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ABSTRACT

We study state taxes as a potential source of spatial misallocation in the United States. We build a spatial general-equilibrium framework that incorporates salient features of the U.S. state tax system, and use changes in state tax rates between 1980 and 2010 to estimate the model parameters that determine how worker and firm location responds to changes in state taxes. We find that tax dispersion leads to aggregate losses and the potential losses from even greater tax dispersion can be large. A government-spending-constant elimination of spatial dispersion in state taxes (which account for 4% of GDP) would increase worker welfare by 0.2%, while doubling spatial tax dispersion would reduce worker welfare by 0.4%.

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1 Introduction

Regional fiscal autonomy varies considerably across countries. In some countries, such as France, Japan, and the United Kingdom, regional governments do not set tax policy. In others, such as Australia, Canada, Germany, Italy, Spain, Switzerland, or the United States, regional governments have varying degrees of autonomy to set tax rates, grant tax breaks, and introduce or abolish taxes. As a result, in these countries tax rates vary considerably across regions. The standard reasoning from recent research studying dispersion in distortions – across firms, as in Restuccia and Rogerson (2008) and Hsieh and Klenow (2009), or across cities, as in Desmet and Rossi-Hansberg (2013) – suggests that regional tax heterogeneity may have negative aggregate effects by distorting the spatial allocation of resources.

To the best of our knowledge, no quantitative evidence on the general-equilibrium tradeoffs between centralized and decentralized tax systems exists.[1] The U.S. is a typical example of a country with a decentralized tax structure, both in terms of the share of total tax revenue collected by regional governments[2] and the degree of spatial dispersion in tax rates.[3] In this paper, we quantify the aggregate effects of dispersion in tax rates across U.S. states. For that, we develop a spatial general-equilibrium framework that incorporates salient features of the U.S. state tax code. In the model, workers decide where to locate based on each state's taxes, wage, cost of living, amenities, and public goods, and firms decide where to locate, how much to produce, and where to sell based on each state's taxes, productivity, factor prices, market potential (a measure of other states' market sizes discounted by trade frictions), and public goods. We use the over 350 changes in state tax rates implemented between 1980 and 2010 to estimate the model parameters that determine how workers and firms reallocate in response to changes in state taxes. Using the estimated model, we compute in general equilibrium the effects on worker welfare and aggregate income of replacing the current U.S. state tax distribution with counterfactual distributions resembling those observed in countries with different levels of regional tax dispersion, including fully harmonized regimes in which the tax rate for each type of tax is the same across states.

A central feature of our analysis is that, when evaluating each counterfactual distribution of state taxes, we hold the level of public spending of every U.S. state constant at its initial level. To accomplish this within our model, we introduce a system of cross-state transfers for each counterfactual tax regime so that every state's budget constraint is exactly satisfied at the initial level of spending. This strategy allows us to isolate the impact of the tax distribution without diving into broader considerations regarding how government spending is allocated.[4] From a theoretical per-

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

[2] According to data for year 2011 from the OECD Fiscal Decentralization Database, the share of total tax revenue collected by U.S. states (20.9%) is very similar to that collected by regions in Germany (21.3%), Spain (23.1%), or Switzerland (24.2%); only significantly lower than that in Canada (39.7%), and significantly larger than what is observed in Australia (15.3%) and Italy (11.7%).

[3] E.g., the standard deviation of the distribution of income tax rates across U.S. states (1.6 percentage points) is similar to that observed across regions in Spain (1.9 percentage points) but 75% smaller than that observed across European Union countries (6.3 percentage points).

[4] These broader considerations have been discussed theoretically in a vast literature on fiscal federalism; e.g., see Gordon (1983) or Oates (1999) for a review. As this literature has pointed out, adding to our analysis an empirical

spective, the question of how the tax distribution impacts the allocation of workers and firms and, through it, aggregate outcomes is distinct from the question of how the distribution of government spending impacts economic activity or how government spending should be allocated across levels of government.[5] This distinction between taxation and spending reflects the empirical reality that, regardless of the level of tax autonomy, in every country with sub-central governments there exist multiple mechanisms to transfer tax revenues across government entities, dissociating in practice the spending capacity of regional governments from their capacity to raise tax revenue.[6]

Our model includes key features from canonical environments used in the fiscal competition literature in the spirit of Flatters et al. (1974) or Wilson (1986).[7] As in these models, we consider an environment consisting of many states, several factors of production which may be fixed (land and structures) or mobile (workers and firms), and state governments that use their revenue to finance public services which may be valued by workers and firms or used as intermediate goods in production. Providing quantitative evidence on the impact of tax dispersion, however, requires incorporating additional features in these environments.

First, we include all the main sources of tax revenue of U.S. state governments – sales, personal income, and corporate income taxes apportioned through firm sales and factor usage – as well as federal taxes and federal transfers to the states. Second, we account for heterogeneity across states in terms of productivity, amenities valued by workers, endowment of fixed factors, factor intensities in production, and trade frictions with other regions, the modeling of which follows the standard approach from quantitative trade models such as Eaton and Kortum (2002) or Anderson and Van Wincoop (2003). Third, firms are monopolistically competitive as in Dixit and Stiglitz (1977) and Krugman (1980).[8] Fourth, workers and firms respectively draw idiosyncratic preferences and productivities across states, and the amount of worker and firm reallocations in response to changes in state taxes depends on the dispersion in the distributions of these draws.[9] As we explain in more detail below, these four ingredients are necessary for our model to match the observed responses of workers and firms to changes in taxes and economic conditions, and to rationalize the observed distribution of economic activity and trade flows across states as an equilibrium outcome of our model.

The resulting framework can be mapped to existing quantitative models of trade and economic geography, allowing us to leverage properties of these models to undertake counterfactuals with

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evaluation of the welfare impact of changes in the distribution of public spending across states would crucially require data on variables that are neither observed nor easily inferred given the information provided in standard datasets (e.g., for each level of government, both their efficiency in providing public goods and the information that they have about individuals' preferences for public services).

[5]E.g., Wildasin (1980) refers to the allocative effects of taxes given any arbitrary distribution of public spending as "locational efficiency".

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

[7]We discuss the connection between our work and this literature in Section 2.

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

[9]This is a common assumption in the local labor markets literature, e.g., see Moretti (2011) and Suárez Serrato and Zidar (2015).

respect to the tax distribution. Specifically, implementing counterfactuals with respect to the tax distribution is equivalent to implementing a specific set of changes in amenities, productivities, bilateral trade costs, and trade imbalances in a standard trade and economic-geography model. However, determining this specific set of equivalent changes in fundamentals and trade imbalances requires using general-equilibrium relationships to determine how much tax bases change in the counterfactual. For example, changes in taxes lead to shifts in public-goods provision, which impact the equilibrium outcomes of our model equivalently to how shifts in amenities and firm productivity impact the equilibrium outcomes of a standard trade and economic geography model; the magnitude of these tax-induced shifts in public goods depends on how much the tax revenue of each state adjusts in general equilibrium.[10] Therefore, implementing counterfactuals in our framework requires simultaneously using a mapping from changes in fundamentals to changes outcomes that is standard in existing trade and economic geography models, as well as a mapping from changes in taxes to equivalent changes in fundamentals that is specific to our environment.

We rely on a simpler version of our model to characterize analytically how worker welfare and aggregate output depend on the tax distribution. In our model, eliminating dispersion in tax rates while keeping government spending constant may have positive or negative effects on worker welfare, output per worker, and aggregate consumption depending on parameter values. Specifically, these responses depend on the correlation between state taxes and state fundamentals, and on three sets of parameters which govern factor mobility, the importance of fixed factors in production, and the preferences for public goods. For example, eliminating tax dispersion increases (reduces) worker welfare if the correlation between state worker keep-tax rates (i.e., the fraction of income that workers keep after taxes) and state productivities is sufficiently low (high). The impact of tax dispersion on aggregate real income is also ambiguous: because state amenities and public goods act as compensating differentials, leading to dispersion in the marginal product of labor across states, eliminating tax dispersion may increase or decrease aggregate real income depending on the initial correlation between state taxes and these compensating differentials. In sum, whether tax harmonization raises worker welfare and aggregate income depends on the values taken by the model parameters.

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

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[10]Even though, as mentioned above, our key counterfactuals keep government spending constant, we need to include an endogenous supply of public goods in the model in order to implement these counterfactuals, i.e., to find the levels of tax rates and inter-state transfers that guarantee that each state can maintain the initial level of public spending in each counterfactual.

spending in the data correspond to higher weights of public services in worker preferences and firm productivity in our model.

We estimate these parameters using observed worker and firm responses to actual tax changes. Our estimation approach uses taxes in other states to instrument for each state's factor prices and government spending. We compute estimates that rely on alternative assumptions on how preferences for government spending vary across states. The resulting estimates always imply that workers' and firms' location decisions are more responsive to after-tax real wages or profits, respectively, than to government spending. For example, assuming that preferences for government spending are constant across states yields a partial elasticity of state employment with respect to after-tax real wages of 1.1 and with respect to government spending of 0.3, and a partial elasticity of the share of establishments with respect to after-tax market potential of 0.9 and with respect to government spending of 0.14. These estimates are in the range of existing work that has estimated similar elasticities using alternative identification strategies.[11]

Our estimation approach guarantees that, in any counterfactual that we implement, the model-implied elasticities of the shares of workers and firms in each state with respect to that state's taxes and general-equilibrium variables (wages, prices, market size, and government spending) coincide with those observed in the data. In addition to these worker- and firm- mobility elasticities, the outcomes of our counterfactuals also depend on state-specific production technologies, productivities, amenities, and trade costs. These distributions are parametrized such that the model exactly reproduces, as an equilibrium outcome, the distribution of economic activity across states (labor and intermediate-input income shares, wages, employment, trade flows, and trade imbalances) observed in 2007, the most recent year for which all the data we need are available. Furthermore, even though we do not use information on states' GDP to quantify the parameters of our model, we find that the states' GDP and tax revenue shares in GDP implied by the estimated model are very similar to those observed in the data.

