently due to trade linkages. General-equilibrium effects on prices and public services largely drive these results.

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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 taxes are modified frequently – between 1978 and 2010, there have been more than 300 instances in which a state has modified its tax rates by at least 0.5 percentage points. State tax reforms are often subject to debate: at the state level, proponents of lower taxes argue that they help create jobs or attract businesses,[1] while opponents counter that they erode the provision of public services with little effect on employment.[2] At the national level, some maintain that harmonizing tax rates across states would be beneficial because it would help curtail "beggar-thy-neighbor" scenarios.[3] Overall, there is little agreement about the implications of these policies.[4]

This paper studies the impact of changes in the distribution of state tax rates on aggregate real income, welfare, and the spatial distribution of economic activity in the U.S. economy. We ask the following two questions: what is the effect of lowering taxes in one state on that state and on other states? And what are the effects of eliminating dispersion in tax rates across all states? These questions are difficult to answer because many general-equilibrium forces may be 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. To the best of our knowledge, no existing analysis has answered these questions. 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 goods – 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. Firms decide where to locate, how much to produce, and where to sell based on each state's taxes, productivity, factor prices, and trade costs with other states. Workers and firms respectively hold idiosyncratic preferences and productivities across states. The amenity and productivity levels of each state are partly a function of spending in public goods, which varies with state tax revenue. Our model incorporates the main taxes used by states in the U.S.: sales, personal income, and corporate income taxes.[5] Firm and worker decisions depend on taxes both 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) 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`.

[5] Our baseline analysis focuses on these three types of taxes because they can be cleanly measured and account for

partial equilibrium – given relative prices and state spending – and in general equilibrium through their impact on prices and public-goods' provision. 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 public spending. Given the level of public 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, the quantity of public goods provided by states is endogenous, and changes in tax rates in a state may further impact its adjusted fundamentals through changes in the level of public spending. Furthermore, changes in tax rates in a state may also impact the quantity of public goods provided in other states and, therefore, their adjusted amenities, productivities, and trade costs.

To measure the effects of alternative state tax structures within our model, we need estimates of the elasticities of firm and worker mobility with respect to state taxes, as well as of the weight of public expenditures in each state's amenity and productivity. We identify these parameters using the model-implied equilibrium relations between worker and firm location, states taxes, and public spending. 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 (a measure of other states' market sizes discounted by trade frictions), factor prices, and public spending.

We estimate the elasticities of firm and worker mobility using these equations and data for the 1980-2010 period. The estimation strategy uses taxes in other states to instrument for each states' factor prices and government spending. Our estimates are close to those in the literature; e.g., we find an elasticity of state employment of 1 with respect to after-tax real wages and of 0.2 with respect to government revenue. The remaining parameters of the model (production technologies and state fundamentals) are calibrated to exactly match the distribution of wages, employment, and trade in 2007, the most recent year in which all the data we need is available. We verify that the model correctly predicts the distribution of variables not targeted by this parametrization, such as state government size relative to GDP and state tax revenue for each type of tax relative to total tax revenue.

Using the estimated model, we predict the impact of changes in the U.S. state tax system on the distribution of economic activity and aggregate outcomes. We start by measuring the effect of lowering taxes in just one state. Specifically, in each state at a time, we simulate a 1 percentage point reduction income tax rates. On average, this policy causes a 0.05% reduction in welfare for the representative U.S. worker and a loss of economic activity in the state enacting the tax change, with employment falling 2.3% and the number of establishments falling by 1.5%. The

the bulk of state tax revenue; see Section 2 for background on the U.S. tax system. The baseline model also accounts for the main sources of federal revenue. We also explore the implications of including local (sub-state) taxes in our model.

general-equilibrium effects produced by the tax reduction largely drive these effects: keeping prices and government spending constant, the tax reduction leads, on average, to a 1.08% employment increase in the state reducing taxes, but when general-equilibrium variables (goods prices, factor prices, and government spending) are allowed to adjust, employment in the state enacting the tax change decreases. The reduction in economic activity in the state lowering taxes leads to a increase in economic activity in other states, who can use newly freed resources. This response is heterogeneous across states depending on the strength of trade linkages: states who export or import relatively more from the state lowering taxes experience a smaller increase in economic activity.

Having established the impact of changing one state's tax rate, we then assess the impact of tax reforms that harmonize tax rates in all states simultaneously. These counterfactuals are motivated by policy proposals that argue against tax dispersion across states, and are in the spirit of misallocation studies analyzing the elimination of distortions across firms, such as Hsieh and Klenow (2007), or, more closely related to our setup, the elimination of distortions across cities, such as Desmet and Rossi-Hansberg (2013). Under very specific parametrizations of our model, specifically if there are no trade costs and government spending is exogenously given, dispersion in tax rates across states can be shown to reduce real income and welfare. However, these parametrizations are not consistent with the observed data. More generally, our estimated model does not impose an answer to the question of whether eliminating tax dispersion generates welfare gains.

We define the spatial misallocation caused by the current state tax distribution as the welfare and real-income gains (if they exist) that would result from eliminating the dispersion in income, sales, and corporate tax rates across states while keeping the size of state governments constant. We perform this counterfactual exercise under two alternative measures of government size. We first undertake an aggregate revenue-neutral counterfactual by bringing all taxes to a level such that the aggregate tax revenue collectively raised by all states in the counterfactual scenario is kept constant. In this counterfactual, there is a redistribution in public spending from initially high-tax states to initially low-tax states. We find evidence consistent with spatial misallocation from state taxes: this reform leads to a 0.69% welfare gain for the representative U.S. worker and to a 0.65% increase in real GDP, or roughly $100 billion in 2009. We find an important role for trade in driving this result: in the absence of heterogeneity in trade linkages across states, the welfare gains from eliminating tax dispersion would be above 1%, suggesting that trade frictions temper the gains from harmonizing tax rates. Second, we undertake a spending-constant counterfactual by bringing all taxes to a level such that the aggregate tax revenue collectively raised by all states in the counterfactual scenario is such that, though a system of cross-state transfers, each state may feasibly keep government spending constant at its initial level. In this counterfactual, the changes in taxes does not imply any change in public spending in any state. This spending-constant counterfactual also suggests the existence of spatial misallocation: it leads to a 0.12% increase in welfare and to a similar increase in real GDP.

We inspect how the results from these counterfactuals depend on alternative parametrizations

and measures of state tax rates. Among these alternative parametrizations, we consider a case in which public goods have no weight in worker preferences and productivity, and alternatives where we allow for heterogeneity across states in workers' preferences for public goods. In the revenue-neutral counterfactuals, the spatial misallocation under these alternative parametrizations is lower than in the benchmark, but still sizable. We measure positive welfare gains in the order of 0.2% under the extreme case that assigns zero weight to public goods in preferences and productivity. In the spending-constant counterfactuals, worker welfare increases by between 0.11% and 0.2% across parametrizations, while the change in real GDP is not sensitive to the different parameter values. We also recompute the counterfactuals adjusting corporate tax rates for subsidies granted to firms by state governments, using effective rates that account for local taxes instead of statutory rates, incorporating progressivity in state and federal income tax schedules, and under parametrizations corresponding to alternative estimation strategies. We find that spatial misallocation from state taxes continue to be present and has a similar order of magnitude to the benchmark under all these cases.

Finally, we illustrate the uses of our framework by using it to gauge the effects of other policies that appeared in public discussions. Specifically, we explore the implications of the sales apportionment of corporate taxes; i.e., the fact that domestic profits of businesses are allocated to states proportionally to their sales shares in order to compute the effective tax rate those businesses face.[6] The model implies that the sales apportionment of corporate taxes distorts the export decisions of firms in addition to their location decision; firms export relatively more to states with lower sales-apportioned corporate taxes. We simulate the implications of alternative apportionment rules, and find stronger distortions from increasing the apportionment of corporate taxes through sales. We identify a relevant role for trade in driving the effects: 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 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).[7] 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.[8]

[6] 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.

[7] 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).

[8] 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).

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 goods valued by workers and firms. In turn, a central feature of our analysis is 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 public goods) using changes over time and space in those policies.[9] 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.

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.[10] These wedges capture distortions that may be due to multiple sources. Rather than inferring distortions from wedges, we focus on the spatial misallocation generated by one specific type of distortion (state taxes) that we can directly observe in the data. Furthermore, we use the observed variation in this distortion to estimate key elasticities and the weight of public goods in preferences and productivity. Additionally, while a great part of the misallocation literature focuses on the impact of distortions on TFP, we study the impact of state taxes on real income and welfare.

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.[11]

[9] 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) considers state subsidies.

[10] See also Hsieh and Moretti (2015), who use a Rosen-Roback model to measure the TFP effects associated with wage dispersion across U.S. cities. We note that, 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; see Section 3.5. 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.

[11] 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

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 presents the model and its general-equilibrium conditions. Section 4 discusses how we estimate the model parameters. Section 5 analyzes the impact of counterfactual changes in the distribution of state taxes in the U.S.. Section 6 concludes.

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 E 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.[12] 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.[13] In 2010, the average across states was 3%; the states with the

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.

[12]The schedule of state income tax rates tends to be progressive, but it is typically much flatter than the federal income tax schedule. Using data from NBER TAXSIM for the period 1980-2010 on the exact tax rate applied to each income level in each state, we find that the best linear approximation to the state income tax of the average state is $.32 + .04 \times INCOME$, where $INCOME$ is measured in thousands of dollars. A similar linear approximation to the federal income tax system for the same time period yields $8.3 + .1 \times INCOME$. Hence, state income taxes are on average 2.5 times flatter than federal income taxes.

[13]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.

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.[14] 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.[15] In 2012, the average corporate income tax rate across states was 6.4%; the states with the highest corporate tax rates were Iowa (12%), Pennsylvania (10%), and Minnesota (10%), while six states had no corporate tax. Apportionment through sales tends to be more prevalent: nineteen states exclusively apportion through sales, while roughly half of the remaining states apply either a 50% or 33% apportionment through sales. The states that exclusively apportion through sales do not earn corporate tax revenue from those business producing in their state as long as they only sell in other states. 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.[16] 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.[17] 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.

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

[15] 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 $\bar{t}^{j} = t_{fed}^{corp} + t_{i}^{l} + \sum_{n} s_{ni}^{j} t_{n}^{x}$, 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.

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

[17] 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).

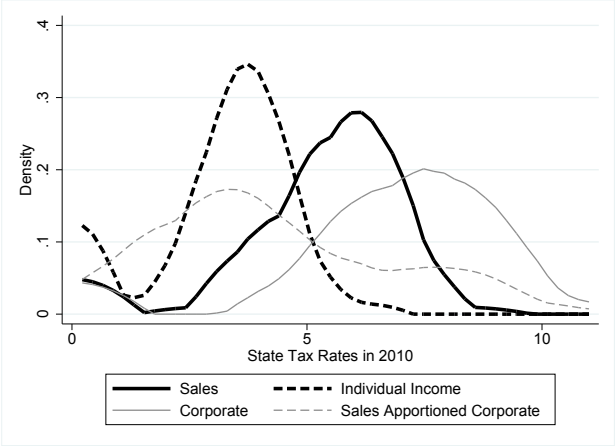
2.2 Dispersion in Tax Rates and Tax Revenue across States

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.[18] 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% .

Local governments also tax residents. Overall, state taxes amount to roughly 60% of state and local tax revenue combined.[19] 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) 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 both use alternative measures of income, corporate and sales tax rates computed as the sum of the state and local tax rates, and include property taxes.

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



[18] 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 15.

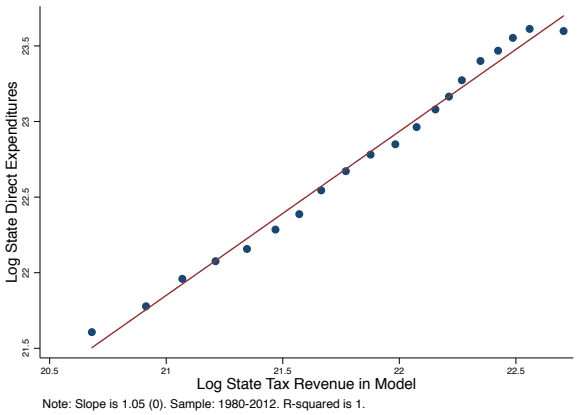
[19] Local governments rely more heavily on property taxes than income, corporate, and sales taxes. Specifically, state taxes make up roughly 90%, 85%, and 80% of consolidated state and local revenue from income, corporate, and sales taxes, respectively, but only 3% of consolidated property tax revenue.

