State Taxes and Spatial Misallocation*

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Abstract

We study state taxes as a potential source of spatial misallocation in the United States. We build a spatial general-equilibrium model in which the distribution of workers, firms, and trade flows across states responds to state taxes and public-service provision. We estimate firm and worker mobility elasticities and preferences for public services using data on the distribution of economic activity and state taxes from 1980 to 2010. A revenue-neutral tax harmonization leads to aggregate real-GDP and welfare gains of 0.7%. Tax cuts by individual states lower own-state tax revenues and economic activity, and generate cross-state spillovers depending on trade linkages.

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1 Introduction

Tax policy varies widely across countries and across regions within countries. In 2012, U.S. states collected roughly $800 billion in tax revenue relying on very different levels of sales, personal income, and corporate income taxes. Recent research studying dispersion in distortions across economic units – across firms, as in Hsieh and Klenow (2009), or across cities, as in Albouy (2009) and Desmet and Rossi-Hansberg (2013) – suggests that this dispersion in state tax rates may have a negative impact on aggregate economic activity. Indeed, policies that would move the state tax structure towards greater tax harmonization have been proposed in both academic and policy discussions.[1] However, little is known about the aggregate effects of dispersion in state tax rates, or, more generally, about how the state tax distribution impacts the U.S. economy.[2]

What is the impact of the state tax distribution on aggregate real income, welfare, and the distribution of economic activity across U.S. states? This question is difficult to tackle because many general-equilibrium forces are at work – changes in state taxes lead to reallocations of workers, firms, and trade flows across states, as well as to changes in the amount of public services provided by state governments – and, to the best of our knowledge, no existing analysis has aimed to answer it. We incorporate tools developed in recent trade and economic geography models, such as Allen and Arkolakis (2014) and Redding (2015), into a general-equilibrium framework that accounts for several types of spatial interactions among states and salient features of the U.S. state tax system. We estimate key parameters – elasticities of firm and worker mobility across states and preferences for public services – using equilibrium relationships implied by the model and data on the distribution of economic activity and taxes across states from 1980 to 2010. Using the estimated model we study the effects of eliminating tax dispersion. We also study the consequences of imposing other counterfactual distributions of state tax rates corresponding to policies that are often the subject of public debate.

In our model, workers decide where to locate based on each state's taxes, wage, cost of living, and amenity level. In turn, firms decide where to locate, how much to produce, and where to sell based on each state's taxes, productivity, factor prices, and market potential (a measure of other states' market sizes discounted by trade frictions). Additionally, workers and firms respectively draw idiosyncratic preferences and productivities across states, according to which they sort spatially. The amenity and productivity levels of each state partly depend on government spending. This spending is financed by sales, personal income, and corporate income taxes apportioned through both firm sales and factor usage.[3] As a result, firm and worker decisions depend on taxes both in partial equilibrium – given relative prices and state spending – and in general equilibrium

[1] For specific policy discussions see Shaviro (1993), Farber (2006), Sullivan (2014), and Wilson (2015) for the U.S., and Keen (1987), Devereux and Pearson (1995), Bénassy-Quéré et al. (2014), and Devereux et al. (2015) for Europe. See Gordon (1983) for a theoretical treatment.

[2] 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.

[3] Our baseline analysis focuses on these three types of taxes as they account for the bulk of state tax revenue; see Section 2 for background on the U.S. tax system. Our model does not take a stand on how state taxes are determined. Doing so is not necessary to study the consequences of imposing counterfactual tax distributions, as we do in this paper.

through the impact of taxes on prices and public-service provision. Specifically, our model implies that state taxes impact the economy through "adjusted fundamentals," defined as functions of exogenous state fundamentals (productivity, amenity, and trade costs), tax rates, and government spending. Given government spending, higher income or sales taxes in one state are equivalent to a lower amenity level in that state in terms of their impact on the distribution of employment and wages. Similarly, higher corporate taxes are equivalent to lower productivity, and changes in sales-apportioned corporate tax rates are equivalent to changes in trade costs. Additionally, government spending in any state depends on the whole distribution of state taxes and, therefore, changes in tax rates in one state also impact the adjusted fundamentals of every other state.

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

We estimate these equations using taxes in other states to instrument for each state's factor prices and government spending; this choice of instruments is consistent with our model, in which taxes in one state impact economic activity in other states only through these general-equilibrium variables. This estimation approach exploits the more than 300 changes in tax rates that we observe over this time span. We estimate a partial elasticity of state employment with respect to after-tax real wages of about 1, and with respect to government spending of about 0.2. Our estimates of the firm-location equation imply a higher elasticity of firm mobility with respect to taxes and a smaller response of firm location to government spending.[4] We calibrate the remaining parameters (production technologies and state fundamentals) such that the model exactly reproduces, as an equilibrium outcome, the distribution of factor shares, wages, employment, and trade flows across states in 2007, the most recent year in which all the data we need are available. As an over-identifying check, we compare the model's predictions for variables that are not targeted by the parametrization against the data. We find that the distributions across states of GDP and of tax revenue shares in GDP implied by the estimated model are highly correlated with those observed in the data.

We define the spatial misallocation caused by the state tax distribution as the welfare and real-income gains (if they exist) that would result from eliminating the dispersion in each type of

[4]These estimates are in the range of existing work that has estimated similar specifications; e.g., Bound and Holzer (2000), Notowidigdo (2013), Suárez Serrato and Wingender (2014), Diamond (2015), Suárez Serrato and Zidar (2015), and Giroud and Rauh (2015). See Section 4.3 and Appendix C.4 for details.

tax across states while keeping the size of state governments constant.[5] We undertake two types of counterfactuals which differ in the measure of government size that is kept constant. First, we undertake a revenue-neutral tax harmonization by simultaneously bringing the common tax rate for each tax to a level such that the tax revenue collectively raised by all states is held constant. We find that a revenue-neutral harmonization of sales, income, and corporate taxes leads to aggregate real-income gains of 0.7%, or roughly $110 billion in 2012, pointing to quantitatively important real-income effects from dispersion in these taxes relative to their 4% revenue share in GDP. Welfare gains are also close to 0.7%. Second, we undertake a spending-neutral tax harmonization by bringing the common tax rate for each type of tax to a level such that the tax revenue collectively raised by all states, jointly with a system of cross-state transfers, can finance the same level of government spending as in the initial scenario in every state. The spending-neutral tax harmonization leads to a 0.12% increase in welfare and to a similar increase in real GDP. As in this counterfactual the distribution of real government spending in each state is kept constant, this result indicates that there are gains from tax harmonization independently from the changes in government spending that an implementation of this policy could imply.

We explore how these results depend both on the values of the parameters determining the impact of public services on preferences and productivity, and on alternative ways of measuring tax rates. First, we relax the assumption that the weight of public services in preferences is the same across all states. Heterogeneity in preferences for public services may temper the gains from tax harmonization if tax rates are higher in states where these preferences are stronger. Consistent with this intuition, we find that the real-income and welfare gains from a revenue-neutral tax harmonization are 30% smaller than in the benchmark if we parametrize the preferences for public services so that they are proportional to the tax revenue share in GDP of each state. However, spatial misallocation continues to be present in this case; moreover, in the spending-neutral tax harmonization, assuming heterogeneous preferences does not alter the welfare and real-income gains relative to the benchmark. Second, we analyze how the results would vary if the weights of public services in preferences and productivity were considerably lower than what our benchmark estimates imply. We find that both the revenue- and spending- neutral tax harmonization continue to deliver welfare and real-income gains when these weights are anywhere between zero and our benchmark estimates; specifically, in the extreme case that assigns zero weight to public services in preferences and productivity, the welfare gains from tax harmonization are 0.2%. Finally, we also study counterfactuals under alternative ways of measuring tax rates; e.g., adjusting corporate tax rates for state subsidies and incorporating progressivity in state and federal income tax schedules. We continue to find gains from eliminating dispersion in income, sales, and corporate tax rates in all these cases.

We also use the estimated model to gauge the effects of other policies that are often the subject

[5]Dispersion in tax rates across states can be shown theoretically to reduce real income and welfare in restricted versions of our model that do not feature some forces such as spatial externalities through home-market effects and government spending. However, the model that we estimate and use as basis for our counterfactuals accounts for these forces, and therefore does not imply that eliminating tax dispersion must lead to real-income and welfare gains.

of public debate. Lower state taxes are said to help create jobs or attract businesses,[6] but also to erode the provision of public services with little overall effect on employment.[7] To inform the ongoing debate on the effects of lowering state taxes, we simulate a 1 percentage point reduction in the individual income tax in each state. On average across states, this policy causes a loss of economic activity in the state lowering taxes. General-equilibrium forces drive the result: the effect of lowering taxes keeping goods prices, factor prices, and government spending constant is to increase economic activity; however, when these variables adjust, activity decreases due to lower pre-tax real wages and to lower tax revenue, which translates into lower provision of public services. This tax change has heterogeneous impacts across states, with the states who export or import relatively more from the state lowering taxes experiencing a relatively smaller increase in economic activity. We also explore the implications of changing the sales apportionment of corporate taxes.[8] In the model, this distortion leads firms to sell more to states with lower sales apportionment. We find aggregate losses from fully apportioning corporate taxes through sales, and gains from moving away from sales apportionment. We identify a relevant role for trade in driving this result, as these gains would be smaller under lower trade costs, suggesting a complementarity between trade frictions and the distortions caused by the sales apportionment.

Our paper contributes to the literature on the aggregate effects of misallocation. A common approach consists in measuring distortions across firms as an implied wedge between an observed allocation and a model-implied undistorted allocation, as in Restuccia and Rogerson (2008) and Hsieh and Klenow (2009), and then undertaking model-based counterfactuals to inspect the aggregate effects of dispersion in these wedges. Recent papers have adopted a similar methodology to analyze misallocation across geographic units, such as Desmet and Rossi-Hansberg (2013) and Brandt et al. (2013).[9] 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.[10] While this literature typically focuses on the impact of distortions on TFP, we study the impact on real income and welfare.

Our framework builds on quantitative economic-geography models that introduce labor mobility into quantitative trade models such as Eaton and Kortum (2002) and Anderson and Van Wincoop (2003), including Allen and Arkolakis (2014), Caliendo et al. (2014), Ramondo et al. (2015), Redding (2015), Bartelme (2015), and Monte et al. (2015). Our research question – the impact of state taxes

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

[7] See "Kansas' Ruinous Tax Cuts," *The New York Times*, Editorial Board, July 13, 2014.

[8] See Section 2.1. There is a substantial debate on state corporate tax apportionment policy (e.g., ITEP (2012) and Mazerov (2005)).

[9] See also Behrens et al. (2011) and Hsieh and Moretti (2015). A related literature on spatial misallocation considers rural-urban income gaps; e.g., Gollin et al. (2013) and Lagakos and Waugh (2013) find productivity gaps between agricultural and non-agricultural sectors which are suggestive of misallocation, and Bryan and Morten (2015) study whether these income gaps reflect spatial misallocation.

[10] For any observed distribution of taxes, our model can rationalize the observed distribution of economic activity (wages, prices, employment, and trade) as an equilibrium outcome corresponding to some joint distribution of productivity, amenities, and trade costs. We do not introduce wedges in the model to save notation, but we note that, if introduced, they would not be separately identified from these fundamentals.

on the U.S. economy – distinguishes our paper from this previous literature. This focus drives our modeling choices, estimation approach, and counterfactuals. Our model combines a number of ingredients already present in existing studies,[11] plus a few new ones dictated by our question; the new ingredients are imperfect firm mobility in the form of idiosyncratic productivity draws across states,[12] a tax structure that encompasses the main taxes used by U.S. states, and a government sector that uses these taxes to finance public services valued by workers and firms. Relative to this literature, a central feature of our analysis is the focus on performing counterfactuals with respect to policy variables that are directly observed (U.S. state tax rates) and the use of observed variation in these same policies to identify the key model parameters.[13] Recent papers considering the impact of different regional policies using related tools include Gaubert (2015) and Ossa (2015).

Our paper is also related to the literature that has analyzed the general equilibrium effects of tax changes. Shoven and Whalley (1972) and Ballard et al. (1985) point out the importance of general equilibrium effects when analyzing large changes in policy. Albouy (2009) studies distortions in the allocation of workers across U.S. cities caused by federal tax progressivity and Eeckhout and Guner (2015) study optimal income taxation across cities.[14] This literature analyzes static environments in which taxes impact the allocation across sectors or regions, as we do here. A large literature in macroeconomics studies the dynamic effects of taxes in the standard growth and real-business cycle model; Mendoza and Tesar (1998), among others, study dynamic effects of taxes in an international setting.

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

[11] Specifically, our model includes an endogenous number of monopolistically competitive firms in each location similarly to Krugman (1991) and Helpman (1998), the use of differentiated products as intermediates as in Krugman and Venables (1995), and workers with idiosyncratic preferences for location as in Tabuchi and Thisse (2002). Similar ingredients appear in the recent quantitative economic-geography literature referenced above.

[12] I.e., in our model, there is imperfect mobility of two factors of production (firms and workers). For a quantitative setup also featuring imperfect mobility of several factors of production see Galle et al. (2015).

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

[14] Relatedly, Albouy (2012) studies optimal transfer schemes in Canada in a Roback spatial-equilibrium setting.

[15] E.g., Devereux and Griffith (1998) estimate the effect of profit taxes on the location of production of U.S. multinationals, Goolsbee and Maydew (2000) estimate the effects of the labor apportionment of corporate income taxes on the location of manufacturing employment, Hines (1996) exploits foreign tax credit rules to show that investment responds to state corporate tax conditions, and Giroud and Rauh (2015) show that C-corporations reduce their activity when states increase corporate tax rates. Chirinko and Wilson (2008) and Wilson (2009) also provide evidence consistent with the view that state taxes affect the location of business activity.

The rest of the paper is structured as follows. Section 2 describes the features of the U.S. state tax system that motivate our analysis. Section 3 develops the model and describes its general-equilibrium implications. Section 4 describes our estimation approach. Section 5 focuses on the spatial-misallocation counterfactuals, and Section 6 presents the results from additional counterfactuals. Section 7 concludes. Detailed derivations, additional figures, and additional details on both estimation and data sources are shown in an Online Appendix.

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 amounted to 4% of U.S. GDP. In this section, we first describe how we measure each tax rate. We then present statistics that summarize the dispersion in tax rates across states. We conclude with evidence on the relationship between state tax revenue and government spending. Appendix F details the sources of the data discussed in this section.

2.1 Main State Taxes

Personal Income Tax States tax the personal income of their residents. The base for the state personal income tax includes both labor and capital income. In our benchmark analysis, we use a flat state income tax rate, and we then explore how our counterfactual results change if we account for the progressivity of income taxes at both the state and federal levels.[16] We compute an income tax rate for each state using the average effective tax rate from NBER TAXSIM, which runs a fixed sample of tax returns through different tax schedules every year and accounts for most features of the tax code (see Appendix F.1 for details). In 2010, the average across states was 3%; the states with the highest income tax rates were Oregon (6.2%), North Carolina (5.2%), and Hawaii (5.0%), while seven states had no income tax.