We find that, in the U.S., tax dispersion leads to aggregate losses. When state income taxes are approximated by a flat tax schedule, our parametrized model predicts that a government-spending-constant elimination of state tax dispersion would increase worker welfare by approximately 0.2% (relative to a 4% share of state taxes in GDP). This prediction holds independently of the assumptions about how preferences for government spending vary across states. In particular, it holds both in the extreme case in which we assign zero weight to public services in preferences and productivity and in the case in which we assume that the observed government size in each state reflects workers' preferences for public services. This result is also robust to alternative ways of measuring effective state tax rates; e.g., to adjusting corporate tax rates for state subsidies, to adjusting income, sales, and corporate taxes to account for local taxes, and to including state and local property taxes. When accounting for the progressivity of state income taxes, we obtain larger worker welfare gains from tax harmonization, which increase to 0.4%, due to the higher initial dispersion in tax rates.

Our parametrized model also predicts larger welfare losses if tax dispersion were to increase in the United States. For example, a government-spending-constant doubling of tax dispersion in the

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[11]See the relationship to this literature in Section 2.

U.S. – which would imply a level of tax dispersion still below other fiscally decentralized entities such as the E.U. – would reduce worker welfare by about 0.4%. Indeed, we find that eliminating tax dispersion maximizes worker welfare among all the distributions of tax rates that modify the overall spatial dispersion in taxes while preserving the current ranking of U.S. states based on their level of taxes. However, we show that this result would be different if the distribution of fundamentals across states in the U.S. was different from that implied by the 2007 data. Consistently with our theoretical analysis in a simpler environment, a tax harmonization that keeps government spending constant would reduce worker welfare if there were a high correlation between initial keep-tax rates and state amenities or productivity. Therefore, the answer to the question of whether a harmonized tax system that keeps government spending constant is superior to an observed spatial tax distribution depends both qualitatively and quantitatively on the specific country and data in question.

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

2   Relation to the Literature

Misallocation   Our paper contributes to the literature on the aggregate effects of misallocation. A common approach consists of measuring distortions across firms as an implied wedge between an observed allocation and a model-implied undistorted allocation, as in Hsieh and Klenow (2009), and then undertaking counterfactuals to inspect the aggregate effects of dispersion in these wedges. Recent papers have adopted a similar methodology to analyze misallocation across geographic units, such as Desmet and Rossi-Hansberg (2013) and Brandt et al. (2013).[12] These wedges capture distortions that may be due to multiple sources. Rather than inferring distortions from wedges, we focus on state taxes that we directly observe in the data. We use observed variation in these taxes to estimate key model parameters.

Trade and Economic Geography   Our framework shares several components with quantitative economic-geography models that introduce labor mobility into trade models, such as Allen and Arkolakis (2014), Ramondo et al. (2015), Redding (2015), Gaubert (2015), and Caliendo et al. (2014).[13] Our research question – the impact of state taxes on the U.S. economy – drives our mod-

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

[13]E.g., as in some of these papers, our model includes an endogenous number of monopolistically competitive firms in each location and congestion forces that are similar to Krugman (1991) and Helpman (1998), the use of differentiated

eling choices, estimation approach, and counterfactuals. Relative to this literature, we incorporate the main taxes imposed by U.S. states and by the federal government as well as a government sector that uses tax revenue to finance public services valued by workers and firms.[14] A central feature of our analysis is that we perform counterfactuals with respect to policy variables that are directly observed (U.S. state tax rates) and use observed variation in these same policies to identify the key model parameters.[15]

Fiscal Competition   The literature on fiscal competition, summarized among others by Oates (1999), Wilson (1999), and Keen and Konrad (2013), typically considers static and perfectly competitive economies with two or more regions and several factors of production, some of which are immobile and some of which are mobile, which may be used to produce a consumption good and a non-traded public good. These basic ingredients are included in our model. Our model generalizes this structure to a multi-region setting in which the distribution of state characteristics can be disciplined using data on the distribution of economic activity.

A central question in this literature has been whether jurisdictions setting tax policies according to the equilibrium of a non-cooperative game deliver a socially efficient allocation. It is well understood from this previous literature that the answer to this question depends on the specific features of the environment in which it is considered, such as: which set of tax instruments jurisdictions may control (e.g., taxes on mobile or fixed factors), how agents value government spending (e.g., whether there is congestion in access to public services), what the objective function of policy makers is (e.g., rent-seeking, maximizing social welfare, or maximizing the welfare of only fixed or mobile factors), or what information each level of government has (e.g., how much each government knows about local preferences). Our focus – assessing the consequences of changes in the tax distribution – does not involve computing the equilibrium of a non-cooperative game, so it does not require taking a stand on the objective function or the information sets of policy makers, or on the process through which observed taxes are determined. Assumptions on how taxes are determined are only relevant at the moment of estimating the parameters of our model, and we discuss these identification assumptions in detail in Section 6.[16]

Within this literature, a body of work following Tiebout (1956) illustrates how heterogeneous preferences for government services across workers can play a central role in determining the efficiency properties of the non-cooperative game among jurisdictions. Quantifying these heteroge-

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products as intermediates as in Krugman and Venables (1995), and workers with idiosyncratic preferences for location as in Tabuchi and Thisse (2002).

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

[15]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.

[16]A recent example of the literature on fiscal competition is Ossa (2015). He uses an economic-geography model with home-market effects to compute the Nash equilibrium of a game where states use lump-sum taxes to finance firm subsidies. In practice, state firm subsidies often take the form of exemptions from corporate taxes; accordingly, we adjust our measures of effective state corporate taxes by the subsidies granted by each state in Section 7.8. Our results barely change when we implement this adjustment; the reason being that total state subsidies only amount to about 10% of the total states' tax revenue. Ossa (2015) does not incorporate state taxes nor uses observed variation in policy to estimate parameters.

neous preferences for a large set of worker types and states is empirically challenging and, therefore, our model assumes that all workers located in the same state have the same valuation for public spending (but this valuation may vary across states). However, as our main counterfactuals hold real government spending fixed, worker location decisions in our counterfactuals do not vary depending on how workers value government services but only on how they value changes in after-tax real wages. We show that our counterfactual results are robust to several alternative approaches to measuring the valuation that workers have for government services.

Factor Mobility in Response to Tax Changes We estimate elasticities of firm and worker location with respect to taxes to identify key structural parameters. Evidence on the effect of taxes on worker mobility includes Bartik (1991) and, more recently, Moretti and Wilson (2015). Estimates of worker mobility across regions include Bound and Holzer (2000), Notowidigdo (2013), and Diamond (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. Within this literature, Suárez Serrato and Zidar (2015) provide evidence on the impact of corporate taxes on worker and firm mobility, Suárez Serrato and Wingender (2014) show that local economic activity responds to public spending, and Giroud and Rauh (2015) show that C-corporations reduce their activity when states increase corporate tax rates.[17] Section 6.3 in Appendix D.6 compares our estimates to estimates from this literature. While the aim of this literature is to quantify the local effects of actual policy changes, we use similar empirical specifications and variation in the data to estimate key parameters of a general-equilibrium model and then use these estimates to study how counterfactual policy changes in one state or simultaneously in many states impact aggregate outcomes in the U.S. economy.[18]

3   Background on the U.S. State Tax System

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

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[17]Additionally, Devereux and Griffith (1998) estimate the effect of profit taxes on the location of production of U.S. multinationals, Goolsbee and Maydew (2000) estimate the effects of the 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. Chirinko and Wilson (2008) and Wilson (2009) also provide evidence consistent with the view that state taxes affect the location of business activity.

[18]Our paper is also related to the literature that has analyzed the general equilibrium effects of tax changes. Shoven and Whalley (1972) and Ballard et al. (1985) point out the importance of general equilibrium effects when analyzing large changes in policy. See Nechyba (1996) for an early CGE model of local public goods. Albouy (2009) studies how federal tax progressivity impacts the allocation of workers and aggregate outcomes. A large literature in macroeconomics also studies the dynamic effects of taxes in the standard growth and real-business cycle model; Mendoza and Tesar (1998), among others, study dynamic effects of taxes in an international setting.

3.1 Main State Taxes

Personal Income Tax   States tax the personal income of their residents. The base for the state personal income tax includes both labor and capital income. We use a flat income tax rate in our benchmark analysis and then explore how our counterfactual results change if we account for the progressivity of income taxes at both the state and federal levels.[19] 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.[20] State tax authorities determine the share of a C-corporation's national profits allocated to their state using apportionment rules, which aim to measure the corporation's activity share in their state. To determine 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 sold.[21] In 2012, the average corporate income tax rate across states was 6.4%; the states with the highest corporate tax rates were Iowa (12%), Pennsylvania (10%), and Minnesota (10%), while six states had no corporate tax. Apportionment through sales tends to be more prevalent: nineteen states exclusively apportion through sales, while roughly half of the remaining states apply either a 50% or 33% apportionment through sales. Since C-corporations account for the majority of net income in the United States, in our benchmark analysis we treat all businesses as C-corporations.[22] 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.

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.[23] In 2012, the average sales tax rate was 5%; the states with the highest sales tax rates were New Jersey

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[19]The schedule of state income tax rates tends to be progressive, but it is typically much flatter than the federal income tax schedule. We compare the progressivity of state and federal income tax rates when we introduce progressive income taxes in Section 7.7.

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

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

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

[23]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).

(10%), California (7.5%), and Indiana (7%), while five states had no sales taxes. In our benchmark analysis, we measure the sales tax rate as the statutory general sales tax rate.

3.2 Dispersion in Tax Rates and in Tax Revenue across States

Both tax rates and tax bases vary considerably across states. Panel (a) of Figure 1 shows the 2010 distribution of sales, income, corporate, and sales-apportioned corporate tax rates.[24] For each tax, rates vary across states, and corporate tax rates are 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.