2.3 Relationship Between State Taxes and Government Spending

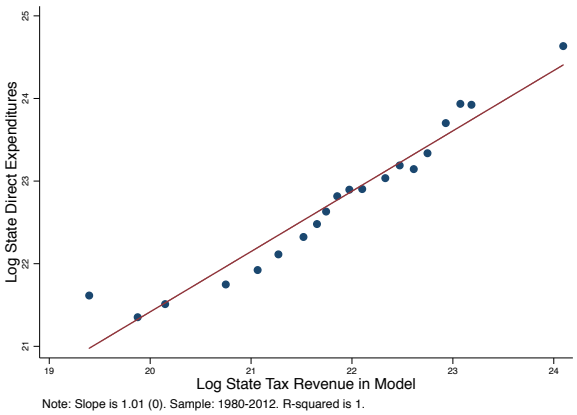
In 2012, direct expenditures by state governments added up to roughly 10% of GDP.[20] State governments typically have balanced budgets (Poterba, 1994), so we assume in our model that changes in state tax revenue translate to changes in state government spending.[21] Figure 2 shows that there is indeed 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.

Figure 2: Comparing State Tax Revenue and Spending

(a) State Fixed Effects



(b) Year Fixed Effects



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

[20] 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.

[21] The taxes that we consider account for about half of total direct spending by states, the rest being accounted for by other taxes, federal grants, and other sources such as utility revenue and insurance trust revenue. SeeBarnett et al. (2014).

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]

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]

[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.

[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

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 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

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

would be endogenous and change in the counterfactuals, but abstract from this margin in our analysis.

[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 5.2.3 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).

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; 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

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

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

where $\bar{t}_i^j$ 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 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:

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

[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.

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-disributed 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. 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 $\overline{\pi}$.[28] 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 $\pi_i\left(z_i^0\right)/\overline{\pi}$) leads to a larger response in the fraction of firms that choose to optimally locate in that location.[29]

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, $\tilde{z}_n/z_n^0 > 1$, reflecting selection. This equation describes a second 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 $p_{ni}(z)$ is the pricing function defined in (11). Using λ_{ni} 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 $\tilde{t}_{ni}$,

$$s_{ni} = \lambda_{ni}\frac{P_n Q_n}{X_i}, \tag{19}$$

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

[29] This structure 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.

[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 the implication of the distributional assumption on the productivity draws that average profits are $\pi\left(\tilde{z}_i\right) = \bar{\pi}$ in every state together with (15) and the fact, implied by (14), that $\frac{\pi_i\left(z_i^0\right)}{\pi_n\left(\tilde{z}_i\right)} = \left(\frac{z_i^0}{\tilde{z}_i}\right)^{\sigma-1}$.

where $P_n Q_n$ are aggregate expenditures on final goods in state n. From the distribution of λ_{ni} we can also construct aggregate state-i sales X_i. By definition, they add up to sales to every state:

$$X_i = \sum_n \lambda_{ni} P_n Q_n. \tag{20}$$

Because of 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.[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- and after-tax profits $\tilde{\Pi}_n$ and Π_n are also proportional to sales:

$$\tilde{\Pi}_n = \frac{X_n}{\sigma}, \tag{21}$$

$$\Pi_n = \left(1 - \bar{t}_n\right) \tilde{\Pi}_n. \tag{22}$$

3.4 Government

State governments use tax revenue R_n to finance public spending G_n. The government budget constraint in state n satisfies:

$$P_n G_n = R_n^{corp} + R_n^y + R_n^c, \tag{23}$$

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

$$R_n^{corp} = t_n^x \sum_{n'} s_{nn'} \tilde{\Pi}_{n'} + t_n^l \tilde{\Pi}_n, \tag{24}$$

$$R_n^y = t_n^y \left(1 - t_{fed}^y\right) \left[w_n L_n + b_n \left(\Pi + R\right)\right], \tag{25}$$

$$R_n^c = t_n^c P_n C_n. \tag{26}$$

The base for corporate tax profits are the pre-tax profits from every state, defined in (21), adjusted by the proper apportionment weights. 25 shows that the base for state income taxes is gross state income of both workers and capital-owners who reside in n, after federal income taxes have been paid. The base for the sales tax in 26 is the total personal consumption expenditure of workers and capital owners, $P_n C_n$, defined in (A.11) in Appendix B.2.

Taxes are also collected by the federal government. Total taxes paid by residents of state n to the federal government are:

$$P_n G_{n,fed} = \left(t_{fed}^y + t_{fed}^w\right) w_n L_n + b_n t_{fed}^y \left(\Pi + R\right) + b_n t_{fed}^{corp} \sum_{n'} \tilde{\Pi}_{n'}. \tag{27}$$

The first term accounts for payroll and income taxes paid by workers, the second term is the income

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

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.

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

$$z_n^A = (1-\bar{t}_n)^{\frac{1}{\sigma-1}-\left(\frac{1}{\varepsilon_F}+\alpha_F\chi_F\right)}\left(\frac{P_nG_n}{GDP_n}\right)^{\alpha_F} * z_n^{1-\alpha_F}, \tag{28}$$

$$\tau_{in}^A = \frac{\sigma}{\sigma-\tilde{t}_{in}} * \tau_{in}, \tag{29}$$

$$u_n^A = (1-T_n)^{1-\alpha_W}\left(\frac{P_nG_n}{GDP_n}\right)^{\alpha_W} * u_n, \tag{30}$$

where $\frac{P_nG_n}{GDP_n}$ is state government spending, defined in (23), over state GDP. After some manipulations, we can express this share as

$$\frac{P_nG_n}{GDP_n} = \frac{t_n^x\frac{P_nQ_n}{X_n} + t_n^l + \left(1-t_{fed}^y\right)\frac{t_n^c+t_n^y}{1+t_n^c}\frac{b_n}{\tilde{\Pi}_n/(\Pi+R)} + \left(\left(1-t_{fed}^y\right)\frac{t_n^c+t_n^y}{1+t_n^c} - \frac{t_n^c}{1+t_n^c}t_{fed}^w\right)(1-\beta_n)\gamma_n(\sigma-1)}{\gamma_n(\sigma-1)+1}, \tag{31}$$

where $\frac{P_nQ_n}{X_n}$ is the share of state expenditures to sales (i.e., a measure of state trade deficit) show in equation (A.18) in Appendix B.2.[32] In Section 4.4 we contrast the estimated model's prediction for this variable against the data.

[32]To reach (31), first replace P_nC_n from (A.11), R_n^y from (25), and R_n^{corp} from (A.16) into the government budget constraint (27), and then normalize by GDP using (A.9).

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 first 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, so that the income generated in state n is spent in state n.[33] 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. In this case, state taxes $\left\{t_n^c, t_n^y, t_n^l, t^x\right\}$ 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 (leading to $T_n = 0$ for all n) 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 ($\bar{t}_n = 0$ for all n) but with a different distribution of productivities (equal to z_n^A). Because government sizes relative to GDP also depend on tax rates, equations (28) to (30) do not allow to compute the exact matching between taxes and adjusted fundamentals but we can generally say that sales and income taxes (both individual and corporate) are similar to a certain distribution of amenities and productivities: the equilibrium outcomes can be rationalized without these taxes but with a different distribution of amenities and productivity (equal to the adjusted ones, z_n^A and u_n^A).

We can rely on this structure to understand how taxes impact welfare in simplified environments. Since welfare v is increasing in the productivity or in the amenity of any state, a tax change leading to higher adjusted productivity or amenities in any particular state improves welfare. Consider, for example, a case with no federal taxes ($t_{fed}^y = t_{fed}^w = 0$), no corporate taxes ($\bar{t}_n = 0$, for all n), and where only workers value government spending ($\alpha_W > 0 = \alpha_F$). From (30), it follows that the adjusted amenities u_n^A are maximized by setting individual income and sales taxes such that $T_n = \alpha_W$.[34] This simplified case shows a force in the model whereby a closer alignment between the tax rates and the weights of government spending in preferences (α_W) is associated with higher welfare. More generally, uniform tax schemes do not necessarily maximize

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

[34] E.g., by setting $t_n^y = \alpha_W$ and $t_n^c = 0$, or $t_n^c = \frac{\alpha_W}{1-\alpha_W}$ and $t_n^y = 0$.

indirect utility due to fiscal interactions within and between states: both corporate taxes $\bar{t}_n$ and personal taxes T_n simultaneously impact the adjusted fundamentals of the own state and of every other state through government size relative to GDP and through trade imbalances. This complicates the characterization of the optimal taxes in the general environment that we use to perform counterfactuals.

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 firms also have incentives to locate near large markets. In turn, the price index of a location decreases with the number of firms, and market size increases with the number of firms and workers.Our model also features agglomeration through public-goods provision. States with a larger number of firms and workers will allow have higher public 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)). Through these agglomeration forces, workers and firms tend to locate in the same state.

At the same time, our model features congestion forces through the use of an immobile factor (land and structures) in production and through selection of heterogeneous firms (as implied by (17)). These two forces push firms and workers to spread across different states.

In light of the presence of both agglomeration and congestion forces in our model, 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, which amounts to assuming that the returns to firms and fixed factors are spent in the same state where they are generated. Appendix B.5 shows the 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 the procedure we follow to assign numbers to the parameters of the model described in Section 3. 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 shares of the fixed factor across states. These parameters are chosen so that the model exactly reproduces the distribution of employment, wages, labor and intermediate-inputs shares of income, bilateral sales and expenditure shares across states, and trade imbalances in a given year; we choose 2007

[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.

because this is the latest year in which all these data are available. In Section 4.3, we present the approach we follow to estimate 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.

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 E.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, $P_i C_i$. 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 are constructed from the difference between state sales and GDP, and total expenditures 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, 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 E.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 goods $P_n G_n$ 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

[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.

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 (21), (A.7) and (A.6) match their empirical counterparts, as described in Table 1. To perform this calculation, we use the value of σ described in Section 4.3.

Parameter	Notation	Match in the Data	Average
Share of intermediates in production in state n	$1-\gamma_n$	$=\frac{\sigma}{\sigma-1}\frac{P_n I_n}{X_n}$	0.62
Labor Share in Production in State n	$1-\beta_n$	$=\frac{\sigma}{\sigma-1}\frac{w_n L_n}{\gamma_n X_n}$	0.68

Table 1: Technology Parameters

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 counterfactual outcome through their impact on the composite A_{in} defined in (A.25) 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.23). We therefore do not need to separately identify the value of all fundamentals. [39] Note that this procedure implies that the estimated model exactly matches the distribution of expenditure shares, sales shares, wages, and employment in 2007.

Ownership Rates We set the ownership rates $\{b_n\}$ to match relative trade imbalances, defined as the ratio of expenditures to sales. Using (A.18) in the Appendix B.2, the following expression uniquely identifies b_n from observables, technology parameters (set in Section 4.2), and the parameter σ (set in Section 4.3):

$$b_n = \frac{\tilde{\Pi}_n}{\Pi + R + t_{fed}^{corp}\tilde{\Pi}}\left[(\sigma - t_n^x)\left(\frac{P_n Q_n}{X_n}\right) - (\sigma-1)(1-\beta_n\gamma_n) - t_n^l\right], \tag{32}$$

where, as shown in (A.19) in Appendix B.2, the term in front of this expression is a function of parameters, tax rates and sales.[40]

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

[39] 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 in a quantitative trade model with respect to trade costs without having to separately identify all the fundamentals.

[40] 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

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 the counterfactual predictions of our model 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 2 shows 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 below. The elasticity of firm mobility, ε_F, and the weight of government spending in productivity, α_F, are estimated using the firm-location equation, as described in Section 4.3.2 below. Appendix section C.5 shows that our estimates for these parameters are in line with previous estimates.[41]

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 2: 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 (23), we obtain the following expression for the share of labor located in state n at time t:

$$\ln(L_{nt}) = a_0 \ln(\tilde{w}_{nt}) + a_1 \ln\left(\tilde{R}_{nt}\right) + \psi_t^L + \xi_n^L + \nu_{nt}^L, \tag{33}$$

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;[42] $\xi_n^L + \nu_{nt}^L \equiv \varepsilon_W/(1+\chi_W\varepsilon_W\alpha_W)\ln(u_{nt})$ 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

$b_n = .14 + 1.36 SHARE_n$ where the standard errors for the intercept and slope are .018 and .28, respectively.