Corporate Income Tax States also tax businesses. The tax base and tax rate on businesses depend on the legal form of the corporation. The tax base of C-corporations is national profits.[17] State tax authorities determine the share of a C-corporation's national profits allocated to their state using apportionment rules, which aim to capture the corporation's activity share within their state. To determine that activity share, states put different weight on three apportionment factors: payroll, property, and sales. Payroll and property factors depend on where goods are produced and typically coincide; the sales factor depends on where goods are consumed.[18] In 2012, the

[16] The schedule of state income tax rates tends to be progressive, but it is typically much flatter than the federal income tax schedule. We compare the progressivity of state and federal income tax rates when we introduce progressive income taxes in Section 5.5.

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

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

average corporate income tax rate across states was 6.4%; the states with the highest corporate tax rates were Iowa (12%), Pennsylvania (10%), and Minnesota (10%), while six states had no corporate tax. Apportionment through sales tends to be more prevalent: nineteen states exclusively apportion through sales, while roughly half of the remaining states apply either a 50% or 33% apportionment through sales. Since C-corporations account for the majority of net income in the United States, in our benchmark analysis we treat all businesses as C-corporations.[19] We also explore how our results change when we apply alternative corporate tax rates that adjust for the fraction of C-corporations in total revenue in each state, or that account for tax subsidies that some states grant to firms, reducing their effective corporate tax rate.

Sales Tax Sales taxes are usually paid by the consumer upon final sale, and states typically do not levy sales taxes on firms for intermediate inputs or goods that they will resell.[20] In 2012, the average sales tax rate was 5%; the states with the highest sales tax rates were New Jersey (10%), California (7.5%), and Indiana (7%), while five states had no sales taxes. In our benchmark analysis, we define the sales tax rate as the statutory general sales tax rate applied only to final consumer sales.

2.2 Dispersion in Tax Rates and in Tax Revenue across States

Both tax rates and tax bases vary considerably across states. Panel (a) of Figure 1 shows the 2010 distribution of sales, income, corporate, and sales-apportioned corporate tax rates.[21] For each tax, rates vary across states, corporate tax rates being the most dispersed; the 90-10 percentiles of the distributions of sales, average personal income, and corporate income tax rates are 7%-1%, 5%-0%, and 9%-0%, respectively. For each type of tax, there are at least five states with 0% rates. These differences in tax structures across states are associated with differences in total tax revenue collected. Panel (b) of the same figure shows the distribution in tax revenue as share of GDP across states. The share of the sum of income, sales, and corporate tax revenue in GDP varies across states between 2% and 7%. While most states collect both income and sales taxes, some rely almost exclusively on sales tax revenue, such as Texas and Nevada, while others are sales-tax free, like New Hampshire and Oregon.

$t_i^l = (1 - \theta_i^x)\, t_i^{corp}$ is the corporate tax apportioned through property and payroll in state i.

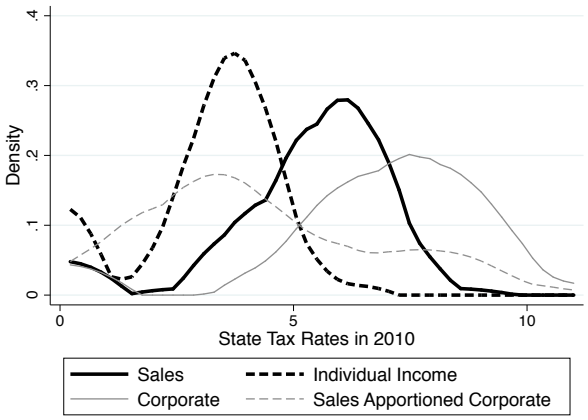
[19] C-corporations accounted for 66% percent of total business receipts in 2007 (PERAB, 2010).

[20] 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).

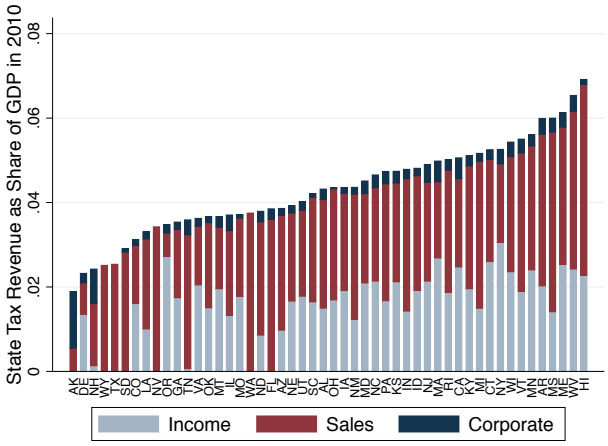
[21] The sales-apportioned corporate tax rate is the product of the sales apportionment factor (which is between 0 and 1) and the corporate rate; i.e., it is $t_n^x = \theta_n^x t_n^{corp}$ defined in footnote 18. Table A.2 in Appendix F.2 shows the state tax rates in 2007 in all 50 states. Table A.1 shows the federal income, corporate, and payroll tax rates in 2007.

Figure 1: Dispersion in State Taxes in 2010

(a) Distribution of Tax Rates Across States



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



Local (sub-state) governments also tax residents. Overall, state taxes amount to roughly 60% of state and local tax revenue combined.[22] Heterogeneity in tax rates across states is also present when both state and local taxes are taken into account. Figure A.1 in the online appendix reproduces Panel (a) of Figure 1 using the sum of state and local tax rates. It shows that cross-state differences in tax rates increase when local tax rates are taken into account.

2.3 Relationship Between State Taxes and Government Spending

State governments typically have balanced budgets (Poterba, 1994), so we assume in our model that changes in state tax revenue translate to changes in state government spending. Figure 2 shows that there is indeed a high correlation between the aggregate 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. Direct expenditures include all government expenditures other than intergovernmental transfers.[23]

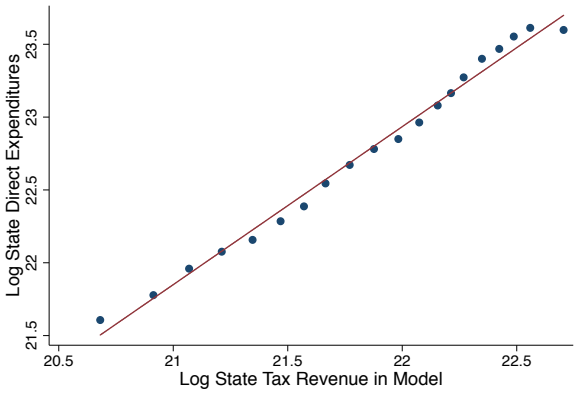
Panel (a) shows a binned scatter plot, which shows the mean of each bin, and a regression line of states' direct expenditures on states' aggregate revenue from personal income, corporate income and sales taxes controlling for state fixed effects, while Panel (b) shows an equivalent regression but controlling for year fixed effects instead. Note that, in both cases, not only is the R^2 is very close to 1, but the slope is also very close to 1. Therefore, a 1% increase in tax revenue is nearly always expected to translate into a 1% increase in state direct expenditures.

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

[23]The main direct-expenditure items are education, public welfare, hospitals, highways, police, correction, natural resources, parks and recreation, government administration, and utility expenditure.

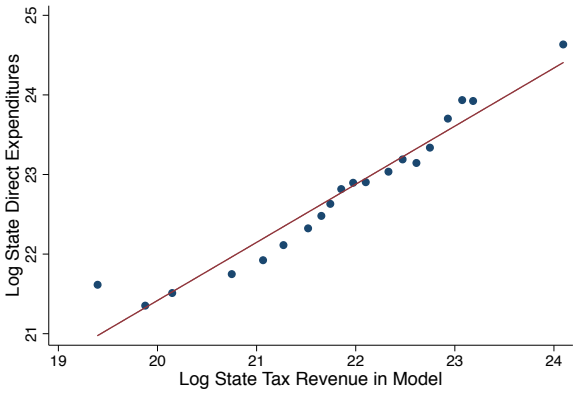
Figure 2: Comparing State Tax Revenue and Spending

(a) State Fixed Effects



Note: Slope is 1.05 (.001). Sample: 1980-2012. R-squared is 1.

(b) Year Fixed Effects



Note: Slope is 1.01 (.005). Sample: 1980-2012. R-squared is 1.

3 Quantitative Trade Model with State Taxes and Public Goods

We model a closed economy with N states indexed by n or i. A mass M of firms and L of workers respectively receive idiosyncratic productivity and preference shocks, which govern how they sort across states. We let M_n and L_n be the measure of workers and firms that locate in state n. We normalize $M = 1$ and $L = 1$, so that M_n and L_n are the fractions of firms and workers located in state n.

Each state n has an endowment H_n of fixed factors of production (land and structures), an amenity level u_n, and a productivity level z_n. There is an iceberg cost $\tau_{ni} \geq 1$ of shipping from state i to state n (if one unit is shipped from i to n, $1/\tau_{ni}$ units arrive). Firms are single-plant and sell differentiated products. To produce, they use the fixed factor, workers, and intermediate inputs. 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.[24]

[24] 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, for any counterfactual change in taxes, there would be an additional aggregate welfare effect through its impact on the size of the federal budget.

3.1 Production Technologies

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

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

where J_i denotes the set of varieties produced in state i and q_{ni}^j is the quantity of variety j produced in state i and 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 (and also its price before sales taxes) is

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

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 $1-\beta_i$ is the labor share in value added in state i. The existence of a fixed factor is one of the sources of congestion in the model; the higher the number of firms and workers located in a given state, the higher the relative price of this fixed factor. Production functions are allowed to vary by state; this flexibility is needed to match the heterogeneity in the shares of total payments to labor and intermediate inputs expenditures in states' GDP observed in the data.[25]

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

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

component is

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

where we define the workers' tax keep-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.[26] 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 u_n 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 efficiency in the provision of government services.[27] 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, $(1 + t_n^c) P_n$.[28] As a result, real consumption equals the pre-tax wage, w_n/P_n, adjusted by income and sales taxes, $1-T_n$. The parameter 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 the reader that we have normalized the mass of workers to 1, the fraction of workers located in state n is

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

where

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

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

[26] The framework could easily be generalized to allow for direct consumption of the fixed factor by workers in equation (5) in the form of housing. In that specification, the price of land would also enter as part of the cost of living. Additionally, the effective tax keep-rate could be modified to also account for average property taxes, and housing supply could be allowed to be elastic. While extending the model with these forces would be straightforward, quantifying them would be less so because property taxes are largely imposed at the local (sub-state) level, and housing supply elasticities vary considerably across cities within states, as documented by Saiz (2010).

[27] I.e., if we had an additional variable z_n^G representing the efficiency or quality of government spending, it would enter multiplicatively with u_n.

[28] Note that equation 6 takes into account 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 the federal income tax rate t_{fed}^y to the average effective federal rate paid by U.S. residents. In section 5.5 we relax this assumption and allow 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).

it as our measure of worker welfare.[29]

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 who 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, $(1-T_n)(w_n/P_n)$, while $\varepsilon_W\alpha_W$ is the partial elasticity with respect to real government services per worker, $G_n/L_n^{\chi_W}$. We rely on these relationships to estimate $\{\varepsilon_W, \alpha_W\}$ 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. 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 across states. 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 its price p_{ni}^j in state n, the quantity exported to state n is $q_{ni}^j = Q_n(p_{ni}^j/P_n)^{-\sigma}$. We first describe the profit maximization problem faced by firms located in a given state, and then solve the firms' location problem. We finally discuss some of the aggregation properties of our model, which are common with standard models of international trade such as Melitz (2003).

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

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

where $\bar{t}_i^j$ is the corporate tax rate of firm j in state i, $x_{ni}^j = P_n Q_n^{\frac{1}{\sigma}}(q_{ni}^j)^{1-\frac{1}{\sigma}}$ are its sales to state n, and $c_i = (w_i^{1-\beta_i} r_i^{\beta_i})^{\gamma_i} P_i^{1-\gamma_i}$ is the the cost of the cost-minimizing bundle of factors and intermediate inputs, where r_i stands for the cost of a unit of land and structures in state i.[30]

All firms face corporate taxes apportioned through sales, payroll, and land and structures.[31] 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

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

[30] 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.

[31] This assumption implies that we treat all companies as C-corporations. In practice, many companies are set up as S-corporations and partnerships. These companies are not subject to corporate income taxes. We ignore them in our baseline model because they represent a small fraction of U.S. business revenues – see our previous discussion in section 2.1. However, in Section 5.6 we perform a robustness check where corporate tax rates are adjusted by the actual share of C-corporations in each state.

profits in corporate taxes apportioned through sales to state n. Firms located in i also pay t_i^l times the pre-tax national profits in corporate income taxes apportioned through payroll and land and structures to state i, and a rate t_{fed}^{corp} in federal corporate income taxes. As a result, the corporate tax rate of firm j is:

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

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 problems with constant marginal production costs in Krugman (1980) or Melitz (2003). When a firm increases the fraction of its sales to state n (i.e., when s_{ni}^j increases), the average tax rate changes depending on the sales-apportioned corporate tax in state n, t_n^x, relative to that in other states. Since the corporate tax base is national profits, firms trade off the marginal pre-tax benefit of exporting more to a given state against the potential marginal cost of increasing the corporate tax rate on its entire profits.

Despite this interaction in the sales decision, the firm problem retains convenient properties from the standard CES maximization problem that allow for aggregation; we describe these properties here and refer to Appendix B.1 for derivations. Specifically, all firms located in a state i have the same sales shares across destinations irrespective of their productivity, i.e., $s_{ni}^j = s_{ni}$ for all firms j located in i; from (10), this leads to a common corporate tax rate across firms, $\bar{t}_i^j = \bar{t}_i$. Additionally, firms set identical, constant markups over marginal costs, but these markups vary bilaterally depending on corporate taxes. The price set in n by a firm with productivity z located in state i is:

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

where

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

The term $\tilde{t}_{ni}$ is a pricing distortion created by heterogeneity in the sales-apportioned corporate tax rates. No dispersion in the sales-apportioned corporate tax rates ($t_n^x = t^x$ for all n) implies $\tilde{t}_{in} = 0$ for all i and n, and the pricing decision becomes 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 sales-apportioned corporate taxes.

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 the profit of a firm with productivity z_i^0 located in i.

Firm j decides to locate in state i if $i = \arg\max_{i'} \pi_{i'}(z_{i'}^j)$. The idiosyncratic component of productivity, ϵ_i^j, is i.i.d. across firms and states and is drawn from a Fréchet distribution, $\Pr(\epsilon_i^j < x) = e^{-x^{-\varepsilon_F}}$. This implies that firm-level profits, $\pi_i(z_i^j)$, are also Fréchet-distributed with shape parameter $\varepsilon_F/(\sigma-1) > 1$. As a result, and reminding the reader that we have normalized the mass of firms to 1, the fraction of firms located in state i is

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

where the expected profits before drawing $\{\epsilon_i^j\}_{i=1}^N$ are proportional to[32]

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

Equation (15) says that 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. A larger value of $\varepsilon_F/(\sigma-1)$ implies that the idiosyncratic productivity draws are less dispersed across states; as a result, locations become closer substitutes, and an increase in the relative profitability of a location (an increase in $\pi_i\left(z_i^0\right)/\bar{\pi}$) leads to a larger response in the fraction of firms that choose to locate there.