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
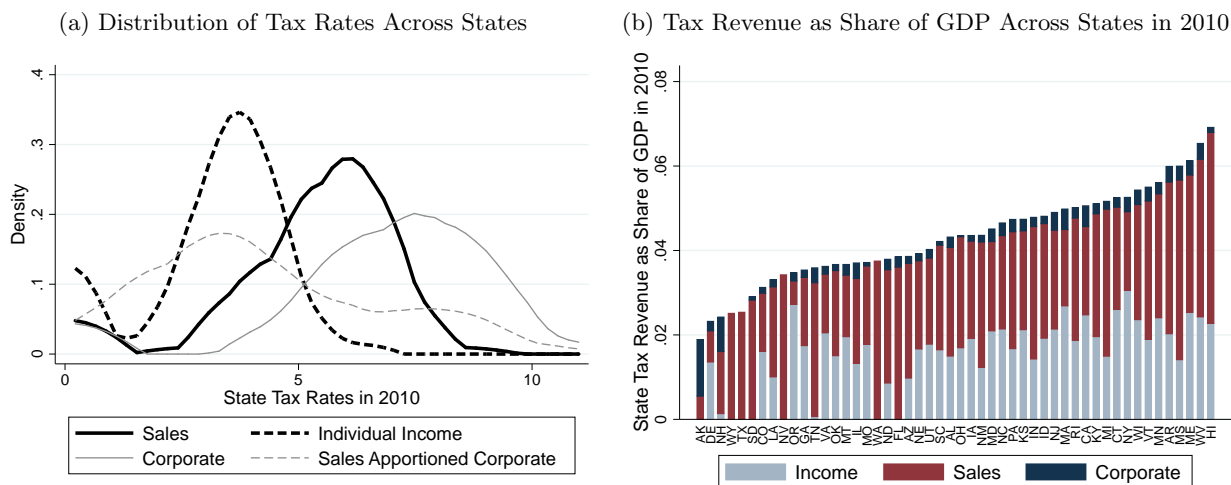
Local (sub-state) governments also tax residents. Overall, state taxes amount to roughly 60% of state and local tax revenue combined.[25] Heterogeneity in tax rates across states is also present when both state and local taxes are taken into account. Figure A.1 in the appendix reproduces panel (a) of 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. In Section 7.8, we recompute the

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[24]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 21. 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.

[25]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.

main counterfactuals using measures of state tax rates that consolidate statutory state and local taxes, including property taxes.

3.3 Relationship Between State Tax Revenue and Government Spending

In addition to the three types of taxes discussed in Section 3.1, a major source of revenue of U.S. state governments comes from the transfers that they receive from the federal government. On average, these transfers amount to roughly 6% of state GDP. Once these federal government transfers are taken into account, state governments typically have balanced budgets (Poterba, 1994). Federal transfers therefore allow state spending to exceed state tax revenue. The actual process determining the level of transfers enjoyed by each state in each year is complex. However, empirically, for the period 1980 to 2010, the size of the total direct expenditures of each state is very well approximated as a state-specific multiplier of that state's tax revenue. That is, letting E_{nt}^G be state n's direct expenditures in year t,[26] $\psi_n > 0$ be a state-specific multiplier, and R_{nt} be state tax revenue, the estimates of the regression

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

yield an R^2 of 0.97. Therefore, our model assumes the relationship $E_{nt}^G = R_{nt} + T_n^{fed \to st}$, where $T_n^{fed \to st} = \psi_n R_{nt}$ is the part of state spending financed through federal transfers.[27]

4 Quantitative Economic Geography Model with State Taxes and Public Goods

4.1 Model Overview

We model a closed economy with N states indexed by n or i. A mass M of firms and L of workers respectively receive idiosyncratic productivity and preference shocks, which govern how they sort across states. We let M_n and L_n be the measure of workers and firms that locate in state n. Changing M or L does not affect the allocation; it scales up M_n or L_n everywhere. Therefore, we normalize M and L to 1, implying that M_n and L_n are the fractions of firms and workers located in state n.

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

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

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

inputs using technologies that may vary across states. Workers receive only labor income, which they spend in the state where they live. Firms and fixed factors are owned by immobile capital owners exogenously distributed across states.

State governments collect personal income taxes t_n^y, sales taxes t_n^c, and corporate income taxes apportioned through sales, t_n^x, or through payroll and fixed factors, t_n^l. Each state uses the tax revenue to finance the provision of public services, which enter as shifters both of that state's amenity and of the productivity of firms that locate in that state. The weight of public services in preferences may vary across states.

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

4.2   Production Technologies

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

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

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

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

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

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

where 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

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inputs expenditures in states' GDP observed in the data.[28]

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

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

4.3 Workers

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

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

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

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

Equations (6) and (7) imply that workers have preferences over amenities, public goods, and final consumption goods.[29] First, the coefficient u_n captures both natural characteristics, like the weather, and the rate at which the government transforms total real spending into services valued by workers; this rate includes the fraction of the state budget used to finance public services valued only by workers.[30] For simplicity, we refer to this term as simply "amenities". Second, the appeal of state n also depends on real government spending, G_n, normalized by $L_n^{\chi_W}$. The parameter χ_W captures rivalry in public goods, and ranges from $\chi_W = 0$ (non-rival) to $\chi_W = 1$ (rival).[31] Third, workers care about the quantity of final goods that they can consume in state n. This quantity equals after-tax wages, $((1 - t_{fed}^y)(1 - t_n^y) - t_{fed}^w)w_n$, normalized by the after-tax price, $(1 + t_n^c) P_n$.[32]

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

[29]The framework could easily be generalized to allow for direct consumption of the fixed factor by workers in the form of housing. Furthermore, housing supply could be allowed to be elastic. In that specification, the price of land would enter as part of the cost of living and the effective tax keep-rate would account for average property taxes. While adding these elements to our model would be straightforward, measuring a state-specific property tax or housing supply elasticity would be less so because both property taxes and housing supply elasticities vary considerably across cities within states, as documented by Saiz (2010).

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

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

[32]Note that equation 7 takes into account that state income taxes can be deducted from federal taxes. In our

As a result, real consumption equals the pre-tax wage, w_n/P_n, adjusted by income and sales taxes, $1 - T_n$. The parameter $\alpha_{W,n}$ captures the weight of state-provided services in preferences. The weight of public services in preferences, $\alpha_{W,n}$, may vary across states, reflecting complementarities between state-specific features such as the weather or natural amenities and government services.

The idiosyncratic taste draw 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

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

where

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

Under the Fréchet distribution, both the ex-ante expected utility of a worker before drawing $\left\{\epsilon_n^l\right\}_{n=1}^N$ and the average ex-post utility of agents located in any state are identical and proportional to v; hence, we adopt it as our measure of worker welfare.[33]

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

4.4   Capital Owners

Immobile capital owners in state n own a fraction b_n of a portfolio that includes all firms and fixed factors, independently of the state in which they are located. We do not need to specify the number of capital owners located in each state n for our computations. In the model, a larger ownership rate relative to other states results in larger trade imbalances. Therefore, we will calibrate the ownership shares b_n to match the observed trade imbalances across states.[34] Capital owners spend their income locally, pay sales taxes on consumption, and pay both federal and state income taxes on their income.[35]

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benchmark analysis, we abstract from the progressivity of both federal and state income taxes. In Section 7.7, we relax this assumption and allow the federal and the state personal income tax rates to be a function of state wage.

[33]The constant of proportionality equals $\Gamma((\varepsilon_W - 1)/\varepsilon_W)$, where $\Gamma(\cdot)$ is the gamma function.

[34]See Section 6.2 for details. Two alternative modeling approaches would be to assume that all workers own equal shares of the national portfolio, or that the returns of that portfolio are spent outside of the model. Under these approaches, the model would lead to empirically inconsistent predictions for trade imbalances across states. In contrast, our current approach allows us to discipline the assumptions on factor ownership with observed data on trade imbalances.

[35]When considering progressive federal and state income in Section 7.7, we will assume that capital owners are subject to the highest marginal federal and state income tax rates. Cooper et al. (2015) show that the majority of

4.5 Firms

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

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

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

where $\bar{t}_i^j$ is the corporate tax rate of firm j if it were to locate in state i, $x_{ni}^j = P_n Q_n^{\frac{1}{\sigma}}(q_{ni}^j)^{1-\frac{1}{\sigma}}$ are its sales to state n, and $c_i = (w_i^{1-\beta_i}r_i^{\beta_i})^{\gamma_i}P_i^{1-\gamma_i}$ is the the cost of the cost-minimizing bundle of factors and intermediate inputs, where r_i stands for the cost of a unit of land and structures in state i.[36]

All firms face corporate taxes apportioned through sales, payroll, and land and structures.[37] A firm j located in state i whose share of sales to state n is s_{ni}^j pays $s_{ni}^j t_n^x$ times the pre-tax national profits in corporate taxes apportioned through sales to state n. Firms located in i also pay t_i^l times the pre-tax national profits in corporate income taxes apportioned through payroll and land and structures to state i, and a rate t_{fed}^{corp} in federal corporate income taxes. As a result, the corporate tax rate of firm j is:

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

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

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business income accrues to very high income earners.

[36]Note that the definition of c_i accounts for the fact that, unlike consumers, firms do not face the sales tax when purchasing the final good to be used as an intermediate. See footnote (23).

[37]This assumption implies that we treat all companies as C-corporations. In practice, many companies are set up as S-corporations and partnerships. These companies are not subject to corporate income taxes. We ignore them in our baseline model because they represent a small fraction of U.S. business revenues – see our previous discussion in Section 3.1. However, in Section 7.8, we perform a robustness check where corporate tax rates are adjusted by the actual share of C-corporations in each state.

Pricing Distortion Through Corporate Taxes Despite the non-separability of the sales decision across markets, the solution to the firm optimization problem retains convenient properties from the standard CES maximization problem that allow for aggregation; we describe these properties here and refer to Appendix B.1 for details. Specifically, all firms located in a state i have the same sales shares across destinations irrespective of their productivity, i.e., $s_{ni}^j = s_{ni}$ for all firms j located in i; from (11), this leads to a common corporate tax rate across firms, $\bar{t}_i^j = \bar{t}_i$. Additionally, firms set identical, constant markups over marginal costs, but these markups vary bilaterally depending on corporate taxes. The price set in n by a firm with productivity z located in state i is:

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

where

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

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

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

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

As in the case of amenities, this common component has an endogenous part that depends on the amount of public spending and an exogenous part, z_i. The endogenous part equals real government spending G_i normalized by $M_i^{\chi_F}$, where the parameter 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, the rate at which the government transforms real spending into services valued by firms, and the share of public goods provided by state governments that increase the productivity of the firms located in their states.[38] 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 distribution implies that

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[38]More specifically, (14) is consistent with first defining $z_i^0 = \left(G_i^F/M_i^{\chi_F}\right)^{\alpha_F} z_{i,0}^{1-\alpha_F}$, where $z_{i,0}$ are natural characteristics, $G_i^F = z_i^F (1 - \theta_i) G_n$ are government services valued by firms, z_n^F is the efficiency or the quality of real spending in services valued by firms, and θ_i^F is the fraction of the state budget dedicated to services valued by firms. Starting from this initial definition, (14) corresponds to defining $z_i = z_{i,0}^{1-\alpha_F} \left(z_i^F \theta_i^F\right)^{\alpha_F}$. Reminding the reader that θ_i^W is the fraction of the state budget dedicated to services valued by workers (see Footnote 30), we note that $\theta_i^F + \theta_i^W$ may be greater than 1. I.e., it is possible that the same government spending is valued by both workers and firms.

firm-level profits, $\pi_i(z_i^j)$, are also Fréchet-distributed with shape parameter $\varepsilon_F/(\sigma - 1) > 1$.[39] 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 $\pi_i \left(z_i^0 \right)$ is the profit of a firm with productivity z_i^0 located in i and $\bar{\pi}$ is proportional to the expected profits before drawing $\{\epsilon_i^j\}_{i=1}^N$.[40] Equation (15) says that the fraction of firms located in n depends on the common component of profits in n, $\pi_i \left(z_i^0 \right)$, relative to that in other locations. A larger value of $\varepsilon_F/(\sigma - 1)$ 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.