[41] For γs and βs equal to the averages in Table 1, the resulting set of parameter estimates satisfies the sufficient conditions for uniqueness of the equilibrium shown in (A.31) and (A.32) 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.

[42] 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.

$\tilde{R}_{nt} = R_{nt}/P_{nt}$ 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 will be 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^L_{nt} .[43] Specifically, our model predicts amenities in a state to be negatively correlated with after-tax real wages and positively correlated with real government spending. Intuitively, higher amenities in a state will attract workers to it, shift out the labor supply curve, and lower wages. Similarly, the increase in the number of workers will raise the tax revenue and thus increase real government spending. Our model thus predicts that the OLS estimate of a_0 will be biased downwards, and the OLS estimate of a_1 will be 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^L_t and ξ^L_n 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, $\boldsymbol{Z}^L_{nt} \equiv (1 - T_{nt}, 1 - t^{corp}_{nt})$, and a vector of tax rates in states other than n at period t, $\boldsymbol{Z}^{L*}_{nt} \equiv (t^{*c}_{nt}, t^{*x}_{nt}, t^{*y}_{nt})$. Specifically, the components of the vector $\boldsymbol{Z}^L_{nt}$ account for state-n sales and income taxes, $1 - T_{nt}$, and for state-n corporate taxes, $1 - t^{corp}_{nt}$ where t^{corp}_{nt} is the corporate tax rate, $t^{corp}_{nt} \equiv t^x_{nt} + t^l_{nt}$. The components of vector $\boldsymbol{Z}^{L*}_{nt}$ are "external" taxes, defined as an inverse-distance to state n weighted average of sales, income, and sales-apportioned corporate tax rates from every state other than n n:

$$t^{*z}_{nt} \equiv \sum_{i \neq n} \omega_{ni} t^z_{it}, \quad with \quad \omega_{ni} = \frac{\ln(dist_{ni})^{-1}}{\sum_{i' \neq n} \ln(dist_{ni'})^{-1}} \quad for \quad z = c, x, y.$$

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 $\boldsymbol{Z}^L_{nt}$ and $\boldsymbol{Z}^{L*}_{nt}$ as instruments for $\tilde{w}_{nt}$ and $\tilde{R}_{nt}$ assumes that both state-n and other states' taxes in any time period t' potentially different from t are, after controlling for year and state effects, mean independent to ν^L_{nt}, which represents amenities and the quality or the efficiency of government spending in state n and period t. Formally,

$$\mathbb{E}[\nu^L_{nt} | \boldsymbol{Z}^L_n, \boldsymbol{Z}^{L*}_n, d_n, d_t] = 0,$$

where $\boldsymbol{Z}^L_n = (\boldsymbol{Z}^L_{n1}, \ldots, \boldsymbol{Z}^L_{nt}, \ldots, \boldsymbol{Z}^L_{nT})$ and analogously for $\boldsymbol{Z}^{L*}_n$. In words, this restriction implies that, conditional on the state and year effects, the amenities in state n and period t are mean

[43] 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^G_{nt}, which represents the efficiency or quality of government spending, it would enter multiplicatively with u_{nt}.

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.

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 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 that

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

Appendix C.2 provides the first-stage estimates in Table A.3 and a discussion of the first-stage results. Table 3 shows the estimates of ε_W and α_W. 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.[44] 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.

Table 3 also reports the estimates of the structural parameters ε_W and α_W . 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) as our preferred specification. It implies a labor supply elasticity ε_W of roughly 1.5 and, given a value $\chi_W = 1$, a public goods parameter α_W of 0.17. As we reduce the value of χ_W, the estimates of the labor supply elasticity become slightly lower. These results line up well with the existing literature which uses different shocks and settings (see appendix section C.5 for details).

[44] 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 the model in Section 3 as described earlier in this section.

Table 3: 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

$$\ln M_{nt} = b_0 \ln\left((1-\bar{t}_n)\, MP_{nt}\right) + b_1 \ln(\tilde{R}_{nt}) + b_2 \ln c_{nt} + \psi_t^M + \xi_n^M + \nu_{nt}^M, \tag{34}$$

where $b_0 \equiv (\varepsilon_F/(\sigma-1)) \times (1/(1+\chi_F \alpha_F(\sigma-1)))$, $b_1 \equiv \varepsilon_F \alpha_F/(1+\chi_F \alpha_F(\sigma-1))$, and $b_2 \equiv -\varepsilon_F/(1+\chi_F \alpha_F(\sigma-1))$; $\psi_t^M = (-\varepsilon_F/(\sigma-1)) \times (\ln(\sigma \bar{\pi}_t)/(1+\chi_F \alpha_F(\sigma-1)))$ is a time effect; and $\xi_n^M + \nu_{nt}^M \equiv ((1-\alpha_F)\varepsilon_F/(1+\chi_F \alpha_F(\sigma-1))) \times \ln(z_{nt})$ accounts for state effects and deviations from state and year effects in log productivity, $\ln(z_{nt})$. The term MP_{nt} is the market potential of state n in year t,

$$MP_{nt} = \sum_{n'} E_{n't} \left(\frac{\tau_{n'nt}}{P_{n't}} \frac{\sigma}{\sigma - \tilde{t}_{n'nt}} \frac{\sigma}{\sigma - 1} \right)^{1-\sigma}, \tag{35}$$

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 (35) are contained in Appendix C.1.

If we were to estimate the coefficients b_0, b_1, and b_2 in (34) using a GMM estimator that relies on the right-hand side variables in equation (34) as instruments, our model predicts that the

resulting estimates would be 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 both in state n as well as in other states, and a shifter for market potential. Specifically, we denote by $\boldsymbol{Z}_{nt}^M \equiv 1 - t_{nt}^{corp} - t_{fed,t}^{corp}$ the vector of own-state taxes, by $\boldsymbol{Z}_{nt}^{M*} \equiv (t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$ the vector of external taxes, and by MP_{nt}^* the exogenous shifter of the market potential term defined in equation (36). Specifically, the vector $\boldsymbol{Z}_{nt}^M$ is the state n keep-rate for corporate taxes; the vector $\boldsymbol{Z}_{nt}^{M*}$ includes the inverse-distance weighted average of the income, sales and sale-apportioned corporate tax rates of every state other than state n. The term MP_{nt}^* has a similar structure to market potential in (35),

$$MP_{nt}^* = \sum_{n' \neq n} E_{n't}^* \left(\frac{\tau_{n'nt}}{P_{n't}^*} \frac{\sigma}{\sigma - \tilde{t}_{n'nt}^*} \frac{\sigma}{\sigma - 1} \right)^{1-\sigma}, \tag{36}$$

but differs from MP_{nt} in that we substitute the components E_{nt}, P_{nt}, and $\tilde{t}_{n'nt}$ that might potentially be correlated with ν_{nt}^M by functions of exogenous covariates that we respectively denote as E_{nt}^*, P_{nt}^*, and $\tilde{t}_{n'nt}^*$. See Appendix C.1 for a precise definition of 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. In this case, the GMM estimator that uses both $\boldsymbol{Z}_{nt}^M$, $\boldsymbol{Z}_{nt}^{M*}$ and MP_{nt}^* as instruments assumes that both state-n and other states' taxes in any time period t' potentially different from t are, after controlling for year and state effects, mean independent to ν_{nt}^M, which represents productivity and the efficiency of government spending in state n and period t in providing goods that affect firms' productivity. Formally,

$$\mathbb{E}[\nu_{nt}^M | \boldsymbol{Z}_n^M, \boldsymbol{Z}_n^{M*}, MP_n^*, d_n, d_t] = 0,$$

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 state n number of establishments only through their effect on real government spending, unit production costs, and market potential in that state. The orthogonality conditions necessary for consistency of our GMM estimator are weaker when we only rely on state and year fixed effects and the vectors $\boldsymbol{Z}_{nt}^{M*}$ and MP_{nt}^* to construct moments. In this case, the resulting GMM estimates will be 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 (36); i.e, they depend on the exact definition of E_{nt}^*, P_{nt}^*, and $\tilde{t}_{n'nt}^*$. As described in AppendixC.1, 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 $\tilde{t}_{n'nt}^*$.[45]

[45]The usage of lagged GDP in the construction of E_{nt}^* implies that the orthogonality restriction from equation 36

Table 4 presents the main 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 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) which correspond to the pair $(\sigma, \chi_F) = (4, 1)$. These estimates are broadly consistent with estimates from different settings (see appendix section C.5 for details).

Table 4: 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.

might not hold. Furthermore, the use of state n taxes in the construction of MP_{n}^{*} implies that the GMM estimator that relies on this instrument will not be inconsistent if we don't maintain the assumption that taxes in state n are independent of the composite ν_{nt}^{M}. In order to test the robustness of our results, we also compute estimates of the coefficients b_0, b_1, and b_2 that rely on alternative definitions of MP_{n}^{*}. For more details and results, see Appendix C.1 and Table A.5.

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.4compare the model implications for the share of state n in national GDP and in the total number of establishments against the data in 2007.[46] Both line up almost perfectly, which reflects that, in the data, both state GDP and number of establishments across states are proportional to sales, as our model predicts

Second, we study the implications of our model for the share of government revenue in state GDP (see equation (31)). 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.[47] 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 of total government revenue coming from each type of tax with the actual shares observed in the data .[48] Overall, 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 and adjust for the share of C-corporations.

5 Assessing the Impact of State Tax Reforms on the US Economy

In this section, we quantify the general-equilibrium impact of changes in state taxes by imposing counterfactual distribution of state taxes. We replace the distribution of state taxes in 2007 with a new distribution keeping every other parameter and federal taxes constant at the 2007 level and recompute the equilibrium of the model. 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 in reaction to exogenous changes in state taxes. Since we are interested in aggregate effects, we compute the following outcomes relative

[46] From (A.9) in Appendix B.2, the share of state n in national GDP 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.20), the share of establishments of state n is proportional that state's share of after-tax profits: $M_n = \frac{\Pi_n}{\Pi} = \frac{(1-\bar{t}_n)\frac{X_n}{\sigma}}{\sum_{n'}\left(1-\bar{t}_{n'}\right)\frac{X_{n'}}{\sigma}}$.

[47] Specifically, the adjusted amenities and productivities in (30) and (28) depend on $\frac{P_nQ_n}{GDP_n}$.

[48] 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.

to the initial values (we use $\widehat{x} = x'/x_{2007}$ to denote the ratio between the value of the variable x in the counterfactual scenario and its initial value):

Worker Welfare Combining (7) and (8), the relative change in welfare for the representative worker is

$$\widehat{v} = \left(\sum_n L_{n,2007} \widehat{v}_n^{\varepsilon_W} \right)^{\frac{1}{\varepsilon_W}}, \tag{37}$$

where, from (5), $\widehat{v}_n$ depends on the change in after-tax real wages in state n and real government services:

$$\widehat{v}_n = \left(\frac{1 - T_n'}{1 - T_{n,2007}} \frac{\hat{w}_n}{\hat{P}_n} \right)^{1-\alpha_W} \left(\frac{\widehat{G}_n}{\widehat{L}_n^{\chi_W}} \right)^{\alpha_W}. \tag{38}$$

Aggregate Real Income We define aggregate real income as the aggregation of real regional GDP: $GDP^{real} = \sum_n \frac{GDP_n}{P_n}$. Equation (A.10) in Appendix B.2 shows the expression for $\widehat{GDP}^{real}$.

Aggregate Real Consumption We also compute the change in the aggregate real consumption of workers, C^W, and capital-owners, C^K, as alternative welfare measures. (A.12) and (A.13) in Appendix B.2 show the expressions that we use to compute the changes in these outcomes.

In addition, we are interested in the importance of general-equilibrium effects and trade frictions in driving these aggregate changes. Therefore, we also consider the following alternative measures.

Direct Welfare Effect We define the direct welfare effect of taxes as their impact on worker welfare keeping every general-equilibrium variable (including government spending) constant. From (37) and (38), this can be constructed using (37) but evaluated at

$$\widehat{v}_n^{direct} = \left(\frac{1 - T_n'}{1 - T_{n,2007}} \right)^{1-\alpha_W}$$

instead of $\hat{v}_n$ in (38). As a result, the direct effect of changes in taxes is an employment-weighted average of the changes in real consumption associated with these tax changes if no reallocation happens and no price change takes place.

G-Constant Effects To gauge the importance of changes in government spending, we compute the effect on worker welfare that results from allowing general-equilibrium effects in every variable except for government spending; this is the welfare effect of a change in taxes in an economy in which each state supplies a fixed endowment of government services regardless of how much tax revenue it collects.[49] The term $\hat{v}^{Gconst} - \hat{v}^{direct}$ is indicative of the importance of the reallocation of workers, firms and trade flows in driving the results .