Productivity Distribution Because firms self-select into each state based on their productivity draws, the productivity distribution in each state is endogenous. However, as in Melitz (2003), aggregate outcomes (in our case, at the state level) can be formulated as a function of a single moment $\tilde{z}_i$ of the the productivity distribution in each state i. This productivity level is endogenous and can be expressed as a function of the number of firms that optimally choose to locate in each state i:[33]

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

The productivity of the representative state-i firm, $\tilde{z}_i$, is larger than the unconditional average of the distribution of productivity draws (i.e., $\tilde{z}_i/z_i^0 > 1$), reflecting selection. This equation describes

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

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

an additional congestion force in the model: because firms are heterogeneous and self-select based on productivity, a higher number of firms locating in a state i is associated with a lower average productivity in state i.

State Aggregates State-i outcomes can be constructed as if in equilibrium all the M_i firms located in state i had 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). We construct the sales shares s_{ni}, which are necessary to compute the corporate tax rate $\bar{t}_i$ in (10) and the pricing distortion $\tilde{t}_{ni}$ in (12), using the identity $s_{ni} = \lambda_{ni} P_n Q_n / X_i$, where $P_n Q_n$ is the aggregate expenditure on final goods in state n. By definition, aggregate sales by firms located in state i are:

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

Because of Cobb-Douglas technologies and CES demand, aggregate payments to intermediate inputs, labor, and fixed factors in state i are constant fractions of X_i.[34] As a result, spatial interactions drive local effects: larger expenditure $P_n Q_n$ in state n acts as a factor-demand shifter in state i through X_i, with its impact depending on the intensity of the trade link, λ_{ni}. Aggregate pre-tax profits $\tilde{\Pi}_i$ are also proportional to sales:

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

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

Contrast with Models with Free Entry This structure has similar implications to a standard economic-geography model with free entry of homogeneous firms such as Helpman (1998) or Redding (2015), in the sense that the number of firms is endogenous and proportional to sales in each location.[35] We assume mobility of heterogeneous firms instead of free-entry of homogeneous firms for three reasons: first, it allows us to use data on patterns of firm mobility to estimate the parameter ε_F (see 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 (2015); third, it allows us to treat mobility of workers and firms symmetrically.[36]

[34] See the expressions (A.6) to (A.8) in Appendix B.2.

[35] Specifically, from (20) and the distributional assumption on the productivity draws, it follows that the number of firms in state i can be expressed as $M_i = \frac{1-\bar{t}_i}{\bar{\pi}} \frac{X_i}{\sigma}$. If, instead, we had assumed free-entry of homogeneous firms with entry cost equal to f_i units of the factors and inputs bundle of each state, the number of firms in state i in our model would be $M_i = \frac{1-\bar{t}_i}{c_i f_i} \frac{X_i}{\sigma}$.

[36] The cost of assuming mobility of heterogeneous firms instead of free-entry of homogeneous firms is that, in the former, taxes do not affect the total number of firms in the economy. We note, however, that in both cases the fraction

3.4 State Government

State governments use tax revenue R_n to finance spending in public services. Motivated by the evidence discussed in Section 2.3, we assume that tax revenue translates 1-to-1 into government spending. Total government spending and revenue in state n is

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

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

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

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

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

The base for corporate tax profits are the pre-tax profits from every state, defined in (20), adjusted by the proper apportionment weights. Equation (23) shows that the base for state income taxes is the income of both workers and capital-owners who reside in n net of federal income taxes; in that expression, $\Pi = \sum_i \Pi_i$ and $R = \sum_i r_i H_i$ are national after-tax profits and returns to land and structures, respectively. The base for the sales tax in (24) is the total personal consumption expenditure of workers and capital owners, $P_n C_n$.[37]

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 (given by (A.7) in Appendix B.2) for all n; vii) the land market clears in every location, i.e., equation (A.8) in Appendix B.2 holds; and viii) the national labor market clears, i.e., $\sum_n L_n = 1$.

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of the total number of firms located in each state is determined independently from the total number of firms (here normalized to 1), i.e., the cross-sectional distribution of firms is scale-independent. As such, allowing for free entry would not affect the part of welfare changes corresponding to the spatial distribution of economic activity, which is the focus of our analysis. However, our analysis could be carried out assuming free entry to assess this additional margin.

[37] $P_n C_n$ is defined in Equation (A.11) in Appendix B.2. As mentioned above, taxes are also collected by the federal government. Expression (A.14) in Appendix B.2 shows the expression for total taxes levied by the federal government in state n.

Adjusted Fundamentals Because of multiple spatial interactions, the entire distribution of state taxes affects the joint distribution of workers, firms, and trade. These effects can be better understood by deriving a general-equilibrium system that determines wages and employment in every state, $\{w_n, L_n\}_{n=1}^N$, and welfare, v, as function of the model's primitives (see Appendix B.3). 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 *adjusted fundamentals* in every state, $\left\{\left\{\tau_{in}^A\right\}_{i=1}^N, z_n^A, u_n^A\right\}_{n=1}^N$:

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

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

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

where P_nG_n/GDP_n is the share of state government spending to GDP. We can express this share as

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

where P_nQ_n/X_n is the share of state expenditure in aggregate sales (i.e., a measure of state trade deficit).[38]

The adjusted fundamentals are functions of state fundamentals (productivity z_n, amenity u_n, and trade costs τ_{in}), tax rates, and government size. State-n 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 tax keep-rate $1-T_n$, and government size relative to GDP as shown in (28). State-n taxes also affect the adjusted fundamentals in states other than n through their impact on the price distortion, the corporate tax rate, and government size relative to GDP in these other states.

Consider the effect of sales-apportioned corporate taxes, $\{t_i^x\}_{i=1}^N$. These 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 corporate 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. In this case, the effective corporate tax is exogenous, $\bar{t}_n = t^x + t_n^l$, and government size relative to GDP in a state n, P_nG_n/GDP_n, becomes a function of state-n taxes only. State taxes $\left\{t_n^c, t_n^y, t_n^l, t^x\right\}$ then affect the allocation exclusively through the adjusted productivities $\left\{z_n^A\right\}$ and the adjusted amenities $\left\{u_n^A\right\}$. Individual income and sales taxes are similar to amenities: given

[38] Equation (A.19) in Appendix B.2 shows the expression for P_nQ_n/X_n. To reach (28), first replace P_nC_n from (A.11), R_n^y from (23), and R_n^{corp} from (A.17) into the government budget constraint (A.14), and then normalize by GDP using (A.9).

government size relative to GDP, the distribution of wages, employment, and welfare can be rationalized with no individual income or sales taxes, but with a different distribution of amenities u_n (equal to the adjusted amenities u_n^A). In the same sense, corporate taxes are similar to productivity: given government size relative to GDP, the equilibrium outcomes can be rationalized without corporate taxes, but with a different distribution of productivities (equal to z_n^A).

Agglomeration Forces, Congestion Forces, and Uniqueness The model features several agglomeration and congestion forces. Due to the agglomeration forces, workers and firms tend to locate in the same state, whereas the congestion forces imply that workers and firms tend to spread across different states.

Specifically, our model features agglomeration through standard home market effects. Because of trade costs, workers (who consume final goods) and firms (which purchase intermediate inputs) have an incentive to locate near states with low price indices and large markets; in turn, the price index decreases with the number of firms, and market size increases with the number of workers. These agglomeration forces are governed by the parameter σ. It also features agglomeration through public-services provision: states with a larger number of firms and workers have higher tax revenue and spending; therefore, larger market size leads to higher utility per worker (see (5)) or firm productivity (see (13)). This agglomeration force decreases with the parameters χ_W and χ_F.[39]

At the same time, our model features congestion through immobile factors in production, leading to a higher marginal production cost when employment increases (see (A.8) in Appendix B.2); through selection of heterogeneous firms, leading to a lower average firm productivity in a state when the number of firms increases (see (17)); and through the presence of immobile capital-owners, who spend their income where they are located.

In light of these opposing forces, it is natural to ask whether the general equilibrium is unique. Allen et al. (2014) establish conditions for existence and uniqueness in a class of trade and economic geography models. Our model fits in that class when technologies are homogeneous across states ($\beta_n = \beta$ and $\gamma_n = \gamma$ for all n), there is no dispersion in sales-apportioned corporate taxes across states ($t_n^x = t^x$ for all n), and there is no cross-ownership of assets across states. Appendix B.4 shows a uniqueness condition from Allen et al. (2014) applied to this restricted model. The condition is satisfied by the parameter values estimated in Section 4, under which we compute the counterfactual results presented in Section 5.[40]

[39] We explore how the results depend on these parameters governing agglomeration forces in Section 5.7.

[40] Changing one parameter at a time around our estimates, we find that these sufficient conditions for uniqueness are violated if the elasticities of firm and labor mobility (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 the elasticity of substitution σ are sufficiently low. When computing the counterfactuals, we experiment with different starting values of our algorithm and always find the same results, suggesting that the system of equations indeed has a unique solution.

4 Data and Estimation

In order to use the model described in Section 3 to evaluate the impact of counterfactual distributions of state taxes, we need first to assign values to the model parameters. Section 4.1 describes the data we use in this procedure. Section 4.2 describes the calibration of the technology parameters, state fundamentals, and ownership rates. Their values are chosen so that the model exactly reproduces the distributions of employment, wages, labor and intermediate-inputs shares of income, bilateral sales, bilateral expenditure shares, and trade imbalances across states in a given year; we choose 2007 because this is the latest year in which all these data are available. In Section 4.3, we present the estimation of the labor and firm mobility elasticities and the weights of government spending in preferences and firm productivity. These parameters are estimated using a longitudinal dataset on the distribution of workers, firms, taxes, and state government revenue across states from 1980 to 2010. In Section 4.4, we study how well the parametrized model fits the distribution of variables that are not targeted by this parametrization strategy.

4.1 Data

For the calibration in Section 4.2, we use measures by state of employment L_n, wages w_n, total sales, GDP, and total expenditures P_nQ_n for the year 2007. As detailed in Appendix F.2, these variables are drawn from the Economic Census of the United States. We also use information from a recently available dataset made available by the B.E.A. on Personal Consumption Expenditures as an input to calculate a measure of aggregate expenditures by state, P_nC_n. Finally, we use information on bilateral trade flows X_{ni} from the Commodity Flow Survey (CFS).

Since the model is cast in closed economy, we construct a measure of total sales in the model, X_n, by subtracting each state's exports to the rest of the world from their total sales.[41] Intermediate-input expenditures P_nI_n are constructed as the difference between state sales and GDP. Total expenditures P_nQ_n are constructed by adding up personal consumption expenditures, intermediate-goods expenditures, and government expenditures. In order to construct bilateral sales shares s_{in} and expenditure shares λ_{in}, we define own-state sales as the difference between total sales and trade flows to every other state.[42]

For the estimation in Section 4.3, we use information for all years between 1980 and 2010 on number of workers and firms, hourly wage, total tax revenues, price indices, and personal income, corporate income, and sales tax rates. As Economic Census data are not available in every year, we use data on the number of workers and establishments from the County Business Patterns (CBP). The information on number of workers and establishments reported in the CBP is consistent with that reported by the Census in those years when both are available. We use the Current Population Survey to construct an hourly wage measure by state. We use regional price indices from the Bureau

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

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

of Labor Statistics. As detailed in Appendix F.1, the data on tax rates and total tax revenues are drawn from the U.S. Census, NBER TAXSIM, the Book of States, and Suárez Serrato and Zidar (2015). State spending on public services, $P_n G_n$, is set equal to the sum of tax revenues that each state collects from the three taxes considered in the model: personal income, corporate income, and sales.

4.2 Calibrated Parameters

Technologies We set the state-specific value-added shares, γ_n, and shares of labor in value added, $1-\beta_n$, so that the intermediate-input and employment shares predicted by the model in (20), (A.6), and (A.7) match their empirical counterparts for each state in the year 2007.[43] The averages across states of our calibrated parameters are: $N^{-1}\sum_n(1-\gamma_n) = 0.62$ and $N^{-1}\sum_n(1-\beta_n) = 0.68$.

Fundamentals The system of equations that characterizes the general equilibrium impact of counterfactual changes in taxes, described in Appendix B.5, 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, these fundamentals enter this system of equations only through the composite A_{in} defined in (A.26) in Appendix B.3. In order to calibrate this composite, we match A_{in} to the function of expenditure shares, wages, and employment described in equation (A.24). We therefore do not need to identify the value of all fundamentals separately.[44] As a result, the parametrized model exactly matches the distributions of bilateral expenditure shares, bilateral sales shares, wages, and employment across states in 2007.

Ownership Rates We set the ownership rates, b_n, to match the ratio of expenditures to sales in each state. Expression (A.21) in Appendix B.2 shows that the set of parameters $\{b_n\}_{n=1}^N$ are uniquely identified as a function of observables, technology parameters in state n, and the parameter σ. The parametrized model exactly matches the distribution of trade imbalances across states in 2007.[45]

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 (2002). We also analyze how the counterfactual predictions of our model change when we assign values to χ_W and χ_F between 0 and 1. The elasticity of substitution across varieties σ is set to 4, which is a central value in the range of estimates of

[43] I.e. $1-\gamma_n = \frac{\sigma}{\sigma-1}\frac{P_n I_n}{X_n}$ and $1-\beta_n = \frac{\sigma}{\sigma-1}\frac{w_n L_n}{\gamma_n X_n}$. For these calculations, we use the value of σ described below.

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

[45] 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, as reported in the BEA regional data on personal incomes (CA 30). In particular, in 2007, we estimate that $b_n = 0.14 + 1.36 SHARE_n$ where the standard errors for the intercept and slope are 0.018 and 0.28, respectively.

the demand elasticity across differentiated products in the international trade literature; see Head and Mayer (2014).[46]

4.3 Estimated Parameters

Table 1 contains our preferred estimates of the parameters ε_W, α_W, ε_F, and α_F. The labor supply elasticity, ε_W, and the share of public goods in preferences, α_W, are estimated using the worker-location equation, as described in Section 4.3.1. 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. Appendix C.4 shows that our estimates for these parameters are in line with estimates presented in the previous literature, even though these ones rely on different identification assumptions.

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

Table 1: Estimated Parameters

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

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

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

where $a_0 \equiv \varepsilon_W(1-\alpha_W)/(1+\chi_W\varepsilon_W\alpha_W)$ and $a_1 \equiv \varepsilon_W\alpha_W/(1+\chi_W\varepsilon_W\alpha_W)$ are functions of structural parameters; $\psi_t^L \equiv -\varepsilon_W/(1+\chi_W\varepsilon_W\alpha_W) * \ln(v_t)$ is a time effect that captures welfare at time t;[47] $\xi_n^L + \nu_{nt}^L \equiv \varepsilon_W/(1+\chi_W\varepsilon_W\alpha_W) * \ln(u_{nt})$ accounts for state effects and deviations from state and year effects in amenities, u_{nt}; $\tilde{w}_{nt} \equiv (1-T_{nt})(w_{nt}/P_{nt})$ is after-tax real wage; and $\tilde{R}_{nt} = R_{nt}/P_{nt}$ is real government spending. Given identification of the parameters a_0 and a_1, the preference for government spending is identified as $\alpha_W = a_1/(a_0+a_1)$. The parameters ε_W and χ_W are not separately identified; therefore, we present estimates for ε_W given values of $\chi_W \in \{0, 0.5, 1\}$.