Equilibrium State Productivity Distribution   Because firms self-select into each state based on their productivity draws, the productivity distribution in each state is endogenous. However, as in Melitz (2003), aggregate outcomes (in our case, at the state level) can be formulated as a function of a single moment $\tilde{z}_i$ of the the productivity distribution in each state i. This productivity level is endogenous and can be expressed as a function of the number of firms that optimally choose to locate in each state i:[41]

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

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

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

Contrast with Models with Free Entry   As in a standard economic-geography model with free entry of homogeneous firms such as Helpman (1998) or Redding (2015), our model predicts that the number of firms in each state is endogenous and proportional to aggregate sales in that

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

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

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

location.[42] There are two reasons to assume mobility of heterogeneous firms instead of free-entry of homogeneous firms. First, in order to analyze corporate taxes, it is convenient to use a model with aggregate profits in every state, whereas free-entry models lead to zero profits. Second, this approach allows us to use data on patterns of firm mobility to estimate a single parameter, ε_F, which determines the elasticity of the firm count in each state with respect to taxes, and to directly compare our estimates with existing work which has already estimated elasticities of firm location with respect to taxes in the public-finance literature.[43]

4.6 State Governments

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

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

The tax revenue collected by state n is

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

where R_n^{corp}, R_n^c, and R_n^y, are government revenue from corporate, sales, and income taxes, respectively. These expressions are defined in (A.24) to (A.20) in Appendix B.2.

Consistent with the empirical evidence shown in Section 3.3, we assume that transfers from the federal government to the state governments in state n are proportional to the tax revenue collected by these state governments, where the constant of proportionality ψ_n may vary by state: $T_n^{fed \to st} = \psi_n R_n$. Combined with (17), this implies that $P_n G_n = (1 + \psi_n) R_n$.[44] The federal government therefore subsidizes a fraction $\frac{\psi_n}{1+\psi_n}$ of spending in state n.[45]

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[42]Specifically, from (A.9) and the distributional assumption on the productivity draws, it follows that the number of firms in state i can be expressed as $M_i = \frac{1-\bar{t}_i}{\bar{\pi}} \frac{X_i}{\sigma}$.

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

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

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

4.7 Federal Government

As we have noted, taxes are also collected by the federal government. Expression (A.21) in Appendix B.2 shows the expression for total taxes levied by the federal government in state n. The federal government uses these taxes either to finance transfers to state governments, $T_n^{fed \to st}$, or to purchase the final good produced in each state, G_n^{fed}, as an input in the production of a national public good, G^{fed}. Therefore, our analysis assumes away issues related to how the public services generated by the federal government impacts worker and firm location.

4.8 General Equilibrium

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

4.9 Adjusted Fundamentals and Implementation of Counterfactuals

The model implies that taxes in any given state may affect outcomes in every state. These cross-state effects are complex, but they can be better understood using a general-equilibrium system that determines wages and employment in every state, $\{w_n, L_n\}_{n=1}^N$, and welfare, v, as functions of the model's primitives.[46] In this system, state taxes $\{t_n^c, t_n^y, t_n^x, t_n^l\}_{n=1}^N$ affect these outcomes through their impact on the *adjusted fundamentals*, $\{\{\tau_{in}^A\}_{i=1}^N, z_n^A, u_n^A\}_{n=1}^N$:

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

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

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

where $P_n G_n / GDP_n$ is the share of state government spending in GDP shown in (A.30) in Appendix B.2. In addition to the adjusted fundamentals, taxes also impact wages, employment, and welfare through their effects on the relative trade imbalances $P_n Q_n / GDP_n$ (i.e., the ratio between state expenditures and GDP), as shown in (A.26). The adjusted fundamentals $\{z_n^A, \tau_{in}^A, u_n^A\}$ become identical to the state fundamentals (productivity z_n, amenity u_n, and trade costs τ_{in}) if we eliminate preferences for government spending ($\alpha_F = \alpha_W = 0$) and set all tax rates to zero.

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[46]This system is derived after manipulating the general-equilibrium conditions enumerated above. See Appendix B.3.

In general equilibrium, the distribution of outcomes across states depends on the distributions of adjusted fundamentals, $\{z_n^A, \tau_{in}^A, u_n^A\}$, and of relative trade imbalances, $\{P_n Q_n / GDP_n\}$, similarly to how it depends on the standard fundamentals and relative trade imbalances in standard economic-geography models such as Allen et al. (2014) or Redding (2015). Therefore, implementing counterfactuals with respect to the tax distribution within our model is equivalent to implementing a specific set of changes in amenities, productivities, bilateral trade costs, and trade imbalances in a standard trade and economic-geography model.

However, this mapping from taxes to adjusted fundamentals and relative trade imbalances depends on the specific aspects of the tax system incorporated in our model. Specifically, the adjusted trade costs and productivity depend on corporate taxes in any state through the average corporate tax $\bar{t}_n$ and the pricing distortion $\{\tilde{t}_{in}\}_i$, both of which depend on the distribution of sales shares $\{s_{in}\}_i$ (see (19) and (21)); the adjusted amenities and productivity depend government size relative to GDP in state n, which depends on own-state taxes and on the relative trade imbalance through the sales apportionment of corporate taxes (see (A.30));[47] the relative trade imbalances depend on both the amount of non-labor income of state n relative to other states and on cross-state corporate tax payments (see (A.26)); and the adjusted amenities depend on sales and income taxes through the worker keep rate, $1 - T_n$ (see (21)).[48]

This discussion implies that, to implement counterfactuals with respect to the tax distribution in our framework, we must simultaneously use a mapping from changes in fundamentals to changes in outcomes that is standard in existing trade and economic geography models, as well as a mapping from changes in taxes to changes in adjusted fundamentals that is specific to our environment. The first mapping is presented in equations (A.44) to (A.48) in Appendix B.5, and the second one in equations (A.50) to (A.52).

4.10   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. 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 (6)) or firm productivity (see (14)). At the same time, our model features

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[47]The base of the sales-apportioned corporate tax in state n are the sales to state n, which equal expenditures in state n. Specifically, the sales-apportioned part of the corporate tax revenue of state n defined in (A.18) can be expressed as $\frac{t_n^x}{\sigma} P_n Q_n$. Therefore, larger expenditures in state n lead to higher government revenues through the sales apportionment of corporate taxes.

[48]In counterfactuals where we implement a progressive state or federal income tax schedules the worker keep rate becomes a function of the wage rate, so that the adjusted amenity also depends on general-equilibrium outcomes.

congestion through immobile factors in production, leading to a higher marginal production cost in a state when employment increases in that state (see (A.8) in Appendix B.2); through selection of heterogeneous firms, leading to a lower average firm productivity in a state when the number of firms increases (see (16)); and through the presence of immobile capital-owners, who spend their income where they are located.[49]

In light of these agglomeration and congestion forces, it is natural to ask whether the general equilibrium is unique. Allen et al. (2014) establish conditions for existence and uniqueness in a class of trade and economic geography models. Our model fits in that class when technologies are homogeneous across states ($\beta_n = \beta$ and $\gamma_n = \gamma$ for all n), there is no dispersion in sales-apportioned corporate taxes across states ($t_n^x = t^x$ for all n), and there is no cross-ownership of assets across states. The last two assumptions imply that the mapping from taxes and outcomes to adjusted fundamentals that we described in the previous section becomes independent of outcomes; i.e., it becomes an exogenous function of taxes. Appendix B.4 shows a uniqueness condition from Allen et al. (2014) applied to this restricted model. The condition is satisfied by the parameter values estimated in Section 6, under which we compute the counterfactual results presented in Section 7.[50]

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

In this section, we characterize analytically how eliminating dispersion in tax rates while maintaining government spending constant in every state impacts two aggregate outcomes: worker welfare v, as defined in (9), and the aggregate real income of all factors, as defined in (A.14) in Appendix B.2. v is a measure of welfare for the representative U.S. worker, while aggregate real income encompasses the combined real consumption of workers and capital-owners in addition to real government expenditures. For this analytical characterization, we restrict ourselves to a simpler version of the model presented in Section 4.

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

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

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[49]The presence of immobile factors of production act as a congestion force in the sense that they lead to dispersion of economic activity across regions. Immobile workers is the source of dispersion in the seminal economic-geography model of Krugman (1991).