[49] In practice, we solve for these counterfactuals by computing the solution to the model in changes but without imposing the government budget constraint and assuming instead that $\hat{G}_n = 1$.

Effects under Low Trade Frictions To explore the implications of trade costs for our results, we also report worker welfare changes starting from a different parametrization that does not match the actual distribution of import and export shares across states (see Section 4.2). Instead, we assume symmetric export and import shares across states.[50] In the absence of corporate taxes, these symmetric export and import shares would be the equilibrium outcomes of our model if there were no trade costs. Hence, this alternative parametrization explores how our counterfactual results would differ in an environment in which trade costs are assumed away.

5.1 Changes in Tax Rates in a Single State

Our first set of counterfactuals answers the question: What are the effects of tax changes in one state on this same state, on other states, and on the aggregate economy? To illustrate the mechanisms at work, we first study the impact of a reduction in the income tax rate in California by 1 percentage point. Then, we simulate a 1 percentage point reduction in the average income tax in all taxes; we implement this counterfactual change in the income tax separately for each state, and report the average effect observed across states.[51]

5.1.1 Reduction in Income Taxes in California

Panel (a) of Table 5 reports the percentage change in aggregate welfare, employment, number of firms, real wage, real GDP, and real government spending both when government spending in every state is kept constant (columns 2 and 3) and when it is forced to change so that every states' government budget is balanced after the tax change in California (last two columns). Keeping government spending constant, this reduction in taxes in California increases the welfare of the representative U.S. worker by 0.12%. From (30), higher tax keep rates, i.e., $(1 - T_n)$, are similar to an increase in amenities in California, which raises the number of workers in this state by 0.72%, in detriment of the labor supply in the rest of the U.S. This increase in labor supply reduces the wage in California. However, because of trade costs, firms are also attracted to California ($\hat{M}_{CA} - 1 = 1.38\%$), leading to an increase in the set of varieties produced in this state. This increase in varieties partially offsets the wage decline through a reduction in the price index. After-tax real wages and rents, however, increase; the combined effect of factor inflow and higher prices boost GDP, which increases in real terms by 0.29%; in the rest of the U.S., the effects on real wages and GDP are flipped due to the reallocation of workers to California. When government spending adjusts in every state to satisfy each states' government budget constraint, government revenue in California falls by 12%. This reduction in tax revenue reduces the provision of public goods in California, 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 California by 1.57% and 1.98%, respectively, and the welfare of the representative U.S. worker decreases by 0.22%.

[50] I.e., we use the artificial import shares $\lambda_{ni} = \frac{X_i}{\sum X_{i'}}$ for all n and $s_{ni} = \frac{E_n}{\sum E_{n'}}$ for all i.

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

Table 5: Reducing Income Tax in CA by 1 percentage point

Change in	G Constant		Total Effect	
	CA	Rest of U.S.	CA	Rest of U.S.
Welfare	0.12%		-0.22%	
Employment	0.72%	-0.09%	-1.57%	0.2%
Firms	1.38%	-0.19%	-0.40%	0.06%
Real Wage	-0.42%	0.05%	-0.42%	-0.07%
Real GDP	0.29%	-0.05%	-1.98%	0.13%
Real Government Spending	0%	0%	-12.49%	0.08%

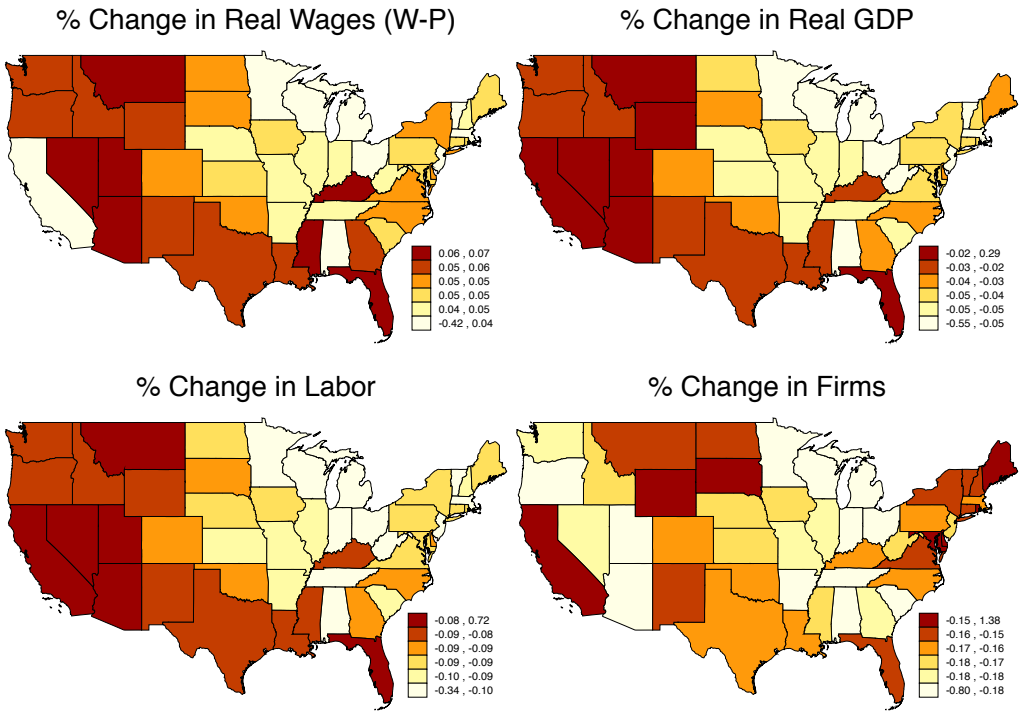
How important are general-equilibrium effects in driving the reported impact in California of its reduction in the income tax rate? Using the solution of the labor supply equation (7), (5), and the benchmark parameters summarized in Table 2, the -1.57% change employment predicted in the case in which public spending is allowed to change can be decomposed as follows:

$$\ln\left(\hat{L}_{CA}\right) = \underbrace{0.99 * \ln\left(\frac{1-T'_{CA}}{1-T_{CA,2007}}\right)}_{1.27\%} + \underbrace{0.99 * \ln\left(\hat{w}_{CA}/\hat{P}_{CA}\right)}_{-0.41\%} + \underbrace{0.20 * \ln\left(\hat{G}_{CA}\right)}_{-2.7\%} - \underbrace{1.18 * \ln\left(\hat{v}\right)}_{-0.26\%}. \tag{39}$$

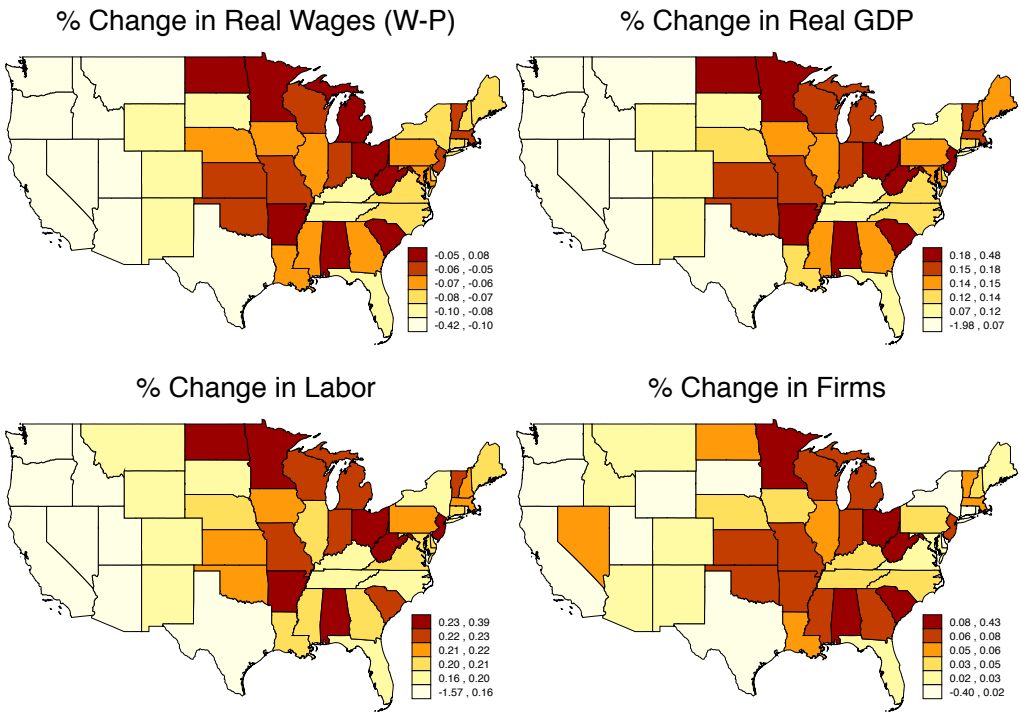
The 1 percentage point reduction in the income tax rate in California is equivalent to a 1.28% increase in its keep-tax rate; given the estimate $a_0 = 0.99$ in (33), this translates to a predicted increase in employment of 1.27%. However, in general equilibrium, the reduction in real wages and in the 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.

What drives the effect in other states of a reduction in the income tax rate in California? Of course, a change in taxes in California can only have an impact in the rest of the U.S. because of the general-equilibrium forces included in the model –as their taxes are not being modified. Figure 3 shows the impact of this tax change state-by-state. There is heterogeneity across states in the changes in real wages, real GDP, employment, and number of firms. When government spending is kept constant, employment in California grows and it shrinks in every other state. However, the negative employment effect is milder in states that are close to California.

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



(a) Holding Government Spending Constant



(b) Total Effect

The bottom panel shows that 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 import and export shares. This relationship can be seen in Figure A.3, which shows the employment change by state as function of each state's share of sales to CA (left panel) and share of spending in goods coming from CA (right panel). In the government spending is allowed to change, the reduction in income taxes is a negative shock to California, which shrinks in terms of both labor and GDP; as a result, employment increases everywhere else, but less so in states that rely more on California either as an export market or a source of final goods or intermediate inputs.

5.1.2 Average Effects of a Reduction in Income Taxes

Our goal now is to assess if the effects of the reduction in income taxes in California described above are representative of what would happen if a typical U.S. state were to reduce its income tax. Therefore we run 49 counterfactuals, one for each state in our data, and re-do the analysis from the previous section for each of them. Table 6 reproduces Table 5, where each element in the table is an average of the corresponding element across the 49 counterfactuals. We see very similar patterns to what we obtained in the specific case of California: typically, when a state lowers income taxes and government spending is kept constant, the state enacting the tax change gains employment and its economy expands. When government spending is allowed to adjust, the effects are reversed: on average, reducing taxes leads to a reduction in welfare. Because California is a large state, the average spillover and aggregate effects are smaller than for the California counterfactual.

Table 6: Reducing all taxes by 1 percent point

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%

To assess the importance of general-equilibrium forces, we compute each component of equation (39) in each counterfactual for the state enacting the tax change, and then take an average of each component across all 49 counterfactuals. Equation (40) shows a large positive direct effect from reducing taxes on the state implementing the tax change, which is partially offset by general-equilibrium forces consisting in lower real wages and more than offset by the reduced supply of

public services.

$$\overline{\ln\left(\hat{L_n}\right)} = \underbrace{0.99 * \overline{\ln\left(\frac{1-T'_n}{1-T_{n,2007}}\right)}}_{1.08\%} + \underbrace{0.99 * \overline{\ln\left(\hat{w_n}/\hat{P_n}\right)}}_{-0.56\%} + \underbrace{0.20 * \overline{\ln\left(\hat{G_n}\right)}}_{-2.97\%} - \underbrace{1.18 * \overline{\ln\left(\hat{v}\right)}}_{-0.06\%}. \quad (40)$$

The average effect in the rest of the U.S. reported in Table 6 hides heterogeneous effects across states. Figure A.4 shows the employment change on states other than the state enacting the tax change as function of each state's share of spending in the state enacting the tax change (left panel) or each state's share of sales to the state enacting the tax change (right panel). Similar to what we observed in Figure A.4, there is heterogeneity in the response to the tax change across states depending on how much they rely on the state whose tax has changed. Lower taxes on average imply a reduction in market size and production for the state enacting the tax change; this releases employment to other states, but states with stronger export and import linkages with the state whose taxes have gone down benefit relatively less.