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

[46] Standard procedures to estimate σ in the international trade literature rely on information on tariffs across countries (e.g., see Caliendo and Parro (2014)). No tariff applies to the exchange of goods between U.S. states, complicating the estimation of σ in our context.

[47] We have normalized total employment to 1. Time variation in aggregate labor supply leads to changes in v_t, hence ψ_t^L captures changes in aggregate labor supply.

its after-tax real wages and positively correlated with its real government spending. Intuitively, higher amenities in a state attract workers, shift out the labor supply curve, and lower wages. Similarly, an increase in the number of workers raises the tax revenue and thus increases government spending. Our model thus predicts that the OLS estimate of a_0 is biased downwards, and the OLS estimate of a_1 is biased upwards.

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

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

We assume that our sample is fixed in the time dimension. In this case, the TSLS estimator that uses both $\boldsymbol{Z}_{nt}^L$ and $\boldsymbol{Z}_{nt}^{L*}$ as instruments for $\tilde{w}_{nt}$ and $\tilde{R}_{nt}$ is consistent if ν_{nt}^L is mean independent of the functions of taxes included in either the vector $\boldsymbol{Z}_{nt}^L$ or the vector $\boldsymbol{Z}_{nt}^{L*}$ in any time period, after controlling for year and state effects. Formally, $\mathbb{E}[\nu_{nt}^L | \boldsymbol{Z}_n^L, \boldsymbol{Z}_n^{L*}, \xi_n^L, \psi_t^L] = 0$, where $\boldsymbol{Z}_n^L = (\boldsymbol{Z}_{n1}^L, \ldots, \boldsymbol{Z}_{nt}^L, \ldots, \boldsymbol{Z}_{nT}^L)$ and analogously for $\boldsymbol{Z}_n^{L*}$.

An implication of this assumption is that income, sales, and corporate tax rates in state n must affect state n employment shares only through their effect on real wages and the provision of public goods in that state. In order to alleviate potential endogeneity concerns arising from correlation between changes in a state n amenities and its own taxes, 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 do 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 $\mathbb{E}[\nu_{nt}^L | \boldsymbol{Z}_n^{L*}, \xi_n^L, \psi_t^L] = 0$.

Appendix C.1 describes the the first-stage estimates. The estimation results are in Table 2. Column (1) shows the OLS estimates, which indicate that higher levels of real government spending and after-tax real wages are correlated with higher supply of labor. Columns (2) and (3) show the TSLS estimates; column (2) uses own-state and external taxes as instruments, while column (3) uses only external taxes. 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 between the OLS and the TSLS estimates is consistent with our model's predictions that amenities in any given state n are negatively correlated with after-tax

real wages in n and positively correlated with real government spending in n.

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. Therefore, we choose the specification in column (3) as our preferred one. It implies a preference for government spending of 0.17 and, given a value $\chi_W = 1$, a labor supply elasticity ε_W of roughly 1.5. These estimates suggest that the elasticity of worker location to after-tax real wages is five times larger than with respect to government spending. These results line up well with the existing literature which uses different shocks to identify local labor elasticities (see Appendix C.4 for details).[48]

Table 2: TSLS Estimates of Local Labor Supply Parameters

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

NOTES: This table shows TSLS estimates. The dependent variable in each column is log of state employment $\ln L_{nt}$. The data are at the state-year level. Each column has 712 observations. Real variables – after-tax real wages $\ln \tilde{w}_{nt}$ and real government expenditures $\ln \tilde{R}_{nt}$ – are divided by a price index variable from the BLS, which is available for a subset of states that collectively amount to roughly 80 percent of total U.S. population. Every specification includes state and year fixed effects. Robust standard errors 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 in (15) with the definition of profits in (16), the pricing equation in (11), and the definition of productivity in (13), we obtain

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

where $b_0 \equiv \left(\varepsilon_F/\left(\sigma-1\right)\right)/\left(1+\chi_F\alpha_F\left(\sigma-1\right)\right)$, $b_1 \equiv \varepsilon_F\alpha_F/\left(1+\chi_F\alpha_F\left(\sigma-1\right)\right)$, and $b_2 \equiv -\alpha_F b_1$; ψ_t^M is a time effect, and $\xi_n^M + \nu_{nt}^M$ accounts for state effects and deviations from state and year

[48] GMM estimates of these parameters are also very similar (see Table A.4 in Appendix C.1).

effects in log productivity, $\ln(z_{nt})$.[49] The term MP_{nt} is the market potential of state n in year t,

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

where $E_{n't} \equiv P_{n't}Q_{n't}$ denotes aggregate expenditures in state n' and unit costs are given by $c_{nt} = (w_{nt}^{1-\beta_n} r_{nt}^{\beta_n})^{\gamma_n} P_{nt}^{1-\gamma_n}$. Details on how we construct measures of all the covariates entering the right-hand side of (32) are contained in Appendix C.2.1.

Given identification of the parameters b_0, b_1, and b_2, the impact of government spending on productivity is identified as $\alpha_F = -b_2/b_1$. The parameters ε_F and χ_F are not separately identified; therefore, we present estimates of ε_F given values of $\chi_F \in \{0, 0.5, 1\}$. Given an assumed value for χ_F, equation (31) contains three reduced-form parameters (i.e., b_0, b_1, and b_2) that jointly identify the two structural parameters ε_F and α_F. We estimate the parameter vector $(\varepsilon_F, \alpha_F)$ using GMM.

Our model predicts that ν_{nt}^M is not mean independent of the market potential, real government spending, and marginal production costs. Therefore, we implement a GMM estimator that uses as instruments a vector of state and year effects, tax rates in both state n and in other states, and a shifter for market potential. Specifically, we use own-state corporate tax keep-rate $\boldsymbol{Z}_{nt}^M \equiv 1 - t_{nt}^{corp} - t_{fed,t}^{corp}$, a vector $\boldsymbol{Z}_{nt}^{M*} \equiv (t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$ of external taxes already defined in (30), and an exogenous shifter MP_{nt}^* of the market potential term. The exogenous shifter of market potential, MP_{nt}^*, is constructed similarly to market potential MP_{nt} in (32), but differs from it in that we substitute the components E_{nt}, P_{nt}, and $\{\tilde{t}_{n'nt}\}_{n'=1}^N$, which according to our model are correlated with ν_{nt}^M, with functions of exogenous covariates. Appendix C.2.2 presents the precise definition of MP_{nt}^* (see equation (A.44)).

Using standard asymptotics in panel data models, we assume that our sample is fixed in the time dimension. The GMM estimator that uses $\boldsymbol{Z}_{nt}^M$, $\boldsymbol{Z}_{nt}^{M*}$, and MP_{nt}^* as instruments assumes that ν_{nt}^M is mean independent of the functions of taxes included in $\boldsymbol{Z}_{nt}^M$, $\boldsymbol{Z}_{nt}^{M*}$, and MP_{nt}^* in any time period, after controlling for year and state effects. Formally, $\mathbb{E}[\nu_{nt}^M | \boldsymbol{Z}_n^M, \boldsymbol{Z}_n^{M*}, MP_n^*, \xi_n^M, \psi_t^M] = 0$, where $\boldsymbol{Z}_n^M = (\boldsymbol{Z}_{n1}^M, \ldots, \boldsymbol{Z}_{nt}^M, \ldots, \boldsymbol{Z}_{nT}^M)$, and analogously for $\boldsymbol{Z}_n^{M*}$and MP_n^*. An implication of this assumption is that corporate tax rates in state n must affect that state's number of establishments only through their effect on the real government spending, unit production costs, and market potential of that state. The orthogonality conditions necessary for consistency of our GMM estimator are weaker when we only rely on state fixed effects, year fixed effects, and the vectors $\boldsymbol{Z}_{nt}^{M*}$ and MP_{nt}^* to construct moments. In this case, the resulting GMM estimates are consistent even if corporate taxes in state n react to changes in the unobserved productivity of state n, as captured in ν_{nt}^M.

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

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

pair $(\sigma, \chi_F) = (4, 1)$, it yields estimates $\varepsilon_F = 3.08$ (1.04) and $\alpha_F = 0.04$ (0.09). These estimates are broadly consistent with estimates found in the existing literature (see Appendix C.4 for details).[50]

Table 3: GMM Estimates of Firm Mobility Parameters

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

NOTES: This table shows the GMM estimates for firm mobility parameters. The dependent variable is log of state establishments $\ln M_{nt}$. The data are at the state-year level. Each column has 661 observations. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total U.S. population. After-tax market potential is 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 Appendix C.2. 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.

4.4 Over-Identification Checks

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

First, Panel (a) of Figure A.2 in Appendix C.3 compares the model implications for the share of state n in national GDP against the data in 2007. Model prediction and data line up almost perfectly, which reflects that, in the data, state GDP is roughly proportional to state sales, as our model predicts.[51]

[50] Table A.5 in Appendix C.2.3 shows that our estimates are robust to alternative definitions of the market-potential instrument MP_{nt}^*.

[51] From (A.9) in Appendix B.2, the share of state n in national GDP in the model is $GDP_n/GDP = (\frac{\gamma_n(\sigma-1)+1}{\sigma})X_n/(\sum_{n'}(\frac{\gamma_{n'}(\sigma-1)+1}{\sigma})X_{n'})$.

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

Third, panels (c) to (e) of Figure A.2 compare the model-implied share in tax revenue for each type of tax against the the actual shares observed in the data.[52] We see a positive correlation between the data and the model-implied shares, although the model tends to over-predict the importance of corporate income taxes and under-predict the importance of individual income taxes. These differences are due in part to the use of average (rather than progressive) income rates for each state and to the model assumption that all companies are C-corporations and therefore pay corporate taxes. In robustness checks, we verify how the results change when we use alternative tax rates that account for progressivity of the income tax and adjust state corporate tax rates for the share of C-corporations in each state.

5 Measuring the Spatial Misallocation from State Taxes

In this section, we measure the impact on welfare and real GDP of eliminating dispersion in tax rates across states. We replace the distribution of state taxes in 2007 with counterfactual distributions which feature no dispersion in tax rates across states in some or all taxes, keeping every other parameter and federal taxes constant. Tables A.1 and A.2 show the 2007 federal and state tax rates. Appendix B.5 shows the system of equations used to compute the counterfactual changes in endogenous variables.

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

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

where, from (5), $\widehat{v}_n$ depends on the change in after-tax real wages and real government spending in state n.[53] The change in welfare is an employment-weighted average of the changes in each state's appeal, as captured by the v_n's. This measure excludes the gains or losses accruing to firms and fixed factors. As a second measure, we consider the change in the aggregate real income of all factors.

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

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

Aggregate real income is defined as the aggregation of real state GDP's: $GDP^{real} = \sum_n GDP_n/P_n$. Equation (A.10) in Appendix B.2 shows the expression for real GDP in the counterfactual relative to the initial scenario.

Impact of Tax Dispersion on Real Income and Welfare In specific parametrizations of our model, dispersion in tax rates across states can be shown to reduce real income and welfare. This is the case, for example, if there are no trade costs, no trade imbalances, government spending does not change with taxes, workers are perfectly mobile, the number of firms in each state is fixed, and there is no dispersion in amenities.[54] However, more generally, it is theoretically ambiguous whether eliminating tax dispersion improves welfare and real income. First, keeping government spending constant, unobserved amenities imply that real income is not maximized when tax rates are homogeneous. Second, our model features agglomeration through home-market effects whereby the returns to locating in a state increase with the number of workers and firms located in that state and in close-by states. Third, when government spending is allowed to change with taxes, the number of workers located in each state impacts the provision of public services in that state and in other states through each state's government budget constraint. Because of these spatial externalities, the market allocation is not generically efficient and, therefore, distortions that make the equilibrium different from the market allocation are not necessarily welfare and real-income reducing. As a result, the assumptions embedded in our model do not imply that eliminating tax dispersion must lead to welfare gains.[55]

Definition of Spatial Misallocation Taxes impact the allocation of labor, firms, and trade flows across regions, and also the allocation of aggregate spending between public services and private consumption. As our focus is on the first channel, we study the effects of eliminating tax dispersion while keeping spending in public services unaffected. We define the spatial misallocation caused by the U.S. state tax distribution as the welfare and real-income gains (if they exist) that would result from eliminating the observed dispersion in tax rates across states in a way that keeps government size constant. We use two measures of state government size. We undertake *revenue-neutral* counterfactuals by bringing each tax to a percentile of its distribution such that the aggregate tax revenue collectively raised by all states is the same as in the initial equilibrium; i.e., $\sum_{n=1}^{N} R'_n = \sum_{n=1}^{N} R_n$, where R'_n is the tax revenue of state n in the counterfactual scenario, for R_n defined in (21). We also undertake *spending-neutral* counterfactuals by bringing each tax to a percentile of its distribution such that the aggregate tax revenue collectively raised by all states jointly with a system of cross-state transfers allows each state to keep government spending constant at its initial level; i.e., $\sum_{n=1}^{N} R'_n = \sum_{n=1}^{N} P'_n G_n$, and $G'_n = G_n$ for all n. In both counterfactuals, dispersion tax rates across states is eliminated; in the revenue-neutral counterfactual, there is a redistribution of real government spending from initially high-tax states to initially low-tax states,

[54] In this case, the production side of our model collapses to the structure in Hsieh and Klenow (2009), with dispersion in tax rates across states in our model playing a similar role to dispersion in wedges across firms in theirs.

[55] Eeckhout and Guner (2015) find that heterogeneity in income taxes across cities may be welfare-maximizing in a setup with externalities from city size.

while in the spending-neutral counterfactual, real government spending is kept constant in all states.

5.1 Benchmark

Table 4 presents the results for the spatial-misallocation counterfactuals using the benchmark parametrization and definitions of tax rates. The first row shows the results for the case in which we eliminate the dispersion in all taxes simultaneously; the remaining rows show the results for the elimination of the dispersion in one tax at a time. The columns labeled "S-neutral" show the results from the spending-neutral counterfactual described above, and the columns labeled "R-neutral" show the results from the revenue-neutral counterfactual described above.[56]

The direct welfare effect of these tax changes, defined as their impact on worker welfare keeping prices, government spending, and employment constant at their initial values, is negligible: because some tax rates increase and others decrease, real consumption does not change at the initial prices.[57]

The spending-neutral elimination of tax dispersion leads to real-GDP and welfare gains of around 0.11%, pointing to the existence of distortionary effects from heterogeneity in taxes keeping the distribution of real government spending constant. The welfare gains are 0.69% in the revenue-neutral counterfactual, with similar gains in terms of real GDP. Simultaneously harmonizing all taxes is important to reach welfare gains, as only eliminating dispersion in sales taxes in a revenue-neutral way leads to slight welfare losses. We also compute changes in real consumption of workers and capital owners; in the revenue-neutral counterfactual, the real consumption of workers increases by 0.3% and consumption of capital owners increases by 0.4%.[58] We recall that these gains correspond to revenue- or spending-neutral changes in taxes whose aggregate tax revenue is 4% of GDP. Therefore, the results point to considerable spatial misallocation from tax dispersion relative to the initial levels of tax revenue in GDP.[59]

Table 4: Removing Tax Dispersion: Benchmark

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

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

[57] We measure the direct welfare effect of tax changes keeping prices, government spending and allocations constant by evaluating (33) using $\widehat{v}_n^{direct} = \left(\left(1 - T_n'\right) / \left(1 - T_{n,2007}\right)\right)^{1-\alpha_W}$ instead of $\widehat{v}_n$.