[50]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 numerically computing the impact of counterfactual distribution of taxes on the equilibrium of our model, we experiment with different starting values of our algorithm and always find the same results, suggesting that the system of equations we employ to compute such equilibrium indeed has a unique solution.

and

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

eliminating the dispersion in $\{T_n\}$ while keeping constant both its mean and the government spending in every state:

i) increases worker welfare if $corr(Z_n^\zeta, (1 - T_n)^\zeta)$ is low enough, and decreases it if it is large enough;

ii) increases worker welfare if $\zeta < 1$ and $corr(Z_n^\zeta, (1 - T_n)^\zeta) \leq 0$, and decreases it if $\zeta > 1$ and $corr(Z_n^\zeta, (1 - T_n)^\zeta) \geq 0$;

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

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

A key implication of this proposition is that the model described in Section 4 includes forces pushing aggregate outcomes in opposite directions in response to a reduction in dispersion in income and sales taxes (entering through T_n) keeping government spending constant. Furthermore, the relative strength of these opposing forces and, therefore, the resulting impact of such a counterfactual change in taxes, depends on the value of parameters such as each states' amenities and productivities, the elasticity of labor mobility, or the degree to which public goods are rival. We discuss in Section 6 the procedure that we follow to estimate these different model parameters.[51]

To grasp the intuition for the results in the proposition, note that worker welfare v, defined in (9), increases with dispersion in the distribution of state-specific "appeal", v_n, defined in (6). This property follows from the discrete-choice nature of the location problem: workers choose the best among many options, implying that higher variance in the appeal of the available options is preferable.[52] Understanding the impact of eliminating dispersion in the worker tax keep-rate T_n on worker welfare then boils down to understanding whether eliminating dispersion in taxes translates to more or less dispersion in the distribution of state appeal, $\{v_n\}$. In equilibrium, that distribution depends on worker tax keep-rates $1 - T_n$ (which directly impact v_n) and fundamentals as captured by the summary measure Z_n (which impact v_n through employment and prices).[53]

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

[52]We note that this property does not rely on the assumption that each worker's preference draws across states are distributed Fréchet. For example, the result also holds in the absence of idiosyncratic draws, so that workers have identical preferences for every state (formally, when $\varepsilon_W \to \infty$).

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

Part i) of the proposition reflects that, when the correlation between worker tax keep-rates and fundamentals is sufficiently large, so is dispersion in state appeal and, as a result, eliminating dispersion in taxes lowers welfare. The opposite happens when the correlation between tax keep-rates and fundamentals is sufficiently low. Part ii) determines what "sufficiently large" and "sufficiently low" exactly means for some particular values of the parameter ζ. Specifically, if $\zeta > 1$ ($\zeta < 1$) eliminating tax dispersion increases (decreases) welfare if the correlation between keep rates and fundamentals is positive (negative).

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

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

and reduces it if $\zeta > 1$. Condition (22) implies that eliminating tax dispersion is likely to increase worker welfare when the parameters α_W, β, and χ_W are large, and when ε_W is small. Specifically, under perfect mobility ($\varepsilon_W \to \infty$) and either no preference for public services or no congestion ($\alpha_W = 0$ or $\chi_W = 0$), eliminating tax dispersion necessarily reduces worker welfare; conversely, for sufficiently low worker mobility ($\varepsilon_W \to 1$) or a sufficiently small labor share ($\beta \to 1$), it necessarily increases it. As above, the intuition for these results follows from the impact that dispersion in tax keep-rates $\{T_n\}$ has on dispersion in state appeals $\{v_n\}$. There are multiple channels through which dispersion in tax keep-rates affect dispersion in state appeals. First, since taxes directly impact state appeal through real consumption, a smaller share of consumption of final goods in preferences naturally tempers the direct gains from tax dispersion. Second, tax dispersion leads to labor-supply dispersion, and the more so the more likely workers are to switch regions (the higher is ε_W). This dispersion in labor-supply affects dispersion in state appeals through two channels. On the one hand, larger congestion in access to public services (higher χ_W) implies that less variation in state appeal results from such an increase in labor-supply dispersion. At the same time, dispersion in labor supply translates into dispersion in wages depending on the curvature of the labor demand: a larger labor share (smaller β) implies that more wage dispersion and, therefore, more dispersion in v_n, results from any given increase in labor supply dispersion.

In order to understand part iii) of the proposition, bear in mind that aggregate real income is maximized when marginal products of labor are equalized across regions. Therefore, eliminating dispersion in worker tax keep-rates will increase or decrease net aggregate real income depending on whether this change in the tax system reduces or increases cross-state dispersion in the marginal product of labor. To gain intuition, consider an even more restricted version of our model with homogeneous workers ($\varepsilon_W \to \infty$) and no congestion in public goods ($\chi_W = 0$). Because workers are homogeneous, in equilibrium they must be indifferent across locations. From (6) this implies $v = u_n G_n^{\alpha_W}((1 - T_n)(MPL_n/P))^{1 - \alpha_W}$ for all n, where we have used that the price index is the same everywhere (and normalized to 1) and that the wage in every state equals the marginal product of labor, $w_n = MPL_n$. Therefore, the marginal product of labor is equalized across all states only if the compensating differentials $u_n G_n^{\alpha_W}(1 - T_n)^{1 - \alpha_W}$, which capture a region's appeal due

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to reasons other than the real wage, do not vary across locations. It is then straightforward to construct examples in which an elimination of tax dispersion reduces output; for example, this result may happen in cases in which there is initially a negative correlation between tax keep-rates and amenities.[54]

Finally, if, as part iv) assumes, we impose homogeneous workers ($\varepsilon_W \to \infty$), no dispersion in amenities ($u_n = u$ for all n), and no preference for public goods ($\alpha_W = 0$), our model becomes formally equivalent to a static version of Restuccia and Rogerson (2008) or to a single-sector version of Hsieh and Klenow (2009) with only labor distortions in either framework.[55] In that case, similarly to these frameworks, eliminating tax dispersion while keeping the mean of taxes constant necessarily increases output, as in this case there is no dispersion in these compensating differentials.[56]

6   Data and Estimation

As discussed in the previous section, removing tax dispersion may increase or decrease worker's welfare and aggregate real income depending on the values of the model's parameters. This section describes how we quantify these model parameters. Section 6.1 describes our data. Section 6.2 discusses the calibration of the production function parameters, state fundamentals, and ownership of capital by state. Section 6.3 discusses the estimation of the elasticities of employment and firm mobility and weights of public goods on preferences and productivity. Section 6.4 shows that the estimated model matches features of data not used in our parametrization.

6.1   Data

We use a variety of data sources to measure different aspects of the U.S. economy. Appendix F provides a full description of our data sources. We use data from the Economic Census to calibrate the technology parameters, state fundamentals and ownership rates. These calibrations, which are described in Section 6.2, require data on employment L_n, wages w_n, total sales, GDP, and total expenditures $P_n Q_n$ that are most recently available for year 2007. Finally, we complement these data with a recently-developed data series by the B.E.A. on Personal Consumption Expenditures as our measure of aggregate consumption by state, $P_n C_n$.

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[54]E.g., let $A_n \equiv u_n G_n^{\alpha_W}$ and $B_n = (1 - T_n)^{1-\alpha_W}$. Consider a case with two states, $n = 1, 2$ and two levels of tax keep-rates, $B_1 = 1/A_1$ and $B_2 = 1/A_2$. In this case, output is maximized because marginal products of labor are equalized across both states in equilibrium ($v^{1/(1-\alpha_W)} = MPL_n$ for $n = 1, 2$). Therefore, in this example, eliminating tax dispersion increases dispersion in marginal products, reducing output. Hopenhayn (2014) studies how the impact of dispersion in firm-specific distortions depends on their correlation with firm productivity.

[55]The states in our context would correspond to firms in these environments, whereas the income tax T_n would impact the allocation similarly to a labor distortion in these environments.

[56]Note that, through the worker's indifference condition across locations, the definition of worker's welfare v in this case becomes the same as the after-tax real wage, i.e., $v = (1 - T_n)w_n$ for all n. Letting $L_n^*(w_n)$ be labor demand, labor-market clearing then implies $\sum_n L_n^*(v/(1 - T_n)) = 1$. If $L_n^*(1/x)$ is convex in x, then an increase in the dispersion of $1 - T_n$ raises the after-tax real wage, v. Under Cobb-Douglas, $L_n^*(1/x) \propto x^{1/\beta}$ is convex in x. More generally, the convexity of labor demand depends on the third derivative of the production function. This implies that, broadly speaking, an elimination of tax dispersion is more likely to lower worker welfare in our quantitative analysis under Cobb-Douglas than under more flexible functional forms, suggesting that the welfare gains from eliminating tax dispersion that we find in the counterfactuals may be conservative.

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.[57] Intermediate-input expenditures, $P_n I_n$, are constructed as the difference between each state's sales and GDP. Total expenditures, $P_n Q_n$, are the sum of personal consumption expenditures, intermediate-goods expenditures, and government expenditures. To construct bilateral sales shares s_{in} and expenditure shares λ_{in}, we use information on bilateral trade flows from the Commodity Flow Survey (CFS) and define own-state sales as the difference between total sales and trade flows to every other state.[58]

We use yearly data from 1980 to 2010 on state-level economic activity to estimate the labor and firm mobility elasticities and the weights of government spending in preferences and firm productivity in Section 6.3. Since data from the Economic Censuses are only available every five years, we rely on the County Business Patterns (CBP) for yearly data on the number of workers and firms.[59] We use data from the Current Population Survey (CPS) to construct an hourly wage measure by state. We use regional price indices from the Bureau of Labor Statistics. As detailed in Appendix F.1, the data on tax rates and total tax revenues are drawn from the Annual Survey of Governments, NBER TAXSIM, the Book of States, and Suárez Serrato and Zidar (2015). We measure state tax revenue as the sum of tax revenue from personal income, corporate income, and sales taxes.

6.2 Calibrated Parameters

Technologies We set the state-specific value-added shares, 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 (A.6), (A.7), and (A.9) match their empirical counterparts for each state in the year 2007.[60] The averages across states of our calibrated parameters are: $N^{-1} \sum_n (1 - \gamma_n) = 0.62$ and $N^{-1} \sum_n (1 - \beta_n) = 0.68$.

Fundamentals The system of equations that characterizes the general equilibrium impact of changes in taxes, described in Appendix B.5, is a function of all fundamentals (endowments of land and structures H_n, productivities z_n, amenities u_n, and trade costs τ_{in}) for every state or pair of states. However, these fundamentals only enter this system of equations through the composite A_{in} defined in (A.36) in Appendix B.3. This feature implies that we do not need to calibrate the value of all fundamentals separately as long as we calibrate the the composite parameter A_{in}.[61] To calibrate this composite, we use the function of expenditure shares, wages, and employment

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

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

[59]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.

[60]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.

[61]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.

described in equation (A.34). As a result, the parametrized model exactly matches the distributions of bilateral expenditure shares, bilateral sales shares, wages, and employment across states in 2007.