5.2 Eliminating Tax Dispersion

We now assess the impact of tax reforms that harmonize tax rates in all states. We define the spatial misallocation caused by the current state tax distribution as the welfare and real-income gains (if they exist) that would result from eliminating the dispersion in income, sales, and corporate tax rates across states while keeping the size of state governments constant.

In a specific parametrization where there are no trade costs, 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, our model collapses to the structure in Hsieh and Klenow (2007), with dispersion in tax rates across states playing a similar role to distortions across firms in their case. In this very specific case, dispersion in tax rates across states will reduce real income and welfare.

However, as long as some of these assumptions are not imposed, it is theoretically unclear whether eliminating tax dispersion will improve welfare and real income. First, keeping government spending constant, unobserved amenities imply that real income is not necessarily maximized under homogeneous taxes. Additionally, keeping government spending constant, trade costs and firm mobility lead to home market effects, whereby the returns to locating in a state are a function of the number of workers and firms located in close-by states. Because of this spatial externalities, the market allocation is not generically efficient and, therefore, any distortion that makes the equilibrium different from the market allocation will not generally be welfare and real-income reducing. Additionally, when government spending is allowed to change with taxes, there are fiscal externalities whereby changes in taxes in one state affect the provision of public goods in the own state and in other states through each state's government budget constraint, which also creates spatial externalities which are not internalized by agents. As a result, our theoretical model does not impose an answer for whether eliminating tax dispersion leads to welfare gains.

5.2.1 Benchmark

Table 7 presents the results for a set of counterfactuals in which we eliminate the dispersion observed in 2007 in tax rates across states. 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. In each of these counterfactuals, we choose the counterfactual tax rate to which we bring taxes in all states to be such that the total revenue collective raised by all states in the U.S. remains constant at its initial level. When we equalize tax rates across states for all taxes simultaneously, we find that aggregate state tax revenue is left constant 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.

Table 7: Removing Tax Dispersion: All taxes to the same percentile

Counterfactual	Welfare Change				Real GDP	Real Consumption	
	Direct	G-constant	Total	Low Trade Costs		Workers	Capital
All state taxes	0.00%	0.12%	0.69%	1.01%	0.65%	0.30%	0.41%
Income Taxes	0.09%	0.13%	0.49%	0.75%	0.29%	0.19%	0.23%
Sales Taxes	0.01%	0.01%	-0.08%	-0.13%	-0.06%	-0.08%	-0.10%
Corporate Taxes	0.00%	0.08%	0.55%	0.72%	0.51%	0.40%	0.35%

The first column shows negligible direct welfare effects (i.e., keeping prices, government spending, and employment constant at their initial values) from removing tax dispersion; because some tax rates increase and others decrease, the real consumption does not change at the initial prices. The second column shows that, keeping government spending constant in every state, the reallocation associated with this reduction in dispersion leads to a welfare gain of 0.12%, pointing to some distortionary effects from heterogeneity in taxes. The remaining rows in the same column show that, when dispersion is removed in a revenue-neutral way in one type of tax at a time, the largest reallocation effect corresponds to corporate taxes. The third column shows that the welfare gain of workers raises to 0.69% when government spending is allowed to adjust. As shown in the fourth column, the worker welfare gains from eliminating tax dispersion are considerably larger (1.01%) under the alternative parametrization that assumes instead that import and export shares are proportional to the share of national sales and expenditures respectively. This suggests that lower trade frictions increases the gains from misallocation, pointing to a complementarity between reducing tax dispersion and eliminating barriers to trade. These results capture the welfare changes of workers; when dispersion in all taxes is eliminated (first row) the gains in real GDP are similar to the total welfare change of workers, with the real consumption of final goods by workers and capital-owners increasing by around half that amount (see last two columns).[52]

[52] Appendix D.3 presents an alternative counterfactual in which all taxes are brought to the mean of their distribution. This counterfactual turns out to be revenue-neutral as well, leading to welfare gains of 0.36% keeping

Even though these gains may appear small, note that they correspond to a revenue-neutral change in taxes whose aggregate tax revenue only adds up to 4% of GDP. Note, additionally, that in undertaking this exercise we keep either the distribution of real government spending (column 2) or total state revenue (column 3) constant at their initial levels, thus isolating the effects of tax heterogeneity from effects associated with the overall levels of taxes and spending. Therefore, the results point to considerably distortionary effects from tax dispersion relative to initial levels of government spending and tax revenue.

5.2.2 Heterogeneous Preferences for Government Spending Across States

The benchmark model assumes that the preference for government spending α_W is constant across states. We consider how allowing for heterogeneity across states in workers' preferences for government services affects our results.[53] 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) and that takes higher values for states with higher Republican party vote shares in national and state-level elections.

In order to estimate α_0 and α_1, we re-write the estimating labor-supply equation 33 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 33 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 in Appendix D.2 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), which implies that, according to our estimates, the political index POL_nhas small predictive power to explain heterogeneity in preferences for public goods across states. Specifically, our estimates imply that $\alpha_{W,n} = \alpha_0 + \alpha_1 POL_n$ only varies 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

government spending constant and total gains of 0.79%. That section also presents the results for alternative values of some of the parameters: higher elasticity of substitution σ, lower congestion in public services χ_W and χ_F, and a parametrization that includes the all-IV's estimate from tables 3 and 4. Spatial misallocation remains in the same order of magnitude under these alternative parametrizations.

[53] 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.

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 of heterogeneous preferences for public spending yields estimates of $\alpha_{W,n}$ between 0.147 and 0.218.

We conduct a revenue-neutral elimination of tax dispersion similar to the one described in Section 5.2 under these alternative parametrizations. Table 8 reports the results. 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 heterogeneity across states moderately reduces the welfare-effects (to 0.49% from the 0.69% benchmark), and has not impact on the real-income effects of misallocation.

Table 8: Removing Tax Dispersion Under Heterogeneous Preferences Across States

Counterfactual	Total Effect		Holding G Constant	
	$\hat{v}$	Real GDP	$\hat{v}$	Real GDP
Political Heterogeneity	0.67%	0.65%	0.12%	0.13%
Revenue/GDP	0.49%	0.65%	0.11%	0.11%

5.2.3 Progressive Income Taxes

Our benchmark analysis uses a flat state income tax, but in practice most states have a progressive income tax. In this section, 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 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 $t_{n2007}^{y}(y) = a_n + b_n y + \varepsilon_n$ and, using the estimates $\left\{\hat{a}_n, \hat{b}_n\right\}_n$, we construct the income tax rate that the representative worker of state n earning wage w_n must pay as $t_n^{y,prog}(w_n) = \hat{a}_n + \hat{b}_n w_n$. We follow the same procedure using information on federal income tax rates, and construct a federal income tax rate for the representative worker of state n in the initial period as $t_{fed}^{y,prog}(w_n) = \hat{a}_{fed} + \hat{b}_{fed} w_n$. 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 caused by our counterfactual changes in taxes. 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).[54]

Table 9: Removing Tax Dispersion under Progressive Income Taxes

Counterfactual	Total Effect		Holding G Constant	
	$\hat{v}$	Real GDP	$\hat{v}$	Real GDP
Federal Progressive Only	1.62%	1.24%	0.14%	0.11%
State Progressive Only	1.27%	0.84%	0.40%	0.11%
State and Federal Progressive	1.58%	1.01%	0.45%	0.11%

Table 9 reports the results. The first line shows the outcome of the revenue-neutral elimination of tax dispersion in all state taxes when the only departure from the benchmark is that federal income taxes are allowed to be progressive The second and third lines allow for state-tax progressivity; in these cases, we undertake the revenue-neutral elimination of tax dispersion by bringing 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) to a percentile of their distribution such that, in the counterfactual scenario, aggregate state tax revenue does not change relative to the initial scenario. The second line performs this exercise without allowing for progressivity in federal income taxes, and the third line does so in the context of progressive federal income taxes. The results show that accounting for tax progressivity increases the gains from a revenue-neutral tax harmonization, and that the bulk of the increase lies in introducing progressive federal income taxes. This result echoes findings in Albouy (2009), who studied misallocation across U.S. cities due to federal income taxes. A reason for this increase is that accounting for progressive income taxes increases tax dispersion relative to our benchmark. .

5.2.4 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 10 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. However, the misallocation effect does not disappear even when we set both α's equal to zero.

Table 10: Removing Tax Dispersion under Lower Preferences for Government Spending

Counterfactual	Total Effect		Holding G Constant	
	$\hat{v}$	Real GDP	$\hat{v}$	Real GDP
Benchmark	0.69%	0.65%	0.12%	0.11%
Lower α's by 25%	0.49%	0.47%	0.14%	0.11%
Lower α's by 50%	0.34%	0.32%	0.15%	0.11%
Lower α's by 75%	0.24%	0.20%	0.17%	0.11%
$\alpha_W = \alpha_F = 0$	0.19%	0.11%	0.19%	0.11%

[54] 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%.

5.2.5 Alternative Definitions of Tax Rates

Table11 reports the results of the revenue-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. We find that this adjustment reduces the real-income and welfare effects of tax dispersion 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. This matches the tax treatment of business defined as C-corporations. In practice, some companies have a different fiscal treatment: non-C-corporations (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 (i.e., S-corporations and partnerships), 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.[55] 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. In order 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.[56] We find considerably larger gains from tax harmonization relative to the benchmark due

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

[56] 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

to larger initial dispersion in state+local taxes than in state taxes.

Table 11: Removing Tax Dispersion under Alternative Definitions of Tax Rates

Counterfactual	Total Effect		Holding G Constant	
	$\hat{v}$	Real GDP	$\hat{v}$	Real GDP
Benchmark	0.69%	0.65%	0.12%	0.11%
Corporate Taxes Adjusted for Tax Subsidies	0.61%	0.64%	0.10%	0.09%
Corporate Taxes Adjusted for Share of C-Corps	0.42%	0.32%	0.06%	0.04%
State+Local Taxes	1.23%	0.91%	-0.09%	0.06%

5.2.6 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.[57] Table 12 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 (28) and the adjusted trade costs in (29), 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 in a context of frictionless trade, where export 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.

Table 12: 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%

$rev_n^{x,s+l} > rev_n^{x,s}$, this adjustment scales up the state tax rates we use in our analysis.

[57] 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.

6 Conclusion

In this paper, we study the effects of alternative tax structures on aggregate real income, welfare, and the spatial distribution of economic activity in the U.S. economy. We construct 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 use it to estimate the elasticities of firm mobility and labor mobility with respect to taxes using data on economic activity and state finances from 1980-2010. Using the estimated model, we measure the general-equilibrium impact of some reforms typically put forth in public policy debates. Overall, our analysis suggests considerable spatial misallocation from tax dispersion relative to the magnitude of state taxes. Additionally, a state tax cut lowers own-state economic activity and impacts other states differently due to trade linkages. General-equilibrium effects on prices and public services largely drive these results.

References

Albouy, D. (2009). The unequal geographic burden of federal taxation. *Journal of Political Economy 117*(4), 635–667.

Allen, T. and C. Arkolakis (2014). Trade and the topography of the spatial economy. *The Quarterly Journal of Economics 1085*, 1139.

Allen, T., C. Arkolakis, and Y. Takahashi (2014). Universal gravity. *NBER Working Paper* (w20787).

Anderson, J. E. and E. Van Wincoop (2003). Gravity with gravitas: A solution to the border puzzle. *The American Economic Review 93*(1), 170–192.

Auerbach, A. (2013). Capital income taxation, corporate taxation, wealth transfer taxes and consumption tax reforms. Technical report, UC Berkeley.

Auerbach, A. J. and M. Devereux (2015, February). Cash-flow taxes in an international setting. Technical report, UC Berkeley and Oxford.

Ballard, C. L., D. Fullerton, J. B. Shoven, and J. Whalley (1985). *A general equilibrium model for tax policy evaluation*. University of Chicago Press.

Ballard, C. L., J. B. Shoven, and J. Whalley (1985). General equilibrium computations of the marginal welfare costs of taxes in the united states. *The American Economic Review 75*(1), pp. 128–138.

Barnett, J. L., C. L. Sheckells, S. Peterson, and E. M. Tydings (2014, December). 2012 census of governments: Finance— state and local government summary report. Technical report, U.S. Census Bureau.

Bartelme, D. (2014). Trade costs and economic geography: Evidence from the us. Technical report, UC Berkeley.

Bartik, T. J. (1991). *Who Benefits from State and Local Economic Development Policies?* W.E. Upjohn Institute for Employment Research.