[58] (A.12) and (A.13) in Appendix B.2 show the expressions for the changes in aggregate real consumption of workers and capital owners, respectively.

[59] In terms of the mechanisms underlying this result, Figure A.3 shows the distributions of the endogenous components of the adjusted productivities z_n^A, amenities u_n^A, and trade costs τ_{ni}^A defined in (25) to (27); eliminating tax dispersion strongly reduces the dispersion in the adjusted productivity and eliminates dispersion in adjusted trade costs. Eliminating tax dispersion does not eliminate the dispersion in the endogenous components of productivity and amenities because these are a function of government spending over GDP, $P_n G_n / GDP_n$, which varies with the technology parameters of each state as shown in (28).

5.2 Role of Trade Frictions

To explore the impact that trade costs have on the potential welfare gains from tax harmonization, we recompute the revenue-neutral elimination of dispersion in all taxes starting from a different parametrization that, instead of matching the actual distribution of bilateral spending and sales shares across states (as done in the benchmark parametrization, see Section 4.2), assumes a world in which each state's spending and sales shares on other states is proportional to the size of the origin and destination states, respectively.[60] In the absence of corporate taxes, these symmetric shares would be the equilibrium outcomes of a model like that presented in Section 3 if there were no trade costs. Hence, this parametrization explores how our counterfactual results would differ in an environment in which trade costs are smaller.

We find larger welfare gains from the revenue-neutral elimination of tax dispersion (1.01%). This result points to a complementarity between reducing tax dispersion and eliminating barriers to trade. It also suggests that, had we assumed away the existence of trade frictions since the outset and analyzed the data through the lens of a frictionless trade model, we would have over-estimated the welfare gains from a revenue-neutral elimination of tax dispersion.

5.3 Heterogeneous Preferences for Government Spending

The benchmark model assumes that the preference for government spending, α_W, is the same across states. However, preferences for public services might be different across states if there exists a complementarity between state-specific features and government services. Such heterogeneity may temper the gains from tax harmonization if tax rates are initially higher in states where these preferences are stronger. We consider here how allowing for heterogeneity across states in workers' preferences for government services affects our results.

We use two measures of heterogeneous preferences. First, we explore the possibility that the differences in the political ideology of state residents have predictive power for the differences across states in the preference for government spending. Specifically, we assume that $\alpha_{W,n} = \alpha_0 + \alpha_1 POL_n$, where POL_n is a standardized political index constructed by Ceaser and Saldin (2005) that takes higher values for states with higher Republican party vote shares in national and state elections. We estimate the parameters ε_W, α_0, and α_1 following a similar procedure to that described in Section 4.3.1.[61] Our estimates imply values of $\alpha_{W,n}$ between 0.161 and 0.175.

We construct a second measure of heterogeneous preferences using the ratio of government spending to GDP to proxy for $\alpha_{W,n}$ as in Michaillat and Saez (2015); i.e., $\alpha_{W,n}^{R/GDP} = R_n/GDP_n$. To isolate the effect of cross-state dispersion in the 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 yields estimates of $\alpha_{W,n}$ between 0.147 and 0.218. This approach approximates the equilibrium of a model in the

[60] I.e., we assume that, in the initial allocation, for any state i spending shares are $\lambda_{ni} = X_i / \sum_{i'} X_{i'}$ for all n, and, for any state n, sales shares are $s_{ni} = P_n Q_n / \sum_{n'} P_{n'} Q_{n'}$ for all i.

[61] We estimate $\hat{\alpha}_0 = 0.17$ (0.07) and $\hat{\alpha}_1 = -0.003$ (0.025), which implies that states with higher Republican party vote have a smaller preference parameter for government spending. However, the small value of $\hat{\alpha}_1$ implies that preferences for public goods do not seem to vary much across states with the political index POL_n. For details on the procedure to estimate ε_W, α_0 and α_1, see Appendix D.3.

spirit of Tiebout (1956), in which individuals sort into communities on the basis of preferences for public services; in that context, our counterfactual that keeps the distribution $\{\alpha_{W,n}\}$ constant would be consistent with a tax-policy shock that does not considerably alter the average preference for government spending of the workers initially sorted into each state.[62]

Table 5 reports the results from the spending-neutral and revenue-neutral counterfactuals under each of these alternatives measures, and compares them with the benchmark. The first measure of heterogeneous $\alpha_{W,n}$ produces similar welfare and real-income effects as our benchmark. For the second measure, allowing for heterogeneity across states moderately reduces the revenue-neutral welfare effects (to 0.49%, from 0.69% in the benchmark), but has no impact on the predictions on real income or on the spending-neutral counterfactual.[63] In sum, allowing for heterogeneity in preferences for government spending across states does not impact the real-income gains from eliminating tax dispersion, nor the welfare gains in the spending-neutral counterfactual.

Table 5: Removing Tax Dispersion Under Heterogeneous Preferences Across States

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

5.4 Lower Weights of Government Spending in Preferences and Productivity

We explore the sensitivity of our results to the weight of public spending in preferences and productivity. Table 6 reports the results for different values of the parameters α_W and α_F. Halving the values of both parameters also halves the real-income and welfare effects in the revenue-neutral counterfactual, but does not affect the predictions from the spending-neutral counterfactual. The table also includes the case with zero weight of government spending in preferences and productivity. This is an extreme case since, as we discuss in Appendix C.4, the evidence in the literature points towards the existence of a positive effect of government spending on preferences and productivity. In this case, spatial misallocation continues to be present and the welfare effects of the spending-neutral tax harmonization counterfactual are of the same magnitude as in the benchmark.

[62] It would be possible to explicitly introduce endogenous sorting of workers with heterogeneous preferences for public services into our model. We note that this type of sorting usually occurs at the level of city or neighborhood, as documented, for example, by Bayer et al. (2007) in the context of school districts. Moreover, there is substantial heterogeneity in government spending across cities or neighborhoods within states; for instance, data from the Census of Governments show that 38 out of the 50 states have both low- and high- spending counties that are, respectively, below the 25th and above the 75th national percentiles. Hence, incorporating worker-specific preferences for public services is unlikely to alter our R-neutral counterfactuals, as workers can sort across locations within states (S-neutral counterfactuals are independent from this assumption).

[63] If we do not rescale $\alpha_{W,n}^{R/GDP}$ to have its mean coincide with the benchmark estimate of α_W and, instead, we just use the raw distribution of R_n/GDP_n to measure $\alpha_{W,n}^{R/GDP}$, we obtain welfare gains of 0.14% and 0.23% in the S-neutral and R-neutral cases, and real-income gains of 0.12% and 0.67% in the S-neutral and R-neutral cases, respectively.

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

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

5.5 Progressive Income Taxes

Our benchmark analysis uses a flat state and federal income tax, but in practice both the federal government and most states have progressive income tax schedules. We explore how our counterfactual results vary if we account for the progressivity of income taxes. We implement three changes with respect to the definition of taxes in our benchmark: we take into account the progressivity in state income taxes, we incorporate progressivity in federal income taxes, and we allow the income tax rate on capital owners to differ from that on workers.

We use data from NBER TAXSIM on average effective income tax rates by state, year, and income group to estimate a linear function of income that best fits the actual relationship between income and average tax rates by state in 2007. Using the estimates $\{\hat{a}_n, \hat{b}_n\}_{n=1}^N$, we construct the income tax rate that a worker with income w living in state n must pay as $t_n^{y,prog}(w) = \hat{a}_n + \hat{b}_n w$. We follow the same procedure using information on federal income tax rates in 2007 and construct a federal income tax rate $t_{fed}^{y,prog}(w) = \hat{a}_{fed} + \hat{b}_{fed} w$.[64] The introduction of these progressive tax schedules in our model generalizes our benchmark results by allowing state income tax rates to change as a result of changes in states' nominal wages. Because our model does not specify the number of capital owners living in a state and, therefore, does not yield a measure of capital income per capita, we assume that every capital owner in a state n pays the highest income tax rate that the progressive tax schedule in state n imposes (i.e., the income tax rate for the highest income bracket).[65]

Table 7 reports the results. The first line shows the outcome of eliminating tax dispersion in all taxes simultaneously when the only departure from the benchmark is that federal income taxes are allowed to be progressive, the second line only allows for progressivity in state income taxes, and the third line allows for progressivity in both federal and state income taxes.[66] The results show that accounting for tax progressivity increases the welfare gains from both the spending- and revenue-neutral tax harmonization.[67] The spending-neutral effects on real GDP do not change with

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

[65] 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%.

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

[67] In the revenue-neutral case, the bulk of the increase in spatial misallocation is due to the introduction of

the introduction of income tax progressivity.

Table 7: Removing Tax Dispersion under Progressive Income Taxes

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

5.6 Alternative Definitions of Corporate Taxes

Table 8 reports the results of the revenue- and spending-neutral elimination in dispersion in all taxes under two alternative ways of measuring corporate tax rates.

Corporate Taxes Adjusted for Subsidies Some states grant firms reductions in their corporate tax liabilities. These subsidies modify the effective corporate tax rate that firms face. 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 in each state; as in Ossa (2015), we use data from the *New York Times* subsidy database (see Appendix F.1 for details). We find that this adjustment reduces spatial misallocation very slightly.

Corporate Taxes Adjusted by Share of C-Corporations In our benchmark model, all firms pay state corporate taxes on their profits and firm owners pay income taxes on after-tax profits, matching the actual tax treatment of the C-corporations. However, pass-through businesses (S-corporations, partnerships, and sole proprietorships) do not pay corporate taxes; only personal income taxes are paid by their owners when profits are distributed. To account for the fact that not all firms are C-corporations, we scale down the statutory corporate tax rate used in our benchmark analysis by the share of employment in C-corporations in each state in 2010 relative to the total employment in that state.[68] This adjustment reduces the welfare and real-income effects of misallocation.

Table 8: Removing Tax Dispersion under Alternative Definitions of Corporate Taxes

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

progressive federal income taxes. This is consistent with results in Albouy (2009), who studied misallocation across U.S. cities due to federal income taxes.

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

5.7 Other Parametrizations

Our benchmark parametrization sets $\sigma = 4$ and assumes that the parameters χ_W and χ_F, which determine congestion in access to public services, equal 1. As we have discussed, these parameters govern the intensity of agglomeration forces in the model. Table A.7 in Appendix D.2 reports the results for $\sigma = 5$ and for different congestion levels between 0 and 1. For each of these cases, we re-estimate the parameters ε_W, α_W, ε_F, and α_F under the same exogeneity assumptions imposed to obtain our benchmark estimates; i.e., state amenities and productivities are mean independent of external taxes.[69] The last row of the table uses estimates of the structural parameters ε_W, α_W, ε_F, and α_F that rely on the assumptions that $\sigma = 4$ and $\chi_W = \chi_F = 1$, but that differ from the benchmark estimates in that we impose the assumption that changes in state amenities and productivities are mean independent not only of external taxes but also of own-state taxes. The results from the spending-neutral counterfactuals change little across all these parametrizations. In the revenue-neutral case, misallocation decreases under larger σ, and is non-monotone in the congestion parameters. The estimation strategy that imposes the assumption that each state's changes in taxes are mean independent of their own changes in amenities and productivity delivers similar spatial misallocation relative to the benchmark for the spending-neutral counterfactual, but considerably larger welfare and real-income effects in the revenue-neutral counterfactual. This is largely due to the higher value of the preference parameter for government spending implied by this estimation approach.

6 Other Policies

6.1 Changes in Tax Rates in a Single State

What are the effects of tax changes in one state on this same state and on other states? To study this question, we compute the effect of a 1 percentage point reduction in the income tax rate of each state, one state at a time.[70] We run each of these fifty counterfactuals twice, keeping government spending exogenously constant, and allowing it to change according to each state's budget constraint. Table 9 reports average percentage changes in employment, number of firms, real wage, real GDP, tax revenue, and real government spending across the fifty counterfactuals, both in the state enacting the tax change ("Own") and on average in other states ("Rest of the U.S."), and both when government spending is kept constant ("G constant") and allowed to change ("Total Effect").[71]

Keeping government spending constant, reducing income taxes increases welfare for the representative U.S. worker. From (27), higher tax keep-rates (i.e., $1 - T_n$) are similar to an increase in amenities, which raises the number of workers in the state lowering taxes in detriment of the rest of

[69] See Tables 2 and 3 for the estimates. Whenever the model restriction $\varepsilon_F > \sigma - 1$ is violated, we re-estimate ε_F and α_F imposing that $\varepsilon_F > \sigma - 1$. This approach results in estimates of α_F similar to the unconstrained estimates.

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

[71] In the G-constant counterfactual, we assume that each state government receives a transfer such that tax revenue in the counterfactual scenario plus this transfer can finance the same level of government spending as in the initial scenario.

Table 9: State-by-state Reduction in Income Tax by 1 Percentage Point

Average Change in	G Constant		Total Effect	
	Own	Rest of U.S.	Own	Rest of U.S.
Aggregate Welfare	0.02%		-0.05%	
Employment	0.70%	-0.01%	-2.32%	0.04%
Firms	1.12%	-0.02%	-1.46%	0.02%
Real Wage	-0.37%	0.01%	-0.57%	-0.02%
Real GDP	0.33%	-0.01%	-2.88%	0.02%
State Tax Revenue	-11.63%	-0.01%	-12.91%	0.01%
Real Government Spending	0%	0%	-13.36%	0.01%

the U.S. This increase in labor supply reduces the wage in that state. Firms are also attracted to the state lowering taxes, leading to an increase in the set of varieties produced in that state. This increase in varieties partially offsets the real-wage decline through a reduction in the price index. After-tax real wages and rents increase; the combined effect of factor inflow and higher prices boost GDP, which increases in real terms; in the rest of the U.S., the effects on real wages and GDP have the opposite sign due to the reallocation of workers.

When government spending adjusts in every state to meet each states' tax revenue, real government spending in the state lowering income taxes falls. The reduction in tax revenue and in the provision of public services in turn reduces both labor supply and the number of firms. As a result, both employment and real GDP fall in the state lowering taxes, and the welfare of the representative U.S. worker decreases.