Ownership Rates Expression (A.28) 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. We measure these trade imbalances as the ratio of aggregate expenditures to sales.[62]

Other Parameters In our model, the parameter $1 - \sigma$ is the partial elasticity of import shares with respect to bilateral trade costs.[63] A common practice in the international trade literature is to identify this elasticity from variation in tariffs across countries. No tariff applies to the exchange of goods between U.S. states, complicating the estimation of σ in our context. Therefore, we will set its value to 4, which is a central value in the range of estimates in the international trade literature; see Head and Mayer (2014). The final set of parameters that we calibrate are the congestion parameters (χ_W, χ_F). As we show in the next section, these parameters are not separately identified from firm- and labor-mobility elasticities $(\varepsilon_F, \varepsilon_W)$. We remain agnostic on the value of the parameters (χ_W, χ_F) and estimate the remaining parameters and present counterfactuals conditional on χ_W and χ_F taking a range of values in the parameter space.

6.3 Estimated Elasticities

In this section, we describe how we use the model's equilibrium conditions from Section 4 and the data described in Section 6.1 to estimate the parameters governing the dispersion of worker preferences across states, ε_W, the share of public goods in worker preferences, $\{\alpha_{W,n}\}$, the dispersion of firms' productivity across states, ε_F, and the share of public goods in firms' productivity, α_F. As the firm- and worker-level parameters are identified by separate equilibrium conditions, we discuss the estimation and identification of parameter vector $(\varepsilon_W, \{\alpha_{W,n}\})$ separately from the estimation and identification of the parameter vector $(\varepsilon_F, \alpha_F)$. We discuss GMM estimates of these parameters in the following two sections, and provide supplemental (OLS and 2SLS) estimates in Appendix D.3. Importantly, Appendix D.6 shows that our estimates are in line with the previous literature, which rely on alternative identifying assumptions.

Estimation of $(\varepsilon_W, \{\alpha_{W,n}\})$

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

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

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

(17):

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

where $a_{0,n} \equiv \varepsilon_W(1 - \alpha_{W,n})/(1 + \chi_W \varepsilon_W \alpha_{W,n})$ and $a_{1,n} \equiv \varepsilon_W \alpha_{W,n}/(1 + \chi_W \varepsilon_W \alpha_{W,n})$ are functions of structural parameters; $\psi_t^L + \xi_n^L + \nu_{nt}^L \equiv \varepsilon_W/(1 + \chi_W \varepsilon_W \alpha_{W,n}) * (\ln(u_{nt}) - \ln(v_t))$ accounts for year and state effects and deviations from state and year effects in amenities, u_{nt};[64] $\tilde{w}_{nt} \equiv (1 - T_{nt})(w_{nt}/P_{nt})$ is after-tax real wage; and $\tilde{R}_{nt} = R_{nt}/P_{nt}$ is real government spending. The state-specific slopes $a_{0,n}$ and $a_{1,n}$ are functions of the structural parameters ε_W, $\alpha_{W,n}$ and χ_W. Given identification of $a_{0,n}$ and $a_{1,n}$, the preference for government spending is identified as $\alpha_{W,n} = a_{1,n}/(a_{0,n} + a_{1,n})$. However, the parameters ε_W and χ_W are not separately identified from (23); therefore, we present estimates of ε_W conditional on different values of χ_W.

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

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

where $\boldsymbol{\xi}^L$ denotes a set of state fixed effects and $\boldsymbol{\psi}^L$ denotes a set of year fixed effects. This orthogonality restriction assumes that the state-year specific amenity shocks, ν_{nt}^L, are mean independent of the vector of instruments $\boldsymbol{Z}_{nt}^L$. Our model, however, predicts amenities in a state to be negatively correlated with its after-tax real wages and positively correlated with its real government spending. Intuitively, higher amenities in a state attract workers, shift out the labor supply curve, and lower wages. Similarly, an increase in the number of workers raises tax revenue and thus increases government spending. Our model thus predicts that the mean independence assumption in equation (24) will not hold if real wages, $\tilde{w}_{nt}$, or real government spending, $\tilde{R}_{nt}$, are included as elements of the instrument vector $\boldsymbol{Z}_{nt}^L$. To obtain consistent estimates of ε_W and $\{\alpha_{W,n}\}$, we use a vector of "external" state tax rates as instruments.[65] Specifically, our estimator employs a vector of inverse-distance weighted averages of sales, income, and sales-apportioned corporate tax rates in every state other than n as instrument vector $\boldsymbol{Z}_{nt}^L$; i.e., $\boldsymbol{Z}_{nt}^L = (t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$, where

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

Given the estimating equation in (23) and the mean independence restriction in (24), we derive a set of unconditional moment conditions and use a GMM estimator to obtain estimates of ε_W and $\{\alpha_{W,n}\}$. We follow different approaches to use the data available to estimate these parameters. The outcome of these different approaches is reported in Table 1. In Section 7, we explore how sensitive our predictions of the impact of the counterfactual of interest on welfare and aggregate real GDP

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

[65] Our model predicts that a GMM estimator based on using real wages, $\tilde{w}_{nt}$, or real government spending, $\tilde{R}_{nt}$, as instruments will be biased downwards in the case of $a_{0,n}$ and biased upwards in the case of $a_{1,n}$. These biases in $a_{0,n}$ and $a_{1,n}$ would therefore imply an upward bias in the estimate of $\alpha_{W,n}$. Section (D.3) shows that, in fact, Ordinary Least Squares (OLS) estimates of a_0 (a_1) are smaller (larger) than Two-Stage Least Squares (2SLS) estimates that rely on the same vector of instruments $\boldsymbol{Z}_{nt}^L$ that we use to compute our GMM estimates of ε_W, $\{\alpha_{W,n}\}$.

Table 1: GMM Estimates of Worker Parameters

Case	ε_W		α_W	
	$\chi_W = 0$	$\chi_W = 1$	$\chi_W = 0$	$\chi_W = 1$
(1) Estimate α_W	1.39***	2.01***	.22***	.22***
	(.34)	(.76)	(.07)	(.07)
(2) Estimate $\alpha_{W,n} = \alpha_0 + \alpha_1 POL_n$			[.21,.22]	[.21,.23]
(3) $\alpha_{W,n} = \frac{R_n}{GDP_n}$	1.19***	1.33***		
	(.35)	(.45)		
(4) $\alpha_W = .05 = \text{Mean } \frac{R_n}{GDP_n}$	1.09***	1.15***		
	(.31)	(.35)		
(5) $\alpha_W = 0$	.93***	.93***		
	(.28)	(.28)		

NOTES: This table shows the GMM estimates for structural parameters entering the labor mobility equation. The dependent variable is log state employment, $\ln L_{nt}$. The data are at the state-year level. Each column has 712 observations. Real variables after-tax real wages $\ln \tilde{w}_{nt}$ and real government expenditures $\ln \tilde{R}_{nt}$ are divided by a price index measure from the BLS, which is available for a subset of states that collectively amount to roughly 80 percent of total U.S. population. Every specification includes state and year fixed effects. Row 1 estimates both ε_W and α_W. Row 2 estimates auxiliary parameters α_0 and α_1 given the values of ε_W from Row 1. For $\chi_W = 0$, $\hat{\alpha}_0 = .21^*(.08)$ and $\hat{\alpha}_1 = .0035(.038)$. For $\chi_W = 1$, $\hat{\alpha}_0 = .22^{**}(.06)$ and $\hat{\alpha}_1 = -.0037(.021)$. The table shows the resulting [Min,Max] values across states. Rows 3-5 calibrate α_W as described in the "Case" column. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

are to the estimates generated by these different approaches.

First, we begin by assuming that $\alpha_{W,n} = \alpha_W$, which increases precision by reducing the number of parameters that need to be estimated. In this case, we estimate the parameter vector $(\varepsilon_W, \alpha_W)$ using the set of moment conditions $\mathbb{E}[\nu_{nt}^L * (\mathbf{Z}_{nt}^L, \boldsymbol{\xi}^L, \boldsymbol{\psi}^L)'] = 0$. Conditional on imposing that public goods enjoyed by workers are rival (i.e., $\chi_W = 1$), our estimates of ε_W and α_W equal 2.01 and 0.22, with standard errors 0.76 and 0.07, respectively.

Second, we allow for workers' preferences for public goods to vary by state. We estimate state-specific preferences in two ways. First, we explore whether the political ideology of state voters correlates with workers' preferences for government spending across states. Specifically, we assume that $\alpha_{W,n} = \alpha_0 + \alpha_1 POL_n$, where POL_n is a standardized political index constructed by Ceaser and Saldin (2005) that takes higher values for states with higher Republican party vote shares in national and state elections. We then estimate the parameters α_0 and α_1 using the set of moment conditions $\mathbb{E}[\nu_{nt}^L * (\mathbf{Z}_{nt}^L, \boldsymbol{\xi}^L, \boldsymbol{\psi}^L, POL_n)'] = 0$ and calibrating ε_W to the value in row 1 of Table 1; i.e., $\varepsilon_W = 2.01$. Conditional on $\chi_W = 1$, we estimate $\hat{\alpha}_0 = 0.22$ (0.08) and $\hat{\alpha}_1 = -0.0037$ (0.021), which implies that states with higher Republican party vote shares have smaller preference parameters for government spending. As a second approach to allow for heterogeneous worker preferences for public goods across states, we use the observed ratio of tax revenue to GDP by state to calibrate the workers' preference parameters for public goods. Specifically, we assume that

$\alpha_{W,n} = R_n/GDP_n$, where the state-specific tax revenue to GDP ratio is the state average during the sample period. This approach yields estimates of $\alpha_{W,n}$ between 0.03 and 0.08. Conditional on these calibrated values of the parameter vector $\{\alpha_{W,n}\}$ and $\chi_W = 1$, we use the set of moment conditions $\mathbb{E}[\nu_{nt}^L * (\mathbf{Z}_{nt}^L, \boldsymbol{\xi}^L, \boldsymbol{\psi}^L)'] = 0$ to estimate the parameter ε_W. The resulting estimate of ε_W is 1.33 (0.45).

An important conclusion from the counterfactual results presented in Section 7 below is that, conditional on using the restrictions implied by the equilibrium equation in (23) and the mean independence restriction in (24) to estimate the elasticity of worker mobility, ε_W, the outcomes of our counterfactual of interest are very robust to the particular values taken by the vector of workers' preferences for public goods, $\{\alpha_{W,n}\}$. To make this conclusion transparent, we further re-estimate ε_W under the alternative assumptions that the public services provided by state governments have an impact on workers' utility that equals the cross-state mean of R_n/GDP_n (i.e., $\alpha_{W,n} = 0.05$) or, in the extreme, have no impact on workers' utility (i.e., $\alpha_{W,n} = 0$). Under these assumptions, we obtain estimates of ε_W of 1.15 (0.35) and 0.93 (0.28), respectively.