Black, S. E. (1999). Do better schools matter? parental valuation of elementary education. *The Quarterly Journal of Economics 114*(2), 577–599.

Bound, J. and H. J. Holzer (2000). Demand shifts, population adjustments, and labor market outcomes during the 1980s. *Journal of labor Economics 18*(1), 20–54.

Bradbury, K. L., C. J. Mayer, and K. E. Case (2001). Property tax limits, local fiscal behavior, and property values: evidence from massachusetts under proposition 2 1/2. *Journal of Public Economics 80*(2), 287 – 311.

Brandt, L., T. Tombe, and X. Zhu (2013). Factor market distortions across time, space and sectors in china. *Review of Economic Dynamics 16*(1), 39–58.

Caliendo, L. and F. Parro (2014). Estimates of the trade and welfare effects of nafta. *The Review of Economic Studies*, rdu035.

Caliendo, L., F. Parro, E. Rossi-Hansberg, and P.-D. Sarte (2014). The impact of regional and sectoral productivity changes on the us economy. Technical report, National Bureau of Economic Research.

Ceaser, J. W. and R. P. Saldin (2005, June). A new measure of party strength. *Political Research Quarterly 58*(2), 245–256.

Cellini, S. R., F. Ferreira, and J. Rothstein (2010). The value of school facility investments: Evidence from a dynamic regression discontinuity design. *The Quarterly Journal of Economics 125*(1), 215–261.

Chay, K. and M. Greenstone (2005, April). Does air quality matter? evidence from the housing market. *Journal of Political Economy 113*(2), 376–424.

Chirinko, R. S. and D. J. Wilson (2008). State investment tax incentives: A zero-sum game? *Journal of Public Economics 92*(12), 2362–2384.

Cooper, M., J. McClelland, J. Pearce, R. Prisinzano, J. Sullivan, D. Yagan, O. Zidar, and E. Zwick (2015, September). Business in the united states: Who owns it and how much tax do they pay? Technical report, University of Chicago Booth School of Business.

Dekle, R., J. Eaton, and S. Kortum (2008). Global rebalancing with gravity: Measuring the burden of adjustment. *NBER Working Paper*.

Desmet, K. and E. Rossi-Hansberg (2013). Urban accounting and welfare. *American Economic Review 103*(6), 2296–2327.

Devereux, M. P. and R. Griffith (1998). Taxes and the location of production: Evidence from a panel of us multinationals. *Journal of public Economics 68*(3), 335–367.

Diamond, R. (2015). The determinants and welfare implications of us workers diverging location choices by skill: 1980-2000. *Mimeo, Stanford University*.

Eaton, J. and S. Kortum (2002). Technology, geography, and trade. *Econometrica 70*(5), 1741–1779.

Eeckhout, J. and N. Guner (2014). Optimal spatial taxation.

Fernald, J. G. (1999). Roads to prosperity? assessing the link between public capital and productivity. *American Economic Review 89*(3), 619–638.

Gaubert, C. (2014). Firm sorting and agglomeration. *Unpublished manuscript, Princeton University*.

Giroud, X. and J. Rauh (2015, August). State taxation and the reallocation of business activity: Evidence from establishment-level data. Technical report, Stanford University.

Goolsbee, A. and E. L. Maydew (2000). Coveting thy neighbors manufacturing: the dilemma of state income apportionment. *Journal of Public economics 75*(1), 125–143.

Gordon, R. H. (1983). An optimal taxation approach to fiscal federalism. *The Quarterly Journal of Economics 98*(4), 567–586.

Haughwout, A. F. (2002). Public infrastructure investments, productivity and welfare in fixed geographic areas. *Journal of Public Economics 83*(3), 405 – 428.

Head, K. and T. Mayer (2013). Gravity equations: Workhorse,toolkit, and cookbook. *Handbook of International Economics Vol. 4*.

Hines, J. R. (1997, May). Altered states: Taxes and the location of foreign direct investment in america. Working Paper 4397, National Bureau of Economic Research.

Holmes, T. J. (1998). The effect of state policies on the location of manufacturing: Evidence from state borders. *Journal of Political Economy 106*(4), 667–705.

Hsieh, C.-T. and P. J. Klenow (2007). Misallocation and manufacturing tfp in china and india. Technical report, National Bureau of Economic Research.

Hsieh, C.-T. and E. Moretti (2015). Why do cities matter? local growth and aggregate growth. Technical report, National Bureau of Economic Research.

ITEP (2012). Corporate income tax apportionment and the 'single sales factor'. Technical report, Institute on Taxation and Economic Policy.

Kline, P. and E. Moretti (2014). Local economic development, agglomeration economies and the big push: 100 years of evidence from the tennessee valley authority. *The Quarterly Journal of Economics*.

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *The American Economic Review*, 950–959.

Mazerov, M. (2005). The 'single sales factor' formulat for state corporate taxes: A boon to economic development or a costly giveaway. Technical report, Center on Budget and Policy Priorities.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica 71*(6), 1695–1725.

Michaillat, P. and E. Saez (2015, July). The optimal use of government purchases for macroeconomic stabilization. Working Paper 21322, National Bureau of Economic Research.

Monte, F. (2014). The local incidence of trade shocks. *Available at SSRN 2337270*.

Moretti, E. and D. Wilson (2015, April). The effect of state taxes on the geographical location of top earners: Evidence from star scientists. Working Paper 21120, National Bureau of Economic Research.

Notowidigdo, M. J. (2011). The incidence of local labor demand shocks. Technical report, National Bureau of Economic Research.

Ossa, R. (2015). A quantitative analysis of subsidy competition in the us. Technical report, National Bureau of Economic Research.

PERAB (2010, August). The report on tax reform options: Simplification, compliance, and corporate taxation. Technical report, The President's Economic Recovery Advisory Board.

Poterba, J. M. (1994, August). State responses to fiscal crisis: The effects of budgetary institutions and politics. *The Journal of Political Economy 102*, 799–821.

Ramondo, N., A. Rodríguez-Clare, and M. Saborío-Rodríguez (2012). Scale effects and productivity across countries: Does country size matter? *NBER Working Paper* (w18532).

Redding, S. J. (2012). Goods trade, factor mobility and welfare. Technical report, National Bureau of Economic Research.

Restuccia, D. and R. Rogerson (2008). Policy distortions and aggregate productivity with heterogeneous establishments. *Review of Economic Dynamics 11*(4), 707–720.

Shoven, J. B. and J. Whalley (1972). A general equilibrium calculation of the effects of differential taxation of income from capital in the u.s. *Journal of Public Economics 1*(3–4), 281 – 321.

Suárez Serrato, J. C. and P. Wingender (2011, November). Estimating the incidence of government spending. Working paper, U.C. Berkeley and International Monetary Fund.

Suárez Serrato, J. C. and O. M. Zidar (2014). Who benefits from state corporate tax cuts? a local labor markets approach with heterogeneous firms. *NBER Working Paper* (w20289).

Wildasin, D. (1991). *Urban Public Finance*. Chur, Switzerland: Harwood Academic Press.

Wilson, D. (2015, February). Competing for jobs: Local taxes and incentives. *Federal Reserve Bank of San Francisco Economic Letter*.

Wilson, D. J. (2009). Beggar thy neighbor? the in-state, out-of-state, and aggregate effects of r&d tax credits. *The Review of Economics and Statistics 91*(2), 431–436.

Zucman, G. (2014). Taxing across borders: Tracking personal wealth and corporate profits. *Journal of Economic Perspectives 28*(4), 121–48.

Appendices for Online Publication

A Appendix to Section 2 (Background)

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

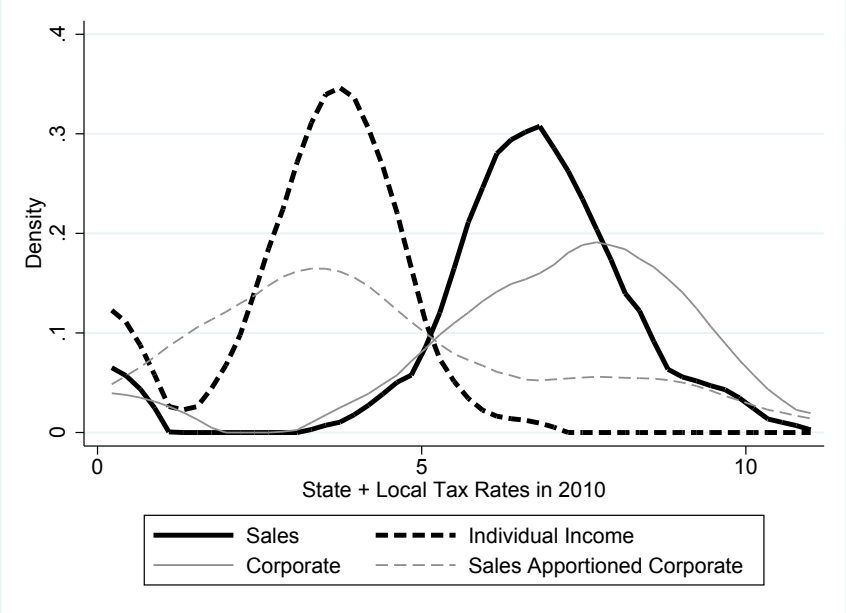


Table A.1: Federal Tax Rates from 2007

Type	Federal Tax Rate
Income Tax t_{fed}^{y}	11.7
Corporate Tax t_{fed}^{corp}	18.0
Payroll Tax t_{fed}^{w}	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 E.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 (21), GDP in state n is

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

From (A.9) and 21, 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

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

where $C_n^W = (1-T_n)\frac{w_n L_n}{P_n}$ is the consumption of workers and $C_n^K = \frac{(1-t_{fed}^y)(1-t_n^y)}{1+t_n^c}\frac{b_n(\Pi+R)}{P_n}$ is the consumption of capital-owners. In the counterfactuals, we compute the value of consumption of workers and capital owners in the new equilibrium relative to its initial value using the following expressions:

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

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

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:[58]

$$P_n Q_n - X_n = (GSI_n - GDP_n) + (R_n^{corp} - TP_n^{corp}), \tag{A.14}$$

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.14) besides GDP as follows:[59]

$$GSI_n = b_n\left(\tilde{\Pi} + R\right) + w_n L_n, \tag{A.15}$$

$$R_n^{corp} = \frac{1}{\sigma}\left(t_n^x P_n Q_n + t_n^l X_n\right), \tag{A.16}$$

$$TP_n^{corp} = b_n \sum_{n'}\left(\bar{t}_{n'} - t_{fed}^{corp}\right)\tilde{\Pi}_{n'}. \tag{A.17}$$

[58] To reach this relationship, first impose goods market clearing (4) to obtain $P_n Q_n = P_n(C_n + G_{n,fed} + G_n + I_n)$. 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 (23) 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.14).

[59] (A.15) and (A.17) are by definition. For (A.16), combine (24) with (20) and (21).

Replacing (A.9) and (A.15) to (A.17) into (A.14), and using (A.7) and (21) to express labor payments and pre-tax profits as function of sales, we obtain:

$$\frac{P_n Q_n}{X_n} = \frac{1}{\sigma - t_n^x}\left((\sigma - 1)\left(1 - \beta_n \gamma_n\right) + t_n^l + \frac{b_n}{\tilde{\Pi}_n / \left(\Pi + R + t_{fed}^{corp}\tilde{\Pi}\right)} \right). \tag{A.18}$$

where, from (21), (22) and (A.8), the denominator in the last term is:

$$\frac{\tilde{\Pi}_n}{\Pi + R + t_{fed}^{corp}\tilde{\Pi}} = \frac{X_n}{\sum_i \left(1 - t_n^l - \bar{t}_n + \beta_i \gamma_i \left(\sigma - 1\right)\right) X_i}. \tag{A.19}$$

Expression (A.18) is used in the calibration to back out the ownership shares b_n from observed data on trade imbalances.

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 $\pi_i\left(\tilde{z}_i\right) = \bar{\pi}$ in every state. From (21) and (22) it follows that the number of firms in state i can be expressed as:

$$M_i = \frac{1 - \bar{t}_i}{\bar{\pi}} \frac{X_i}{\sigma}. \tag{A.20}$$

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.[60] 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.[61]

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.

$$\sum_n \lambda_{in} = 1 \text{ for all } i; \tag{A.21}$$

[60] 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: $M_i = \frac{1-\bar{t}_i}{c_i f_i}\frac{X_i}{\sigma}$.

[61] 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.