General-Equilibrium Effects on the State Reducing Taxes How important are general-equilibrium effects in driving the employment reduction in the state reducing income taxes? The parameter values in Table 1 imply that the average change in employment in the state reducing taxes can be decomposed as follows:[72]

$$\overline{\ln\left(\hat{L_n}\right)} = \underbrace{0.99 * \overline{\ln\left(\frac{1-T'_n}{1-T_{n,2007}}\right)}}_{1.08\%} + \underbrace{0.99 * \overline{\ln\left(\hat{w_n}/\hat{P_n}\right)}}_{-0.56\%} + \underbrace{0.20 * \overline{\ln\left(\hat{G_n}\right)}}_{-2.95\%} - \underbrace{1.18 * \overline{\ln\left(\hat{v}\right)}}_{0.06\%}, \qquad (34)$$

where the bar over each variable denotes an average across the fifty counterfactuals. The first term in the right-hand side of (34) is the direct effect from the tax change; given the estimate of a_0 in (29) and the average change in worker tax keep-rates, it leads on average to an increase in employment.[73] However, in general equilibrium, the reduction in income taxes leads to lower tax revenue, which translates into lower provision of public services. Given the estimates of a_0 and a_1 in (29), the reduction in real wages and in the provision of public services due to lower tax revenue more than offsets the positive direct effect from the increase in the tax keep-rate, leading to a fall

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

[73] Note that this is different from the 0.7% change in own employment in the G-constant counterfactual reported in Table 9 because that number includes both the direct effect and the general-equilibrium effects through prices and aggregate welfare, i.e., the second and fourth components in the right-hand side of (34).

in employment in the state reducing income taxes. The largest part of the reversal is driven by the reduction in government spending.[74]

Heterogeneous Impact Across States The impact of a change in taxes in one state on other states is heterogeneous. For illustration purposes, we first focus on the reduction in the income tax in one large state, California. Figure A.4 in Appendix E shows the heterogeneous response across states in terms of real wages, real GDP, employment, and number of firms. When government spending in every state is kept constant, employment in California grows and it shrinks in every other state, but the negative employment effect is smaller in states that trade more with California. The effects are reversed when government spending adjusts: economic activity in California shrinks and states in the East Coast gain more in terms of employment and number of firms than the states that are geographically closer to California. This heterogeneity across states is caused by heterogeneity in trade flows between California and every other state, which affect the parametrized model through the spending and sales shares. Figure A.5 in Appendix E shows the employment change by state as a function of each state's sales share to California (left panel) and share of spending in goods coming from California (right panel). Employment increases relatively less in states that rely more on California as either an export market or a source of imported products. Figure A.6 in Appendix E reproduces the same figure averaging across all fifty counterfactuals; the pattern in Figure A.5 is indeed representative of what happens when a typical U.S. state reduces its income tax rate.[75]

6.2 Changes in Apportionment Rules

A large number of states have increased the sales apportionment factor in the last 20 years. While some analysts argue that payroll-based apportionment may be more distortionary that sales apportionment,[76] our analysis identifies a distortionary effect of sales apportionment on trade flows and prices. Table 10 reports the effects of moving to either 0%, 50%, or 100% sales-apportionment of corporate taxes simultaneously in every state. As shown in Table A.2, most states use sales-apportionment rates of 33% or 50%. Moving to no-sales-apportionment increases welfare by 0.22%, while moving fully into sales apportionment reduces welfare. In our model, sales apportionment may cause larger distortions because it impacts both the adjusted productivities in (25) and the adjusted trade costs in (26), while payroll-based apportionment only impacts the adjusted productivities.

[74] If we assume, as in Section 5.3, that the preference parameter for government spending in each state equals the tax revenue share of GDP ($\alpha_{W,n}^{R/GDP} = R_n/GDP_n$), then the average reduction in employment in the state lowering taxes falls from 2.32% to 1.02%, and the four components of (34) become 1.44%, -1.36%, -1.14%, and 0.06%, respectively.

[75] Even though the distribution of worker preference and firm productivity draws in our model has the independence of irrelevant alternatives property, trade linkages imply that, in general equilibrium, a shock in one state has heterogeneous impacts on other states. A natural extension of our framework would be to also allow for heterogeneity in linkages through labor mobility. This force can be introduced in our model by allowing for bilateral labor mobility similar to how migration or commuting flows are introduced in Tombe et al. (2015), Monte (2015), or Monte et al. (2015), or for state-of-birth parameters in utility as in Diamond (2015).

[76] See Auerbach (2013), Zucman (2014), and Auerbach and Devereux (2015) for discussions on the costs and benefits of sales apportionment.

In order to assess the extra role of the trade-cost distortion, we recompute this counterfactual under a counterfactual scenario with lower trade costs as we did in Section 5.2. In this alternative parametrization, sales and spending shares in the initial scenario are assumed to be proportional to the size of the trading partner. In this case, the welfare gains of moving away from sales apportionment are considerably smaller. The smaller welfare loss from moving into sales apportionment under low trade costs suggests a complementarity between trade frictions and the distortions caused by the sales apportionment.

Table 10: Sales Apportionment of Corporate Income

Sales	Welfare Change		
Apportionment	G Constant	Total	Low Trade Costs
0%	0.05%	0.22%	0.08%
50%	0.01%	0.05%	0.04%
100%	-0.03%	-0.11%	-0.01%

7 Conclusion

We quantify the effect of changes in the distribution of state taxes on aggregate real income, welfare, and the spatial distribution of economic activity in the U.S. economy. We construct a model that draws on recent trade and economic geography models, and complements them by including salient features of the U.S. state tax structure. Some advantages of our exercise are that it is based on a model that includes several sources of spatial interactions and that is estimated using variation in taxes and economic activity across states. The model exactly matches the distribution of economic activity in a base year and has predictions for moments not used for estimation that align well with the data. Using the estimated model, we measure the general-equilibrium impact of harmonizing U.S. state taxes and of other reforms typically put forth in public policy debates.

Our results suggest quantitatively important effects on aggregate real income and welfare (around 0.7%) of a revenue-neutral harmonization of sales, income, and corporate taxes, whose aggregate tax revenue across all states amounts to 4% of U.S. GDP. These effects are driven by the reallocation of workers, firms, trade flows, and government spending across states. Changes in public-service provision are important, but we also find aggregate gains from tax harmonization when the distribution of government spending across states is kept unchanged. Our results also highlight the importance of accounting for general-equilibrium forces when studying the effects of tax changes, and of accounting for trade frictions when studying the impact that a change in taxes in one state has on other states.

The framework could be readily applied to study other related questions, such as how the state tax structure affects states' responses to similar state- or aggregate-level shocks, or to compare the implications of sales- versus income-based tax systems. It could also be extended to study the state-level and aggregate impact of policy reforms that alter cost-sharing rules between federal and state governments (e.g., Federal Medical Assistance Percentages in Medicaid). In addition to contributing to the ongoing debate about the impacts of the state tax structure in the U.S.,

our framework could be combined with data on the European economy to inform similar debates taking place within the European Union.[77] Finally, a similar approach that combines a quantitative spatial equilibrium model with an estimation of key parameters using data on tax rates could be used to tackle questions related to taxation rules of multinational corporations.[78]

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[77] See Bénassy-Quéré et al. (2014) and Bettendorf et al. (2010).

[78] See Devereux et al. (2015) and Auerbach and Devereux (2015).

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Appendices for Online Publication

A Appendix to Section 2 (Background)

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

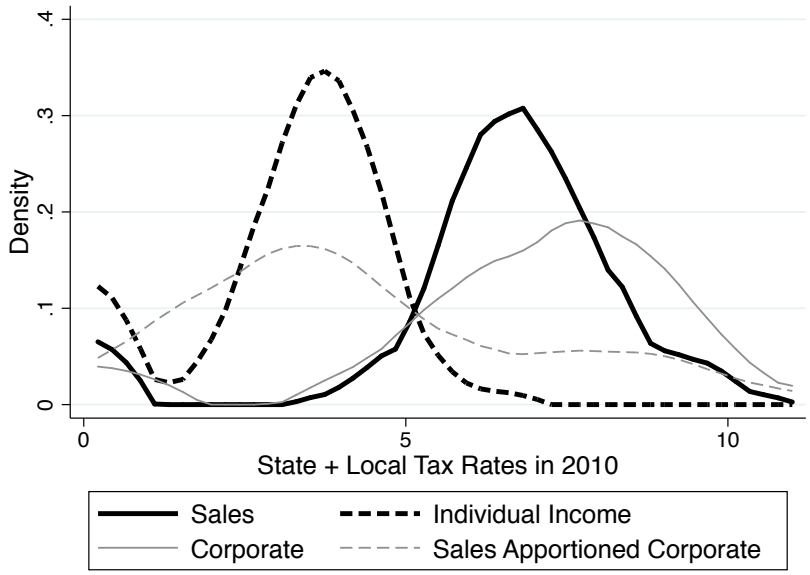


Table A.1: Federal Tax Rates from 2007

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

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

Table A.2: State Tax Rates from 2007

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

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

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

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

B.2 Additional State-Level Variables

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Trade Imbalances 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:[79]

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

Letting $R = \sum_n r_n H_n$ and $\tilde{\Pi} = \sum_n \tilde{\Pi}_n$ be the pre-tax returns to the national portfolio of fixed factors and firms ,

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

we can write each component of (A.15) other than GDP as follows:[80]

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

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

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

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

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

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

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

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

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

B.3 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.

$$\sum_n \lambda_{in} = 1 \text{ for all } i. \tag{A.22}$$

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

$$\sum_i s_{in} = 1 \text{ for all } n. \tag{A.23}$$

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

$$\lambda_{in} = A_{in} \left(\frac{w_n}{\bar{\pi}} \right)^{1-\kappa_1} L_n^{1-\kappa_{2n}} \left(\frac{w_i}{\bar{\pi}} \right)^{\sigma-1} L_i^{-\kappa_3}, \tag{A.24}$$

$$s_{in} = \lambda_{in} \frac{P_i Q_i}{X_i} \frac{(w_i/\bar{\pi}) L_i}{(w_n/\bar{\pi}) L_n} \frac{(1 - \beta_n) \gamma_n}{(1 - \beta_i) \gamma_i}, \tag{A.25}$$

where A_{in} is given by

$$A_{in} = \left(\frac{H_n^{\beta_n \gamma_n} \Theta_{1n} z_n^A}{\frac{\sigma}{\sigma-1} \tau_{in}^A} \frac{\left(\Theta_{2i} u_i^A \right)}{\left(\Theta_{2n} u_n^A \right)^{1-\gamma_n+\alpha_F}} v^{\alpha_F - \gamma_n} \right)^{\sigma-1}, \tag{A.26}$$

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

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

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

The parameters $\{\kappa_1, \kappa_{2n}, \kappa_3\}$ in (A.24) and (A.25) are given by:

$$\kappa_1 = (\sigma-1)\left(\frac{1}{\varepsilon_F} + \alpha_F\chi_F + 1\right), \tag{A.27}$$
$$\kappa_{2n} = (\sigma-1)\left[\left(\frac{1}{\varepsilon_F} - \alpha_F\,(1-\chi_F) + \beta_n\gamma_n\right) - (1-\gamma_n+\alpha_F)\left(\frac{1}{\varepsilon_W} - \alpha_W\,(1-\chi_W)\right)\right], \tag{A.28}$$
$$\kappa_3 = (\sigma-1)\left(\frac{1}{\varepsilon_W} - (1-\chi_W)\,\alpha_W\right). \tag{A.29}$$

Equations (A.22) to (A.26), together with (8), (A.19), and (28) give the solution for import shares $\{\lambda_{in}\}$, export shares $\{s_{in}\}$, employment shares $\{L_n\}$, wages relative to average profits $\{w_n/\bar{\pi}\}$, government sizes $\{P_nG_n/GDP_n\}$, relative trade imbalances $\{P_nQ_n/X_n\}$, and utility v.[81] The endogenous variables not included in this system (e.g., the fraction of firms, M_n) can be recovered using the remaining equilibrium equations of the model.

B.4 Uniqueness

Consider a special case of the model in which i) technologies are homogeneous across regions ($\beta_n = \beta$ and $\gamma_n = \gamma$ for all n); ii) there is no dispersion in sales-apportioned corporate taxes across states ($t_n^x = t^x$ for all n); and iii) there is no cross-ownership of assets across states. In this case, the adjusted amenities and productivities u_n^A and z_n^A defined in (27) and (25) are primitives (exogenous functions of fundamentals and own-state taxes). Define:

$$K_{in} = \tau_{in}^{1-\sigma},$$
$$\gamma_n = \overline{A}_n^{\sigma-1} w_n^{1-\kappa_1} L_n^{1-\kappa_2}, \tag{A.30}$$
$$\delta_i = \left(\frac{\overline{u}_i}{\overline{W}}\right)^{\sigma-1} w_i^{\sigma} L_i^{1-\kappa_3}, \tag{A.31}$$

where

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

Using these definitions and the definition of import shares in (A.24), it follows that Conditions 1 to 3 of Allen et al. (2014) are satisfied. We must show that their condition 4' is also satisfied. First, combining the solution for $\{w_n, L_n\}$ from (A.30) and (A.31) 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.30) and (A.31), and (A.7) allows us to write

[81] The terms u_n^A, τ_{in}^A, and z_n^A which enter in (A.26) are function of the export shares $\{s_{in}\}$ and government sizes $\{P_nG_n/GDP_n\}$. Government sizes and trade deficits also depend on the terms $\{\tilde{\Pi}_n, \tilde{\Pi}, \Pi + R\}$. These variables can be expressed as a function of export shares, labor compensation and parameters.

$\overline{\lambda}^{1+a} = \sum_n C_n \gamma_n^d \delta_n^e$, 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 their Corollary 2 to reach a uniqueness condition for the system of equations in $\{L_n, w_n, v\}$ in (A.22) to (A.23):

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

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

where κ_1 to κ_3 are defined in (A.27) to (A.29). These steps hold taking as given the value of $\overline{\pi}$; since (the inverse of) $\overline{\pi}$ enters as a proportional shifter of wages, the condition applies to the solution of $\left\{L_n, \frac{w_n}{\overline{\pi}}, v\right\}$.