As the first column in Table 1 shows, imposing the opposite assumption that public goods are non-rival ($\chi_W = 0$) does not affect the value of α_W, and slightly decreases the estimates of ε_W that result from the different estimation approaches described above. Appendix D.3 provides supplemental estimates and discussion.[66]

Estimation of $(\varepsilon_F, \alpha_F)$

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

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

where $b_0 \equiv (\varepsilon_F/(\sigma - 1))/(1 + \chi_F \alpha_F \varepsilon_F)$, $b_1 \equiv -\varepsilon_F/(1 + \chi_F \alpha_F \varepsilon_F)$, and $b_2 \equiv -\alpha_F b_1$; ψ_t^M is a time effect, and $\xi_n^M + \nu_{nt}^M$ accounts for state effects and deviations from state and year effects in log productivity, $\ln(z_{nt})$.[67] Unit costs are given by $c_{nt} = (w_{nt}^{1-\beta_n} r_{nt}^{\beta_n})^{\gamma_n} P_{nt}^{1-\gamma_n}$ and the term MP_{nt} is the market potential of state n in year t,

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

where $E_{n't} \equiv P_{n't} Q_{n't}$ denotes aggregate expenditures in state n'. The market potential of state n is a measure of the market size for a firm located in state n once trade costs with other states

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

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

are taken into account.[68] Details on how we construct measures of all the covariates entering the right-hand side of (27) are contained in Appendix D.1.

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

Conditional on assumed values for χ_F and σ, equation (26) 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. To identify the parameters ε_F and α_F, we rely on moment conditions derived from the following mean independence assumption:

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

where $\boldsymbol{Z}_{nt}^M$ is a vector of instruments, $\boldsymbol{\xi}^M$ denotes a set of state fixed effects, and $\boldsymbol{\psi}^M$ denotes a set of year fixed effects. This orthogonality condition requires the elements of $\boldsymbol{Z}_{nt}^M$ be mean independent of the state-year specific productivity shocks ν_{nt}^M , which invalidates including unit production costs, c_{nt}, real government spending, $\tilde{R}_{nt}$, or market potential, MP_{nt}, as elements of the instrument vector $\boldsymbol{Z}_{nt}^M$. The instrument vector $\boldsymbol{Z}_{nt}^M$ incorporates a vector of inverse-distance weighted averages of sales, income, and sales-apportioned corporate tax rates in every state other than n; i.e., $(t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$ where each of these covariates is constructed as indicated in equation (25). Additionally, the vector $\boldsymbol{Z}_{nt}^M$ also incorporates an exogenous shifter MP_{nt}^* of the market potential term. This exogenous shifter of market potential is constructed similarly to market potential MP_{nt} in (27), but differs from it in that we substitute the variables 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 D.2 presents the precise definition of MP_{nt}^* (see equation (A.61)).

As Table 2 shows, conditional on assuming that public goods enjoyed by firms are rival (i.e., $\chi_F = 1$), our estimates of ε_F and α_F equal 3.15 and 0.05, with standard errors 0.77 and 0.06, respectively. As in Table 1, the second and third rows present estimates in which we calibrate α_F and estimate ε_F subject to the calibrated value of α_F. Specifically, we use two different calibration strategies for α_F. First, similar to the calibration performed on α_W above, we assume that α_F is equal to the cross-state average of tax revenue over GDP; i.e. $\alpha_F = 0.05$. As our baseline estimate of α_F is very close to this value, the impact of this calibration on our estimate of ε_F is minimal regardless of what the value of χ_F is. Second, we impose the extreme assumption that firms' productivity is unaffected by the provision of government services; i.e. $\alpha_F = 0$. In this case, we obtain an estimate of ε_F that is somewhat smaller than the baseline estimate when public goods are rival, $\chi_F = 1$, and almost the same as the baseline estimate when public goods are non-rival, $\chi_F = 0$.

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

Table 2: GMM Estimates of Firm Parameters

Case	$\chi_F = 0$		$\chi_F = 1$	
	ε_F	α_F	ε_F	α_F
Estimate α_F	2.70***	0.05	3.15***	0.05
	(0.33)	(0.06)	(0.77)	(0.06)
$\alpha_F = .05$	2.70***		3.12***	
	(0.61)		(0.45)	
$\alpha_F = 0$	2.67***		2.67***	
	(0.32)		(0.32)	

NOTES: This table shows the GMM estimates for structural parameters entering the firm mobility equation. The dependent variable is log state establishments, $\ln M_{nt}$. The data are at the state-year level. Real variables are after-tax market potential $\ln((1 - \bar{t}_n)(MP_{nt}))$, unit costs c_{nt}, and real government expenditures $\ln \tilde{R}_{nt}$ use a price index measure from the BLS, which is available for a subset of states that collectively amount to roughly 80 percent of total U.S. population. Each column has 609 observations, which is slightly lower than the worker estimation due data requirements for the market potential and unit costs terms (see Appendix D.1 for details). Every specification includes state and year fixed effects. Row 1 estimates both ε_F and α_F. Rows 2-3 calibrate α_F as described in the "Case" column. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

In Section 7, we compute our counterfactual of interest for all the estimates presented in Table 2, and show that the main conclusions of our analysis are robust to both the assumptions imposed on the value of the parameter χ_F and to the different approaches we follow to parametrize ε_F and α_F. Appendix D.4 provides supplemental estimates and discussion.

6.4 Over-Identification Checks

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

First, Panel (a) of Figure A.2 in Appendix D.5 compares the model implications for the share of each state in national GDP against the data in 2007. Model predictions and data line up almost perfectly, which reflects that, in the data, state GDP is roughly proportional to state sales, as our model predicts.[69]

Second, we verify the implications of the estimated model for the share of government revenue in state GDP (see equation (A.29)). 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.

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

Third, panels (c) to (e) of Figure A.2 compare the model-implied shares in total state tax revenue for each type of tax against the the actual shares observed in the data.[70] 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 tax rates and to the model assumption that all companies are C-corporations and, therefore, pay corporate taxes. In robustness checks, we verify how the results change when we use alternative tax rates that account for progressivity of the income tax and adjust state corporate tax rates for the share of C-corporations in each state.

7 Counterfactuals

In this section, we quantify the impact on welfare and aggregate real GDP of varying the dispersion in state tax rates while keeping public spending in every state constant. We consider counterfactual distributions of taxes with little or no dispersion in tax rates, resembling what is observed in countries without regional fiscal autonomy, and counterfactual distributions with larger dispersion in tax rates, resembling what is observed in other fiscally decentralized countries or supra-national entities like the E.U., where observed spatial heterogeneity in tax rates is larger than across states within the U.S.

Sections 7.1 and 7.2 illustrate the forces at work. The subsequent sections present the results of the main counterfactuals.

7.1 Changes in the Location of Workers and Firms in the Counterfactuals

Given that our estimation procedure uses the empirical relationships in (23) and (26) to identify the key model parameters, in any counterfactual we implement, the model predicted changes in the location of employment and firms will be consistent with the observed impacts of tax changes on these two variables in our sample. For example, whenever we use the estimated coefficients from the first row and second column of Table 1 (i.e., α_W estimated and $\chi_W = 1$), the change in employment in state n predicted by the model in response to any change in taxes (either in n or in other states) will be consistent with the estimated relationship

$$\ln\left(\hat{L}_n\right) = 1.09 * \ln\left(\frac{1 - T'_n}{1 - T_{n,2007}}\frac{\hat{w}_n}{\hat{P}_n}\right) + 0.31 * \ln\left(\hat{G}_n\right) - 1.39 * \ln\left(\hat{v}\right). \tag{29}$$

Similarly, whenever we use the estimated coefficients from the first row and second column of Table 2 (i.e., α_F estimated and $\chi_F = 1$), the change in the number of firms in state n predicted by the

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[70]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.

model in response to any change in taxes will be consistent with the estimated relationship

$$\ln\left(\hat{M}_n\right) = 0.89 * \ln\left(\frac{1 - \bar{t}'_n}{1 - \bar{t}_n}\frac{\hat{MP}_n}{\hat{\pi}}\right) - 2.69 * \ln\left(\hat{c}_n\right) + 0.14 * \ln\left(\hat{G}_n\right).$$ (30)

For these values of the parameter vector, workers are about 4 times more responsive to after-tax real wages than to government spending, while firms are about 6 times more responsive to after-tax market potential than to government spending. As (29) and (30) make clear, the changes in the number of workers and firms located in each state caused by a change in state taxes depend on the values of the variables $\hat{w}_n/\hat{P}_n$, $\hat{G}_n$, $\hat{v}$, $\hat{MP}_n/\hat{\pi}$ and $\hat{c}_n$; we compute these changes in factor and final good prices, public goods provision, and market potential using the general-equilibrium structure of the model.

7.2 Single-State Tax Changes

We compute the effect of a 1 percentage point reduction in the income tax rate of each state, one state at a time, while keeping government spending constant in every state, i.e., imposing $\hat{G}_n = 1.$[71] Table 3 reports average percentage changes across the fifty counterfactuals for the variables indicated in column 1; for each variable, column 2 reports average changes for the state enacting the tax change ("Own") and column 3 for the average of the other states ("Rest of the U.S."). Hence, the table can be interpreted as the response to a 1 percentage point reduction in the income tax in the typical U.S. state. To compute the numbers in Table 3, we use the point estimates reported in the first row of Tables 1 and 2.[72]

The first row in Table 3 shows that reducing the income tax rate in up to 1 percentage point in the average state is equivalent to a 1.12% increase in workers' disposable income in that state (the keep-tax rate $1 - T_n$ increases from 74% to 75%).[73] From (21), higher keep-tax rates are similar to higher amenities, generating an increase in the number of workers. On average, the workforce of the state that lowers its income tax by 1 percentage point increases by 0.84%. This increase in labor supply reduces the pre-tax nominal wage. The increased workforce and the reduction in nominal wages make this state more attractive for firms, both through a reduction in labor costs and through an expanded market size; as a result, the number of firms increases by 0.41%. Due to the increase in product variety and the effect of trade costs, the increase in the number of firms in the state lowering taxes in turn reduces the cost of producing the final good by 0.1%. Combined,

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[71]In the counterfactuals in the sections below, government spending is kept constant in every state by implementing a system of cross-state transfers that allows every state to finance the initial level of government spending. Here, we simply keep government spending constant in every state and drop the budget constraint of each state government as a restriction of the model that must be satisfied in the counterfactual equilibrium. Alternatively, each counterfactual reported in this subsection can be thought of as a counterfactual in which we both reduce the income tax rate of one state in 1 percentage point and simultaneously change the efficiency of all state governments in providing public services so that state governments bound by their budget constraint are still able to provide the same level of public services observed in the initial scenario (i.e., $z_n^{\hat{W}} = (\hat{G}_n)^{-1}$, where the parameter z_n^W is defined in Footnote 30). These two interpretations of the results presented here are equivalent because, from the perspective of individual workers, all that matters for their location and welfare is the product $z_n^{\hat{W}}\hat{G}_n$.