Additionally, condition 20, which determines aggregate sales from i, is equivalent to imposing s that sales shares from every state add up to 1:

$$\sum_i s_{in} = 1 \text{ for all } n. \tag{A.22}$$

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:

$$\lambda_{in} = A_{in} \left(\frac{w_n}{\bar{\pi}}\right)^{1-\kappa_1} L_n^{1-\kappa_{2n}} \left(\frac{w_i}{\bar{\pi}}\right)^{\sigma-1} L_i^{-\kappa_3}, \tag{A.23}$$

$$s_{in} = \lambda_{in} \frac{P_i Q_i}{X_i} \frac{(w_i/\bar{\pi})\, L_i}{(w_n/\bar{\pi})\, L_n} \frac{(1-\beta_n)\,\gamma_n}{(1-\beta_i)\,\gamma_i}, \tag{A.24}$$

where A_{in} in λ_{in} is given by

$$A_{in} = \left(\frac{H_n^{\beta_n \gamma_n} \Theta_{1n} z_n^A}{\frac{\sigma}{\sigma-1} \tau_{in}^A} \frac{\left(\Theta_{2i} u_i^A\right)}{\left(\Theta_{2n} u_n^A\right)^{1-\gamma_n+\alpha_F}} v^{\alpha_F - \gamma_n} \right)^{\sigma-1}, \tag{A.25}$$

where $\left\{z_n^A, \tau_{in}^A, u_n^A\right\}$ are defined in (28) to (30) 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.23) and (A.24) are given by:

$$\kappa_1 = (\sigma-1)\left(\frac{1}{\varepsilon_F} + \alpha_F\chi_F + 1\right), \tag{A.26}$$

$$\kappa_{2n} = (\sigma-1)\left[\left(\frac{1}{\varepsilon_F} - \alpha_F\,(1-\chi_F) + \beta_n\gamma_n\right) - (1-\gamma_n+\alpha_F)\left(\frac{1}{\varepsilon_W} - \alpha_W\,(1-\chi_W)\right)\right], \tag{A.27}$$

$$\kappa_3 = (\sigma-1)\left(\frac{1}{\varepsilon_W} - (1-\chi_W)\,\alpha_W\right). \tag{A.28}$$

Equations (A.21) to (A.25), together with (8), (A.18), and (31) 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.[62] 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) there is no cross-ownership of assets across states. In this case, the adjusted amenities and productivities u_n^A and z_n^A

[62] The terms u_n^A, τ_{in}^A, and z_n^A which enter in (A.25) 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.

defined in (30) and (28) are primitives (exogenous functions of fundamentals and own-state taxes). Define:

$$K_{in} = \tau_{in}^{1-\sigma},$$
$$\gamma_n = \overline{A}_n^{\sigma-1} w_n^{1-\kappa_1} L_n^{1-\kappa_2}, \tag{A.29}$$
$$\delta_i = \left(\frac{\overline{u}_i}{\overline{W}}\right)^{\sigma-1} w_i^{\sigma} L_i^{1-\kappa_3}, \tag{A.30}$$

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.23) 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.29) and (A.30) 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.29) and (A.30), 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.21) to (A.22):

$$\frac{\sigma-(1-\kappa_3)}{\sigma(1-\kappa_2)-(1-\kappa_3)(1-\kappa_1)} > 1, \tag{A.31}$$
$$\frac{\kappa_1-\kappa_2}{\sigma(1-\kappa_2)-(1-\kappa_3)(1-\kappa_1)} > 1, \tag{A.32}$$

where κ_1 to κ_3 are defined in (A.26) to (A.28). 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 $\left\{(t_n^y)', (t_n^c)', (t_n^x)', \left(t_n^l\right)'\right\}_{n=1}^N$. 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.21) and (A.22) hold:

$$\sum_n \lambda_{in} \hat{\lambda_{in}} = 1 \text{ for all } i, \tag{A.33}$$
$$\sum_i s_{in} \hat{s_{in}} = 1 \text{ for all } n, \tag{A.34}$$

where, using (A.23) and (A.24) and normalizing $\hat{\bar{\pi}} = 1$,

$$\hat{\lambda_{in}} = \hat{A_{in}} \hat{w_n}^{1-\kappa_1} \hat{L}_n^{1-\kappa_{2n}} \hat{w_i}^{\sigma-1} \hat{L}_i^{-\kappa_3} \tag{A.35}$$

$$\hat{s_{in}} = \hat{\lambda_{in}} \left(\frac{P_i \hat{Q}_i}{X_i} \right) \frac{\hat{w}_i \hat{L}_i}{\hat{w}_n \hat{L}_n} \tag{A.36}$$

and where using (A.25)

$$\hat{A}_{in} \propto \left(\frac{\hat{z_n^A}}{\hat{\tau_{in}^A}} \frac{\hat{u_i^A}}{\left(\hat{u_n^A}\right)^{(1-\gamma_n)+\alpha_F}} \hat{v}^{\alpha_F - \gamma_n} \right)^{\sigma-1} \tag{A.37}$$

and where, from (29) to (30),

$$\hat{\tau_{in}^A} = \frac{\sigma - \tilde{t}_{in}}{\sigma - \left(\tilde{t}_{in}\right)'}, \tag{A.38}$$

$$\hat{z_n^A} = \left(\frac{1 - (\bar{t}_n)'}{1 - T_n} \right)^{\frac{1}{\sigma-1} - \left(\frac{1}{\varepsilon_F} + \alpha_F \chi_F\right)} \left(\frac{P_n \hat{G}_n}{GDP_n} \right)^{\alpha_F}, \tag{A.39}$$

$$\hat{u_n^A} = \left(\frac{1 - T_n'}{1 - T_n} \right)^{1-\alpha_W} \left(\frac{P_n \hat{G}_n}{GDP_n} \right)^{\alpha_W} \tag{A.40}$$

Additionally, labor shares must add up to 1 :

$$\sum L_n \hat{L_n} = 1. \tag{A.41}$$

The variables $\left\{ \frac{P_n \hat{Q}_n}{X_n}, \frac{P_n \hat{G}_n}{GDP_n}, T_n', \left(\bar{t}_n\right)', \left(\tilde{t}_{in}\right)' \right\}_{n=1}^{N}$ 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.18), (31), (6), (10), and (12). Hence, these equations, together with (A.33) to (30), give the solution for $\left\{ \hat{\lambda_{in}}, \hat{s_{in}}, \hat{L_n}, \hat{w_n} \right\}$ and $\hat{v}$.[63]

C Appendix to Section 4.3 (Estimated Parameters)

C.1 Measurement of Covariates Used in the Estimation of Firm Equation

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[64] 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: $c_{nt} = \left(w_{nt}^{1-\beta_n} P_{nt}^{\beta_n} \right)^{\gamma_n} P_{nt}^{1-\gamma_n}$.[65]

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}.

[63] 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 $\Pi' + R' = \sum_i \left(1 - (\bar{t}_i)' + \beta_i \gamma_i (\sigma - 1)\right) \frac{w_i L_i \left(\hat{w_i} \hat{L_i}\right)}{\sigma}$.

[64] 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.

[65] 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.

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 E_{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 E_{nt} as a function of state GDP by combining equations (A.7), (A.9), and (A.18) to obtain

$$E_{nt} = \frac{(\sigma - 1)(1 - \beta_n \gamma_n) + a_{nt} + t_n^l}{\sigma - t_n^x} \frac{\sigma}{\gamma_n (\sigma - 1) + 1} GDP_{nt}, \tag{A.42}$$

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.[66]

We construct MP_{nt}^* using the expression in equation (36) . 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 $E_{n't}^*$ using (A.42) with lagged GDP instead of period $t's$ GDP,[67][68]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) 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 $P_{n,t}^* = 1 + t_{n,t}^c$. 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}, $\overline{s}_{in} = \frac{s_{in,1993} + s_{in,1997}}{2}$. Each of these approaches produces similar estimates of the parameters.

[66] 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.

[67] A sufficient condition for an instrument that depends on lagged GDP to be exogenous is that the error term in equation (36) is independent over time.

[68] I.e., $E_{nt}^* = \frac{(\sigma-1)(1-\beta_n\gamma_n)+a_{nt}+t_n^l}{\sigma - t_n^x} \frac{\sigma}{\gamma_n(\sigma-1)+1} GDP_{n,t-1}$

C.2 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.

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.3 Appendix Table to Section 4.3.2 (Firm-Mobility Elasticity)

Table A.5: Robustness of Firm Mobility Parameters

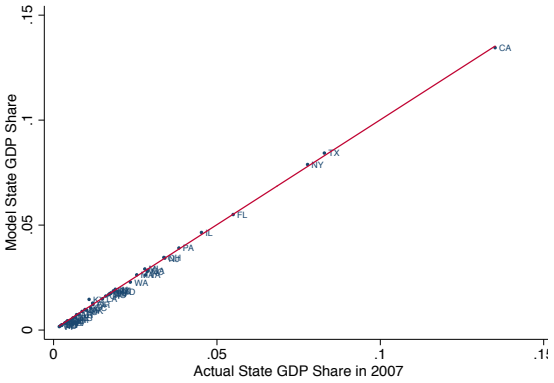
	A. All IVs				B. External IVs			
	Using $P^*_{nt}=1$		Using $\bar{s}_{in}$		Using $P^*_{nt}=1$		Using $\bar{s}_{in}$	
	Fix $\sigma=4$	Fix $\sigma=5$	Fix $\sigma=4$	Fix $\sigma=5$	Fix $\sigma=4$	Fix $\sigma=5$	Fix $\sigma=4$	Fix $\sigma=5$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\chi_F=0$								
ε_F	2.44***	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.

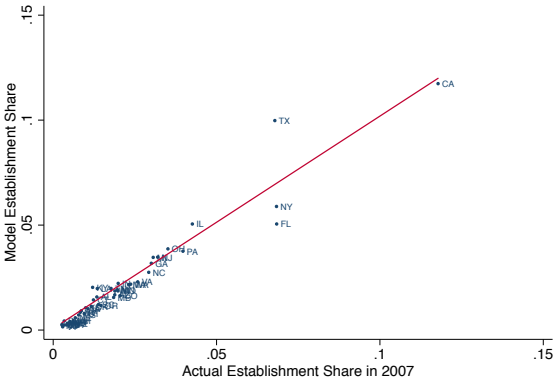
C.4 Appendix Figure to Section 4.4 (Over-Identification Checks)

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

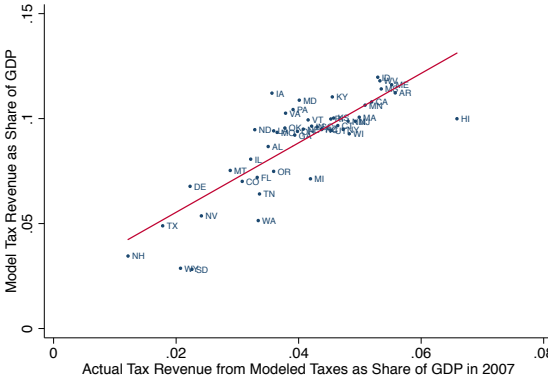
(a) State GDP Share



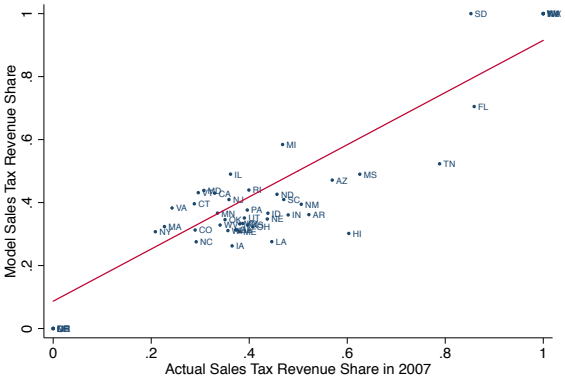
(b) Share of Establishments



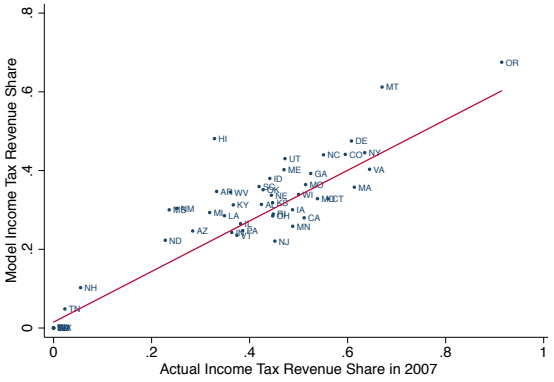
(c) State Tax Revenue as Share of GDP



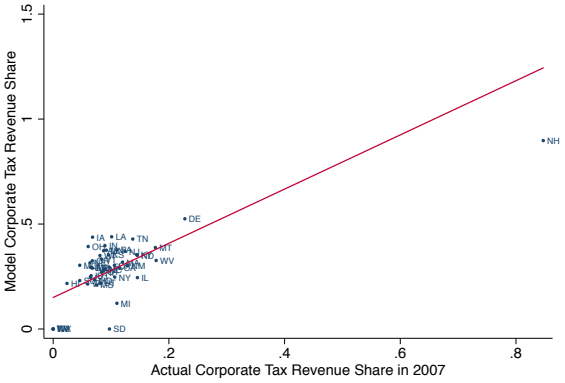
(d) Sales Tax Revenue Share



(e) Income Tax Revenue Share



(f) Corporate Tax Revenue Share



C.5 Comparison with Existing Estimates

Previous researchers have estimated regressions similar to (33) and (34) 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 $\varepsilon_F = 5.33$.[69]

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,[70] while others focus on the productivity effects of large investment projects.[71] However, very few papers estimate specifications similar to (33) and (34). 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 (33) and (34). These differences notwithstanding, our structural parameters are close to those in the literature.