B.5 General Equilibrium in Relative Changes

To perform counterfactuals, we solve for the changes in model outcomes as function of changes in taxes. Consider computing the effect of moving from the current distribution of state taxes, $\left\{t_n^y, t_n^c, t_n^x, t_n^l\right\}_{n=1}^N$ to a new distribution $\{(t_n^y)', (t_n^c)', (t_n^x)', (t_n^l)'\}_{n=1}^N$. Letting $\hat{x} = x'/x$ be the counterfactual value of x relative to its initial value, we have that the changes in import shares, export shares, employment shares, and wages $\{\hat{\lambda_{in}}, \hat{s_{in}}, \hat{L_n}, \hat{w_n}\}_{n=1}^N$ as well as the welfare change $\hat{v}$ must be such that conditions (A.22) and (A.23) hold:

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

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

where, using (A.24) and (A.25),

$$\hat{\lambda_{in}} = \hat{A_{in}} \hat{w_n}^{1-\kappa_1} \hat{L}_n^{1-\kappa_{2n}} \hat{w_i}^{\sigma-1} \hat{L}_i^{-\kappa_3}, \tag{A.36}$$

$$\hat{s_{in}} = \hat{\lambda_{in}} \left(\frac{P_i \hat{Q}_i}{X_i}\right) \frac{\hat{w_i} \hat{L}_i}{\hat{w_n} \hat{L}_n}, \tag{A.37}$$

where using (A.26),

$$\hat{A}_{in} \propto \left(\frac{\hat{z_n^A}}{\hat{\tau_{in}^A}} \frac{\hat{u_i^A}}{\left(\hat{u_n^A}\right)^{(1-\gamma_n)+\alpha_F}} \hat{v}^{\alpha_F - \gamma_n} \right)^{\sigma-1}, \tag{A.38}$$

and where, from (25) to (27),

$$\hat{\tau_{in}^A} = \frac{\sigma - \tilde{t}_{in}}{\sigma - \left(\tilde{t}_{in}\right)'}, \tag{A.39}$$

$$\hat{z_n^A} = \left(\frac{1-(\bar{t}_n)'}{1-T_n}\right)^{\frac{1}{\sigma-1} - \left(\frac{1}{\varepsilon_F} + \alpha_F \chi_F\right)} \left(\frac{P_n \hat{G}_n}{GDP_n}\right)^{\alpha_F}, \tag{A.40}$$

$$\hat{u_n^A} = \left(\frac{1-T_n'}{1-T_n}\right)^{1-\alpha_W} \left(\frac{P_n \hat{G}_n}{GDP_n}\right)^{\alpha_W}. \tag{A.41}$$

Additionally, labor shares must add up to 1 :

$$\sum L_n \hat{L_n} = 1. \tag{A.42}$$

The variables $\left\{\frac{P_n \hat{Q}_n}{X_n}, \frac{P_n \hat{G}_n}{GDP_n}, T_n', (\bar{t}_n)', \left(\tilde{t}_{in}\right)'\right\}_{n=1}^N$ can be expressed as function of the original taxes $\left\{t_n^y, t_n^c, t_n^x, t_n^l\right\}_{n=1}^N$, the new tax distribution $\{(t_n^y)', (t_n^c)', (t_n^x)', (t_n^l)'\}_{n=1}^N$, and the new export shares $\{\hat{s_{in}} s_{in}\}_{n,i=1}^N$ using (6), (10), (12), (A.19), and (28). Hence, these equations, together with (A.34) to (A.42), give the solution for $\left\{\hat{\lambda}_{in}, \hat{s}_{in}, \hat{L}_n, \hat{w}_n\right\}$ and $\hat{v}$.[82]

[82]Note that the new government sizes and trade deficits also depend on the new values of $\tilde{\Pi}$ and $\Pi + R$;

C Appendix to Section 4.3 (Estimated Parameters)

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

Table A.3 provides the estimates of the first-stage regression corresponding to the TSLS estimation of the parameters of labor-supply equation. 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 $\ln(1-T_{nt})$ in column (1) 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 that these taxes have 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 tax keep-rate 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 $\ln(1-T_{nt})$ 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 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.

these variables can be expressed as a function of initial conditions and changes in the endogenous variables, $\tilde{\Pi}' = (1/\sigma)\sum_i w_i L_i(\hat{w}_i\hat{L}_i)$ and $\Pi' + R' = (1/\sigma)\sum_i \left(1-(\bar{t}_i)' + \beta_i\gamma_i(\sigma-1)\right) w_i L_i(\hat{w}_i\hat{L}_i)$.

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 structural parameters entering the labor mobility equation. The dependent variable is log state employment, $\ln L_{nt}$. The data are at the state-year level. Each column has 712 observations. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total US population. Every specification includes state and year fixed effects. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

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

C.2.1 Construction of Covariates

To construct measures of market potential MP_{nt}, real government services $\tilde{R}_{nt}$ and unit costs c_{nt}, we need data on prices. We use the consumer price index from the Bureau of Labor Statistics. This is the same price data that is used in the estimation of the labor equation to construct measures of real government spending and real wages.

Constructing unit costs also requires data on the price of structures r_{nt}, which is is not available at an annual frequency. Therefore, to construct an annual series of unit costs, we set the local price of structures equal to the local price index, resulting in the following measure of unit costs: $c_{nt} = \left(w_{nt}^{1-\beta_n} P_{nt}^{\beta_n}\right)^{\gamma_n} P_{nt}^{1-\gamma_n}$.[83]

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

We also need information on expenditures $P_{nt}Q_{nt}$ to build MP_{nt}. Since expenditures are not observed in every year, we follow the predictions of the model and construct a proxy for $P_{nt}Q_{nt}$ as a function of state GDP by combining equations (A.7), (A.9), and (A.19) to obtain

$$P_{nt}Q_{nt} = \frac{(\sigma - 1)(1 - \beta_n\gamma_n) + a_{nt} + t_n^l}{\sigma - t_n^x} \frac{\sigma}{\gamma_n(\sigma - 1) + 1} GDP_{nt}, \tag{A.43}$$

where $a_{nt} \equiv \frac{b_n}{\tilde{\Pi}_n / \left(\Pi + R + t_{fed}^{corp}\tilde{\Pi}\right)}$. State GDP is observed in every year, but a_{nt} is not. Hence, to compute a yearly measure of $P_{nt}Q_{nt}$, we set its value to that observed in the calibration: $a_{nt} = a_{n,2007}$ for all t.[84]

C.2.2 Construction of Instrument for Market Potential

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

$$MP_{nt}^* = \sum_{n' \neq n} E_{n't}^* \left(\frac{\tau_{n'nt}}{P_{n't}^*} \frac{\sigma}{\sigma - \tilde{t}_{n'nt}^*} \frac{\sigma}{\sigma - 1}\right)^{1-\sigma}. \tag{A.44}$$

To implement this expression, we need to construct measure of the variables E_{nt}^*, P_{nt}^*, and $\tilde{t}_{n'nt}^*$. We construct E_{nt}^* using (A.43) with lagged GDP instead of period $t's$ GDP.[85] We set $P_{n,t}^* = 1 + t_{n,t}^c$. 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 $s_{iit}^* = \frac{1}{\sum_{i \neq n} \ln(dist_{in})^{-1} + 1}\ \forall t$.

C.2.3 Robustness of Firm-Mobility Parameters

We explore alternative ways to define the variable MP_{nt}^* in Table A.5. Columns (1), (2), (5) and (6), use a measure of MP_{nt}^* that differs from the one described above in that P_{nt}^* is set to equal 1. The results are very similar

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

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

[85] I.e., $E_{nt}^* = \frac{(\sigma-1)(1-\beta_n\gamma_n)+a_{nt}+t_n^l}{\sigma - t_n^x} \frac{\sigma}{\gamma_n(\sigma-1)+1} GDP_{n,t-1}$. A sufficient condition for an instrument that depends on lagged GDP to be exogenous is that the error term in equation (A.44) is independent over time.

to those obtained in the baseline definition of MP^*_{nt}, using $P^*_{n,t} = 1 + t^c_{n,t}$. Columns (3), (4), (7) and (8) present estimates that use a measure of MP^*_{nt} in which, for the construction of the terms $\tilde{t}^*_{n'nt}$, we use hypothetical sales shares s^*_{in} constructed as the average over the observed sales shares observed in the two periods that precede those used to construct MP_{nt}, $\overline{s}_{in} = \frac{s_{in,1993}+s_{in,1997}}{2}$. All these approaches produce similar estimates of the parameters.

Table A.5: Robustness of Firm Mobility Parameters

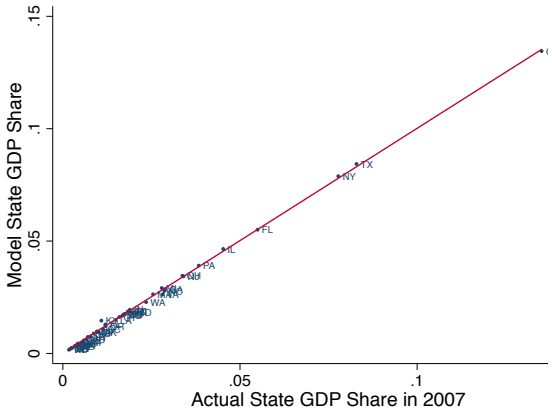
	A. All IVs				B. External IVs			
	Using $P^*_{nt} = 1$		Using $\bar{s}_{in}$		Using $P^*_{nt} = 1$		Using $\bar{s}_{in}$	
	Fix $\sigma = 4$	Fix $\sigma = 5$	Fix $\sigma = 4$	Fix $\sigma = 5$	Fix $\sigma = 4$	Fix $\sigma = 5$	Fix $\sigma = 4$	Fix $\sigma = 5$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\chi_F =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

NOTES: This table shows the GMM estimates for firm mobility parameters using alternate definitions of the instrument for market potential MP^*_{nt}. The dependent variable is log state establishments $\ln M_{nt}$. The data are at the state-year level. Each column has 661 observations. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total US population. Every specification includes state and year fixed effects. Each specification in the first four columns uses all instruments in $\boldsymbol{Z}^M_{nt}$. Each specification in the last four columns, which are labeled external instruments, do not use the own-state tax instruments in $\boldsymbol{Z}^M_{nt}$. Robust standard errors clustered by state are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

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

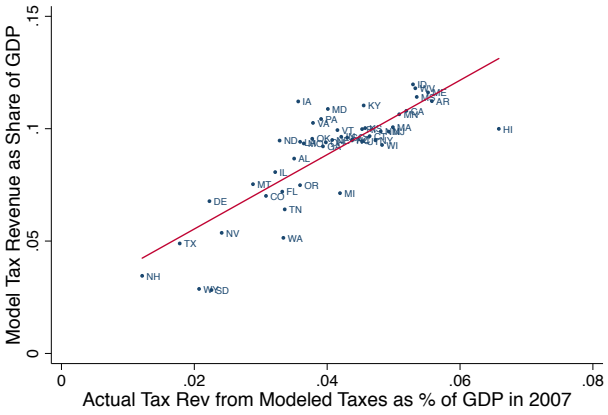
Figure A.2: Over-identifying Moments: Model vs Data

(a) State GDP Share



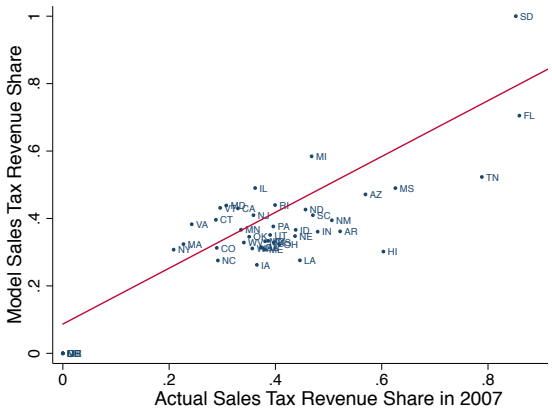
Note: Slope is 1 (0). R-squared is 1.

(b) State Tax Revenue as Share of GDP



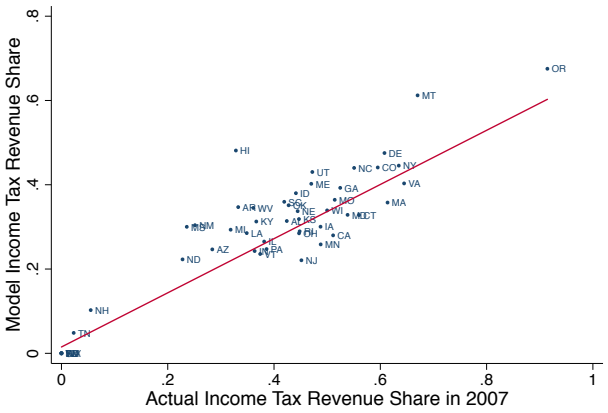
Note: Slope is 1.65 (.14). R-squared is .74.

(c) Sales Tax Revenue Share



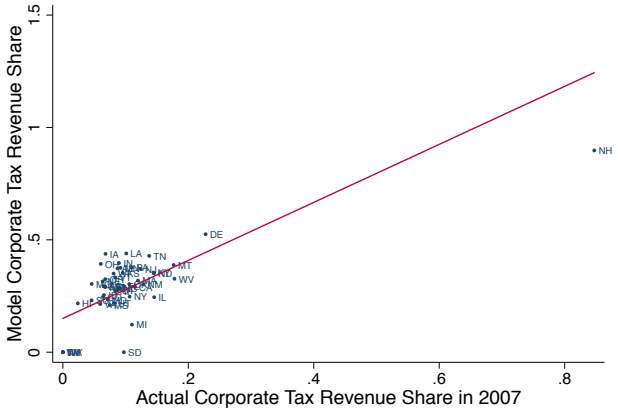
Note: Slope is .83 (.05). R-squared is .85.

(d) Income Tax Revenue Share



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

(e) Corporate Tax Revenue Share



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

C.4 Comparison with Existing Estimates

Researchers have previously estimated regressions similar to (29) and (31) using sources of variation different from ours to identify the labor and firm mobility elasticities. Table A.6 compares our estimates of ε_W, α_W, ε_F, and α_F to those that we would have constructed if we had used estimates of the elasticity of labor and firms with respect to after-tax wages and public expenditure from six recent studies. The parameter that is most often estimated is the elasticity of labor with respect to real wages; this previous literature implies estimates of ε_W with mean value of 1.79. Our benchmark number of $\varepsilon_W = 1.49$ is within the range of these estimates. Our estimate of ε_F is between the firm-mobility parameters reported in Suárez Serrato and Zidar (2015) and Giroud and Rauh (2015).

Concerning α_W and α_F, there is substantial evidence that public expenditures have amenity and productivity value for workers and firms, respectively, which is consistent with $\alpha_W > 0$ and $\alpha_F > 0$. Some studies infer positive amenity value for government spending from land rents,[86] while others focus on the productivity effects of large investment projects.[87] However, very few papers estimate specifications similar to (29) and (31). The estimates of the effects of variation in federal spending at the local level from Suárez Serrato and Wingender (2014) imply $\alpha_F = 0.10$ and $\alpha_W = 0.26$.

Of course, all these comparisons are imperfect due to differences in the source of variation, geography, and time dimension; for example, all of these studies use smaller geographic units than states. Additionally, not all specifications include the same covariates as our estimating equations (29) and (31). These differences notwithstanding, our structural parameters are close to those in the literature.

[86] 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.

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

Table A.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 (2013)	$a_0 = 3.47$[b]	2.44				Bartik	MSA (1980-2000)
Suárez Serrato and Wingender (2014)	$a_0 = 1.58$[c]	1.44				Bartik and Census Instrument	County Group (1980-2009)
	$a_0 = 2.9$, $a_1 = 1.02$, $b_1 = 0.26$[d]	1.94	0.26		0.10		
Diamond (2015)	$a_0 = 3.10$[e]	2.29				Bartik	MSA (1980-2000)
Suárez Serrato and Zidar (2015)	$a_0 = 1.28$[f]	1.23				Bartik	County Group (1980-2009)
	$a_0 = 2.63$, $b_0 = 3.35$[g]	2.06		5.33		Business Tax	
Giroud and Rauh (2015)	$b_0 = 0.40$[h]			1.34		Corporate Tax	Firm-Level (1977-2011)

This table reports the values of our structural parameters implied by estimates of specifications similar to (29) and (31) found in the previous literature. Whenever needed, we assume the values used in our baseline parametrization of $\sigma = 4$, $\chi_W = 1$, $\chi_F = 1$, and $\alpha_W = 0.17$ in recovering structural parameters. When the effects are only reported separately for skilled and unskilled workers we use a share of skilled workers of 33% to average the effects.

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

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

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

[d] The parameters a_0 and a_1 come from Table 10 in Suárez Serrato and Wingender (2014) by manipulating the structural parameters as follows: $a_0 = 1/\sigma^i$ and $a_0 = \psi^i/\sigma^i$ for each skill group. The parameter b_1 comes from using the effect of spending on firm location (see Footnote 35) and by noting that this effect is equal to $1 - (\kappa_i^{GS} + (1 - \kappa_i^{GS})/(1 - \alpha_i))\frac{\partial W^i}{\partial F}$ in Suárez Serrato and Wingender (2014). The parameters 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 (2014). We then average these effects by the college share above.