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

[70] 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.

[71] 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 (33) and (34). 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.20 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).

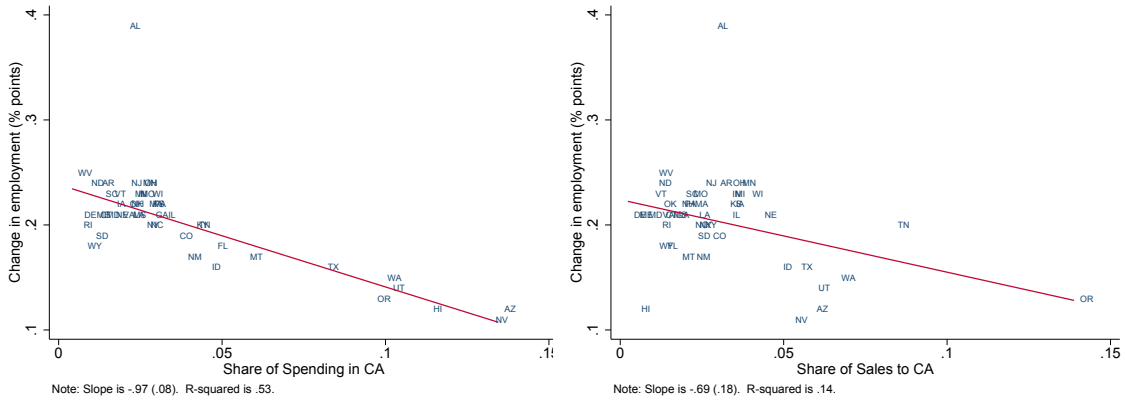
[h] Giroud and Rauh (2015) report an elasticity of number of establishment with respect to corporate taxes of 0.4.

D Appendix to Section 5 (Counterfactuals)

D.1 Appendix Figures to Section 5.1 (Changes in Tax Rates in a Single State)

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

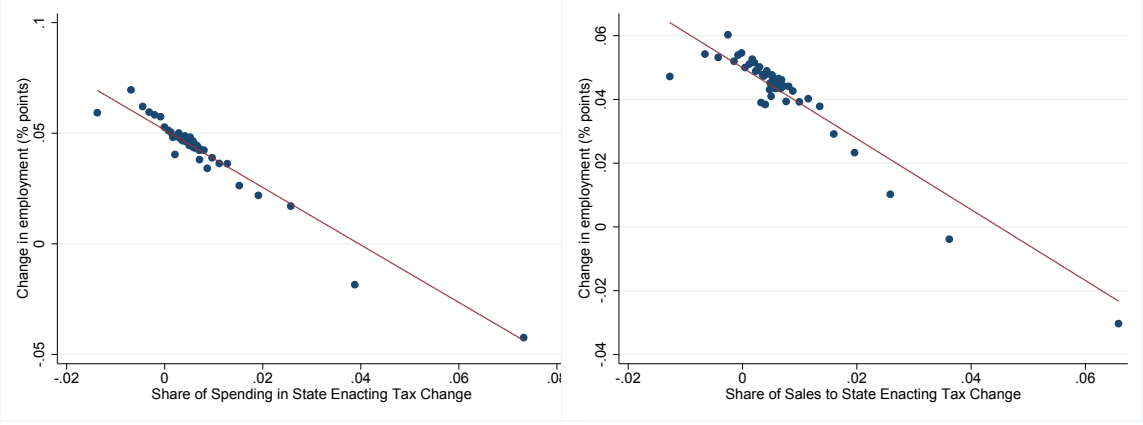
(a) Employment Changes and Spending Shares (b) Employment Changes and Sales Shares



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.4: 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.

D.2 Appendix Table to Section 5.2.2 (Heterogeneous Preferences for Government Spending)

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 $\ln L_{nt}$. See section **??** for more detail. 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 Additional Counterfactuals

Bringing All Taxes to the Mean Table A.8 performs an alternative measurement of spatial misallocation due spatial dispersion in tax rates where, for each type of tax, we replace the tax rate in every state with its average across states. The first row shows the effect of removing dispersion in every tax simultaneously, and the remaining rows show the effect of removing dispersion in one tax at a time. The first column shows that, contrary to the revenue-neutral counterfactual that we just discussed, the direct effect from bringing all taxes to their mean tax rate 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. The second column shows that, keeping government spending constant, the reallocation associated with this reduction

in dispersion leads to a welfare gain of 0.36%. Again, the larger gains from reallocation (i.e., the difference between columns 2 and 1) originate from corporate taxes. When general-equilibrium variables including government spending are allowed to change (column 3), the total welfare gain increases to 0.79%.[72] We also observe gains in terms of real GDP and aggregate real consumption, and find stronger effects under the parametrization that assumes lower trade costs.

Table A.8: Removing Tax Dispersion: All taxes to the Mean

Counterfactual	Welfare Change				Real	Real Consumption	
	Direct	G-constant	Total	Low Trade Costs	GDP	Workers	Capital
All state taxes	0.24%	0.36%	0.79%	1.11%	0.60%	0.54%	0.29%
Income Taxes	-0.19%	-0.16%	0.99%	1.24%	0.65%	0.20%	0.26%
Sales Taxes	0.45%	0.45%	-1.00%	-1.08%	-0.68%	-0.17%	-0.20%
Corporate Taxes	0.00%	0.08%	0.87%	1.03%	0.66%	0.54%	0.29%

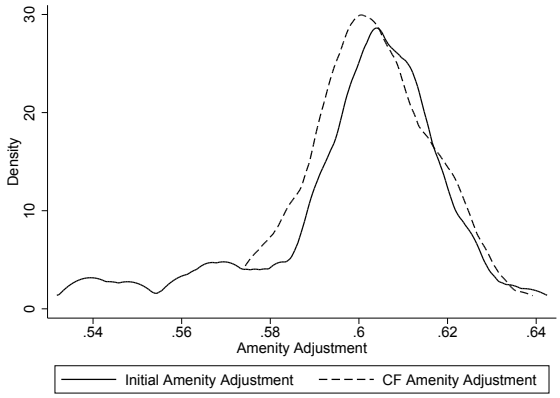
Figure A.5 shows the distributions of the endogenous components of the adjusted productivities z_n^A amenities u_n^A, and trade costs τ_{ni}^A (see (28)-(29)) in 2007 and when tax dispersion is removed. Bringing all taxes to the mean strongly reduces dispersion in the adjusted productivity and eliminates dispersion in adjusted trade costs; however, it leads to a leftward shift in the adjusted amenities.[73] Note that we would expect reductions in adjusted amenities or productivities and increases in adjusted trade costs to lead to with lower welfare. Hence, the results suggest that the welfare gains are associated with the reductions in dispersion in the adjusted fundamentals that we see in the counterfactual and not with changes in the levels of their distributions.

[72] Bringing all taxes to the mean of their distributions and allowing all general-equilibrium variables to the mean happens to be nearly revenue-neutral, with the aggregate state tax revenue declining very slightly by 0.02%.

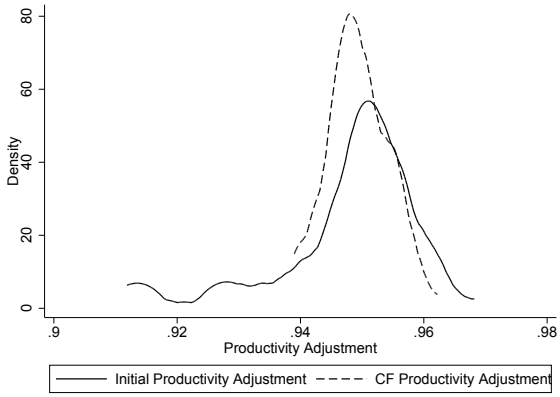
[73] For the case of the trade-cost adjustment, the counterfactual distribution is degenerate at 1. Eliminating tax dispersion does not eliminate dispersion in the adjustments to productivity and amenities because government spending over GDP, $\frac{P_n G_n}{GDP_n}$, is part of these adjustment but varies with the technology parameters of each state. See equation (31).

Figure A.5: Removing Tax Dispersion: Adjustment to the Fundamentals

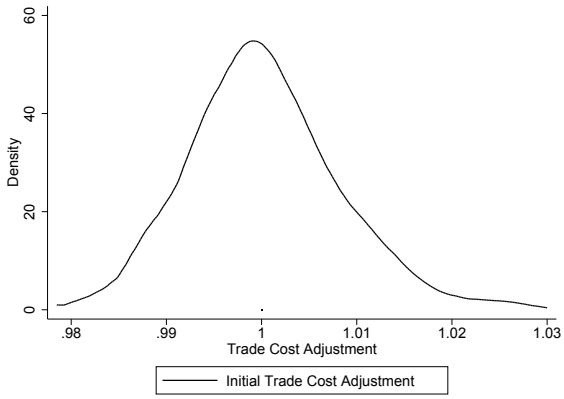
(a) Amenity Adjustment



(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 (29) to (30). The distribution labeled "Pre" corresponds to initial values from 2007; "Post" corresponds to bringing all taxes to the mean. In Panel (c), the "post" distribution is degenerate at 1 because $\tilde{t}_{in}=0$ for all i,n.

Alternative Values of σ and χ Our benchmark parametrization sets the value $\sigma = 4$ and assumes that the congestion parameters χ_W and χ_F equal 1. Rows 2-4 of Table A.9 report the results of the revenue-neutral elimination in dispersion in all taxes 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 3 and 4.[74] The last row uses the structural parameters corresponding to the all-IV's estimation strategy from these two tables. We find that the effects of misallocation on welfare and GDP decrease somewhat with σ, and are non-monotone with the congestion parameters. The effects across these estimates are between 0.59% and 0.78%, relative to 0.69% in the benchmark. The all-IV's estimation strategy delivers considerably larger welfare and real-income effects of misallocation (2.3% and 2.7%, respectively). We see that the effect is largely due to the higher value of the preference for government spending implied by this estimate, as the G- constant counterfactuals deliver results similar to the benchmark.

Table A.9: Removing Tax Dispersion under Alternative Parametrizations

Counterfactual	Total Effect		Holding G Constant	
	$\hat{v}$	Real GDP	$\hat{v}$	Real GDP
Benchmark	0.69%	0.65%	0.12%	0.11%
Higher demand elasticity	0.59%	0.44%	0.08%	0.07%
Medium congestion	0.78%	0.88%	0.12%	0.11%
No congestion	0.63%	0.64%	0.13%	0.10%
All IV's	2.35%	2.66%	0.09%	0.13%

E 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.

E.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);

[74] 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.

- 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 $t_n^{y,s+l} = t_n^{y} \times \frac{R_n^{StandLocal,y}}{R_n^{State,y}}$.

E.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: $P_n I_n = X_n - GDP_n$
  - Total state spending and revenue: $P_n G_n = R_n = T_n^c + T_n^y + R_n^{corp}$.
  - Sales from state n: $X_n = X_n^{Total} - Exports_n^{ROW}$.
  - Expenditures: $P_n Q_n = P_n C_n + P_n I_n + P_n G_n + P_n G_n^{fed}$
  - 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: $\lambda_{in} = \frac{X_{in}}{\sum_{n'} X_{in'}}$.

E.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)