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

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

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

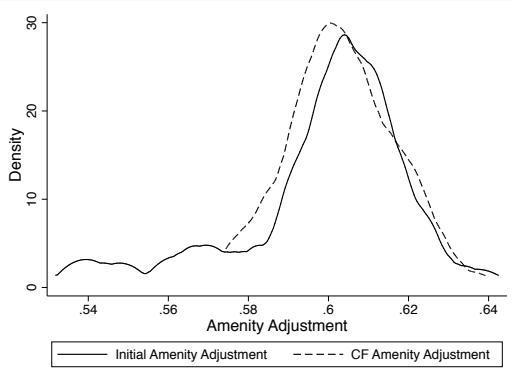
[h] Giroud and Rauh (2015) report an elasticity of number of establishment with respect to corporate taxes of 0.4.

D Appendix to Section 5 (Spatial Misallocation)

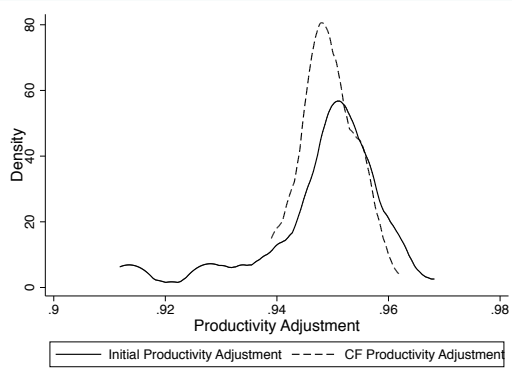
D.1 Appendix Figure to Section 5.1 (Benchmark)

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

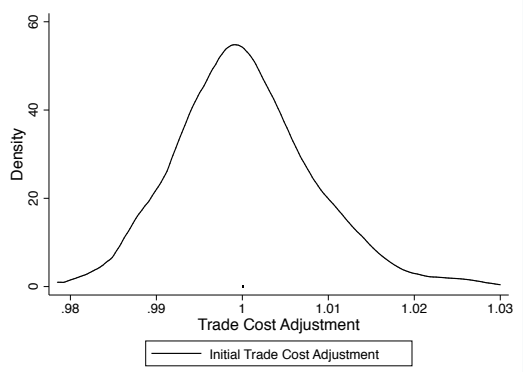
(a) Amenity Adjustment



(b) Productivity Adjustment



(c) Trade Cost Adjustment



Notes: panels (a), (b) and (c) show, respectively, the distributions of $(1-T_n)^{1-\alpha_W}(P_nG_n/GDP_n)^{\alpha_W}$, $(1-\bar{t}_n)^{\frac{1}{\sigma-1}-\left(\frac{1}{\varepsilon_F}+\alpha_F\chi_F\right)}(P_nG_n/GDP_n)^{\alpha_F}$, and $\frac{\sigma}{\sigma-\tilde{t}_{in}}$ which enter in the adjusted fundamentals in (25) to (27) under the initial parametrization and in the counterfactual without tax dispersion. In Panel (c), the counterfactual distribution is degenerate at 1 because $\tilde{t}_{in}=0$ for all i,n.

D.2 Appendix Table to Section 5.7 (Other Parametrizations)

Table A.7: Removing Tax Dispersion under Alternative Parametrizations

Counterfactual	Welfare		Real GDP	
	S-neutral	R-neutral	S-neutral	R-neutral
Benchmark	0.12%	0.69%	0.11%	0.65%
Higher demand elasticity ($\sigma=5$)	0.08%	0.59%	0.07%	0.44%
Medium congestion ($\chi_W=\chi_F=0.5$)	0.12%	0.78%	0.11%	0.88%
No congestion ($\chi_W=\chi_F=0$)	0.13%	0.63%	0.10%	0.64%
All IV's	0.09%	2.35%	0.13%	2.66%

D.3 Appendix to Section 5.3 (Heterogeneous Preferences for Public Services)

For this counterfactual, we assume that $\alpha_{W,n} = \alpha_0 + \alpha_1 POL_n$, where POL_n is a standardized political index constructed by Ceaser and Saldin (2005). In order to estimate α_0 and α_1, we re-write the estimating labor-supply equation (29) substituting the term α_W by the function $\alpha_0 + \alpha_1 POL_n$. Now, the parameters a_0 and a_1 in (29) vary across states:

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

Under the assumption that POL_n is independent of the amenity shocks in state n and the exogeneity assumptions described in Section 4.3.1, we use a GMM estimator to consistently estimate the parameters ε_W, α_0 and α_1. Table A.8 shows the results. Under the external-IV's and $\chi_W = 1$ specification we find $\hat{\alpha}_0 = .17$ (0.07) and $\hat{\alpha_1} = -.003$ (0.025).

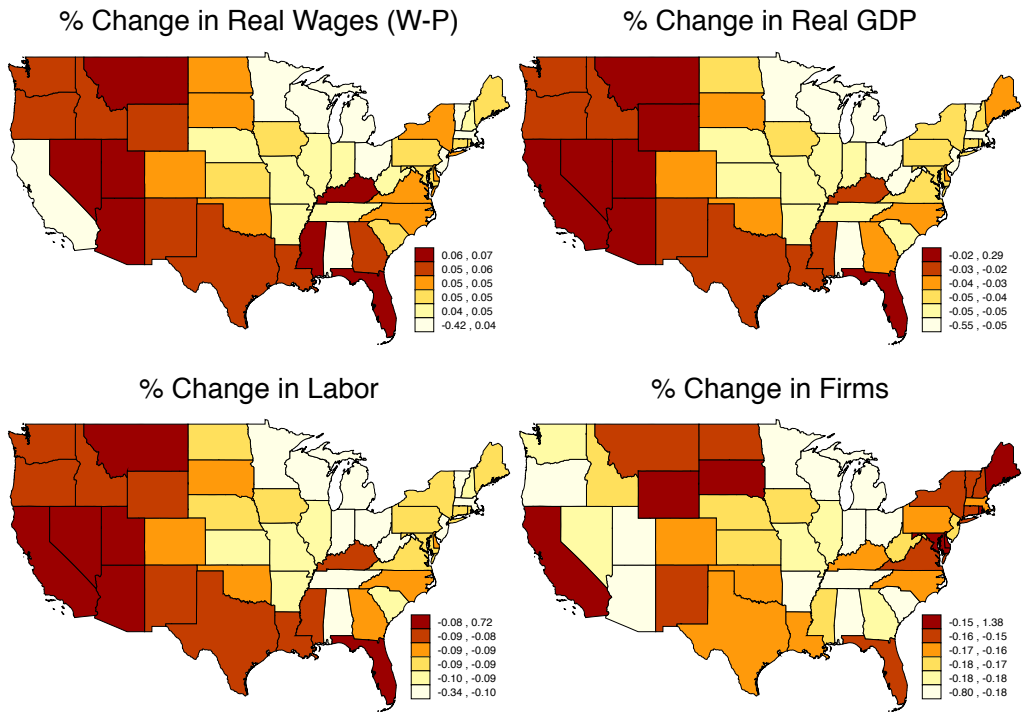
Table A.8: GMM Estimates of Heterogeneous Labor Mobility Parameters

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

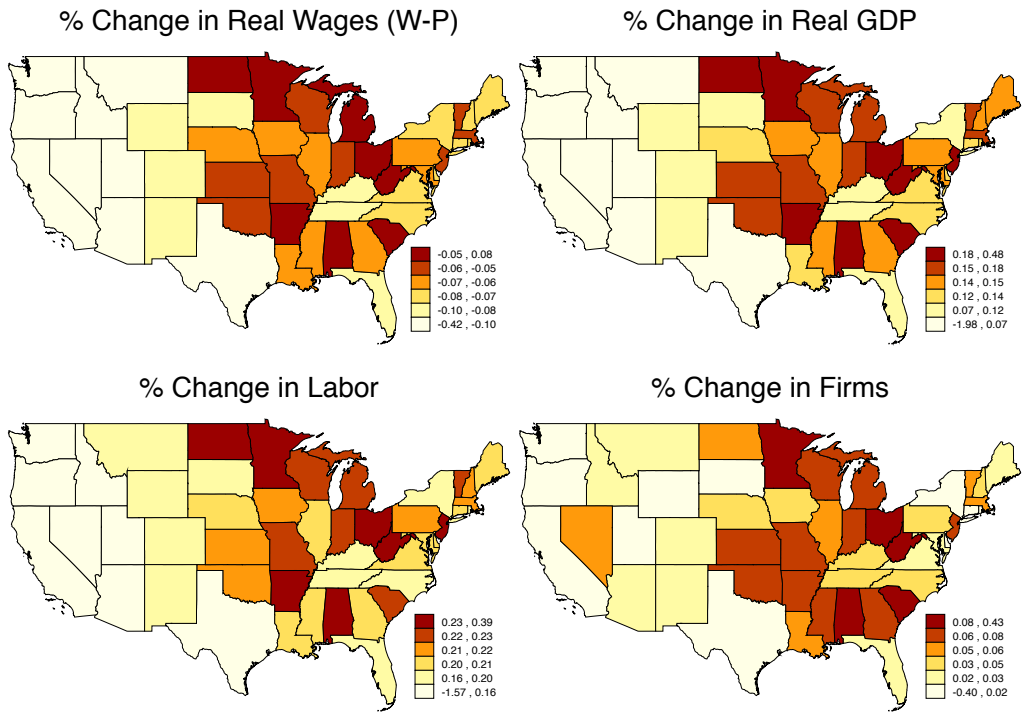
NOTES: This table shows the GMM estimates for heterogeneous labor mobility parameters. The dependent variable is log state employment $\ln L_{nt}$. The data are at the state-year level. Each column has 712 observations. Real variables are divided by a price index variable from BLS that is available for 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.

E Appendix to Section 6 (Other Policies)

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



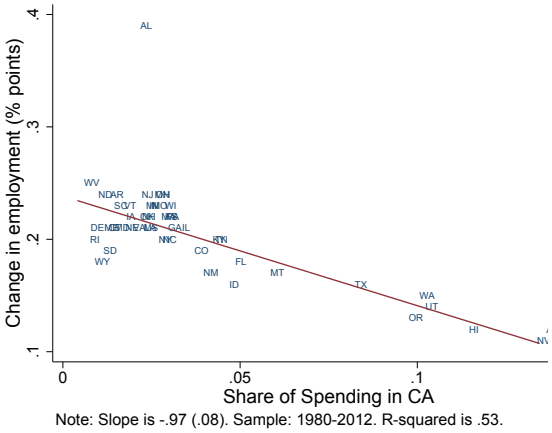
(a) Holding Government Spending Constant



(b) Total Effect

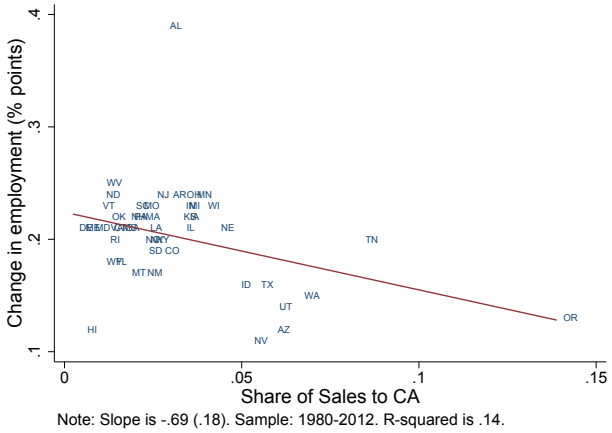
Figure A.5: Lowering Income Tax in California by 1 Percent Point

(a) Employment Changes and Spending Shares



Note: Slope is -.97 (.08). Sample: 1980-2012. R-squared is .53.

(b) Employment Changes and Sales Shares

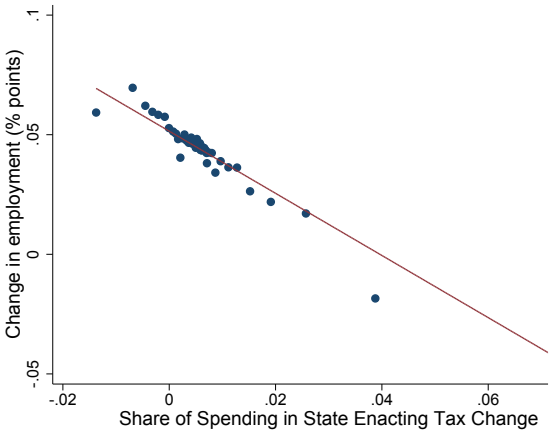


Note: Slope is -.69 (.18). Sample: 1980-2012. R-squared is .14.

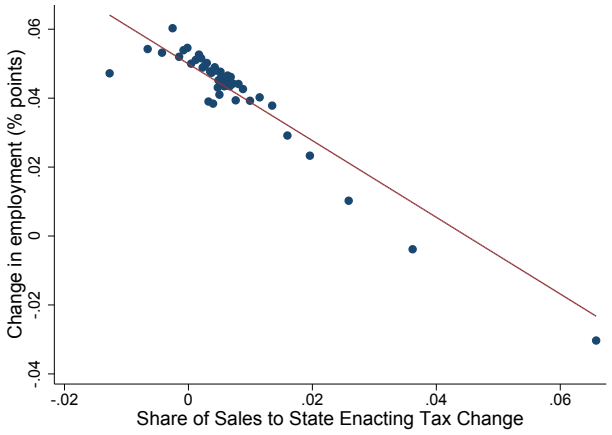
Note: The left panel shows the change in employment by state when there is a 1 percentage point reduction in income taxes in California against California's share in each state spending. The right panel shows the change in employment by state when there is a 1 percentage point reduction in income taxes in California against California share of each state's sales. California is excluded from both graphs.

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

(a) Employment Changes and Spending Shares



(b) Employment Changes and Sales Shares



Note: we run 49 counterfactuals consisting of a 1 percentage point 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.

F Data Sources

In this section we describe the data used in sections 2.1, 4, and 5.

F.1 Government Finances

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

- State direct expenditures (for Figure 2): Source: U.S. Census Bureau – Governments Division; Dataset: State Government Finances; Variable: direct expenditures.

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

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

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

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

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

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

- Corporate taxes adjusted for subsidies (for Section 5.6): We use data from the New York Times Subsidy database to compute state corporate tax rates net of subsidies, which amounted to $16 billion in 2012.[88] We first calculate an effective corporate tax rate by state by dividing corporate tax revenues by total pre-tax profits, which are given in A.9 by $\tilde{\Pi}_n = GDP_n / (\gamma_n(\sigma - 1) + 1)$. Since these effective rates are smaller than statutory tax rates, we adjust them by the ratio of statutory corporate rates to effective corporate rates in order to match the statutory rates. We next compute a subsidy rate by dividing state subsidies by the same tax base as above, and further multiply this ratio by the same adjustment factor as above. The net-of-subsidy, effective corporate tax rate is then the difference between the adjusted effective corporate rate and the adjusted subsidy rate.

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

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

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

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

F.2 Calibration (Section 4.2) and Over-Identification Checks (Section 4.4)

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

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

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

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

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

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

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

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

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

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

F.3 Estimation (Section 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 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)