[72]I.e., we assume $\{\varepsilon_W, \varepsilon_F, \alpha_W, \alpha_F, \chi_W, \chi_F\} = \{2.01, 3.15, 0.22, 0.05, 1, 1\}$.

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

the inflow of workers and firms raises real GDP by 0.52%. The inflow of workers increases the congestion in access to public services and, therefore, reduces the government services enjoyed by each worker in the state lowering taxes. However, the after-tax real wages increase compensates for this extra congestion in public services and the appeal of the state lowering income taxes (v_n defined in (6)) ends up raising by 0.44%.

Table 3: Lowering Income Tax in One State

Change in	Own	Rest of U.S.
Keep Rate $(1 - T_n)$	1.12%	0%
Employment	0.84%	-0.02%
(Pre-tax) Nominal Wage	-0.43%	0.01%
Firms	0.41%	-0.01%
Real GDP	0.52%	-0.01%
State Effect (v_n)	0.44%	0.01%

This change in taxes in one state has a heterogeneous impact on other states. To gain intuition about these cross-state effects of changes in taxes, we focus on the reduction in the income tax in one large state, California. Figure A.3 in Appendix E.1 shows the heterogeneous response across states in terms of employment and number of firms. Since government spending is kept fixed, the reduction in the income tax increases employment in California and typically reduces it in every other state. However, this negative employment effect in other states is smaller in those states that trade more with California. In these states, the increase in California's market size implies a larger increase in market potential and a larger reduction in the cost of imported varieties relative to states that trade less with California.

7.3 Implementing Spending-Constant Counterfactuals

In each counterfactual performed in the subsequent sections, we replace the distribution of state taxes in 2007, $\{t^y_{n,2007}, t^c_{n,2007}, t^l_{n,2007}, t^x_{n,2007}\}^N_{n=1}$, with alternative distributions $\left\{ (t^y)', (t^c)', (t^l)', ('t^x) \right\}$ of the form

$$\left(t^j_n \right)' = a^j + b * t^j_{n,2007} \tag{31}$$

for $n = 1, .., N$, $j = y, c, l, x$, and $a^j, b \geq 0$. I..e., we either implement tax-harmonization counterfactuals in which all states have the same tax rates ($b = 0$) or counterfactuals such that the ranking of U.S. states by their original tax rates is the same as the ranking by their counterfactual tax rates, but the dispersion of the state tax distribution can change ($b > 0$).

As we discussed in the introduction, our aim is to isolate the impact of the tax distribution without diving into broader considerations on how government spending is allocated. To do so, we allocate the total tax revenue collected by U.S. states in the counterfactual equilibrium through a system of inter-state transfers such that public spending in every state is kept constant at the initial level and all state government budgets are balanced. Since these inter-state transfers must add up to zero, such transfer system exists if and only if in the counterfactual equilibrium the consolidated

budget constraint of all state governments satisfies

$$\sum_{n=1}^{N} P_n' G_{n,2007} = \sum_{n=1}^{N} R_n' + \left(T_n^{fed \to st} \right)'. \tag{32}$$

Therefore, in every counterfactual tax distribution that we implement, the counterfactual equilibrium is consistent with (32).[74]

For each counterfactual distribution of taxes that we implement, we compute changes in two aggregate measures, worker welfare and aggregate real income. Combining (8) and (9), worker welfare in the counterfactual scenario relative to its initial value is

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

where the change in state n appeal, $\widehat{v}_n$, in our counterfactual depends on the changes in after-tax real wages and population in state n.[75] The change in worker welfare $\widehat{v}$ is an employment-weighted average of the changes in each state's appeal. This measure does not account for the gains or losses accruing to firms and fixed factors. Therefore, as a second measure, we consider the change in the sum of the aggregate real income of workers and owners of firms and fixed factors. Equation (A.14) in Appendix B.2 shows the expression for real GDP in the counterfactual relative to the initial scenario.[76]

7.4   Aggregate Effects of Eliminating Tax Dispersion

Table 4 presents the results from replacing the distribution of state taxes in 2007 with a counterfactual distribution that features no dispersion in sales, corporate, and personal income tax rates across states. The different rows show the predictions of our model when we follow each of the multiple approaches described in Section 6.3 to estimate $\{\alpha_{W,n}\}$, ε_W, α_F, and ε_F. In this section, we present results using estimates computed under the assumption that the public goods enjoyed by firms and workers are both rival ($\chi_W = \chi_F = 1$) and, in Section 7.8, we present analogous results under the assumption that both types of public goods are non-rival ($\chi_W = \chi_F = 0$).

A comparison of the constant-spending results in the third and fourth columns of this table shows that the outcomes are basically invariant to the assumptions on how preferences for public

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[74]Given a value of b, to implement each counterfactual we set a^j for $j = y, c, l, x$ equal to a percentile p of the initial distribution of tax type j such that, at the percentile p, condition (32) is satisfied. Note that p does not vary with j, so that implementing each counterfactual only requires finding the p such that (32) holds.

[75]From (6), $\widehat{v}_n = \left(\frac{1-T_n'}{1-T_{n,2007}} \frac{\widehat{w}_n}{\widehat{P}_n} \right)^{1-\alpha_W} \left(\frac{\widehat{G}_n}{\widehat{L}_n^{\chi_W}} \right)^{\alpha_W}$.

[76]Our welfare analysis is performed under the assumption that the implemented changes in state taxes have no impact on the quantity of the public good provided by the federal government, G^{fed}. In the model, the value of G^{fed} does not affect the allocation of workers or firms. Therefore, if it were to change in reaction to the changes in state taxes in our counterfactual, all model predictions on the distribution of workers and firms, wages, prices, and aggregate real GDP would be identical to those reported here. Only the value of $\widehat{v}$ would be affected by changes in G^{fed}. Generally, predicting how G^{fed} changes in reaction to changes in state taxes requires taking a stand on how changes in the federal government purchases of the final good in every state, $\{G_n^{fed}\}$, translate into changes in G^{fed}. The model in Section 4 is agnostic about this production function of the federal government.

Table 4: Removing Tax Dispersion: Benchmark

Parametrization		Constant Spending		Variable Spending	
$\alpha_{W,n}$	α_F	Welfare	GDP	Welfare	GDP
0.22	0.04	0.15%	0.12%	0.98%	0.92%
$\alpha_0 + \alpha_1 POL_n$	0.04	0.15%	0.12%	0.96%	0.93%
$\frac{R_n}{GDP_n}$	0.04	0.17%	0.12%	0.39%	0.94%
$\frac{R_{n'}}{GDP_{n'}}$ of random $n' \neq n$	0.04	0.17%	0.11%	0.38%	0.95%
0.00	0.00	0.20%	0.10%	0.16%	0.10%
0.22	0.00	0.16%	0.10%	0.48%	-0.05%
0.00	0.04	0.19%	0.11%	0.44%	0.93%

goods vary across states that we impose when estimating the parameters $\left(\varepsilon_W, \{\alpha_{W,n}\}_n, \varepsilon_F, \alpha_F\right)$. Specifically, the first row in Table 4 presents counterfactual results computed using the estimates of $(\varepsilon_W, \alpha_W, \varepsilon_F, \alpha_F)$ that rely on the assumption that preferences for public goods do not vary across states, reported in the first row of Tables 1 and 2. Rows two and three show that similar results are obtained when we use instead estimates that allow for heterogeneity across states in workers' preferences for public goods, no matter whether we measure this heterogeneity as a function of the political preferences of voters in those states or as the observed ratio of tax revenue to GDP in each state. In the fourth row we perform an exercise in which, for each state n, we set $\alpha_{W,n}$ to the value of the ratio $R_{n'}/GDP_{n'}$ for a different state n' randomly chosen; in row five, we adopt the extreme assumption that government spending is valued neither by firms nor by workers;[77] in row six, we only set to zero the parameter α_F and, in row seven, we do the same with the parameter vector $\{\alpha_{W,n}\}$.

Therefore, regardless of which parametrization we impose, the welfare and real output gains from a tax harmonization that keeps public spending constant in every state are always close to 0.2% and 0.1%, respectively. We note that these taxes account for 4% of U.S. GDP. We also note that, on net, 0.1% of the workforce is reallocated in the counterfactual.

The robustness of our model predictions for the spending-constant counterfactual to the different approaches to parametrize $\{\alpha_{W,n}\}$ and α_F may seem in contradiction with the discussion in Section 5, where we show that the value of these parameters matters for whether tax dispersion has a positive or a negative impact on welfare in a simpler version of our model. However, one should not interpret Table 4 as implying that the results for the spending-constant counterfactual are invariant no matter what is assumed about $\{\alpha_{W,n}\}$ and α_F. Instead, the right interpretation is that the values of these parameters have minimal impact once all the other parameters are consistent with the observed data and the estimating equations (23) and (26).

In contrast, the results reported in the columns labeled "variable spending" illustrate that the aggregate consequences of eliminating tax dispersion without imposing a cross-state transfer system are more sensitive to different parametrizations of $\{\alpha_{W,n}\}$ and α_F. In the "variable spending" counterfactuals, changes in taxes lead to changes in the distribution of government spending. When

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[77]This is an extreme case since, as we discuss in Appendix D.6, the evidence in the literature points towards the existence of a positive effect of government spending on preferences and productivity.

government spending can change, different assumptions described in Section 6.3 under which we estimate $\{\alpha_{W,n}\}$ and α_F lead to worker welfare gains that vary between 0.16% and 1%. This result highlights that assumptions on the distribution of preferences for government spending can be important. However, in our main spending-constant counterfactuals of interest, assumptions on the distribution of preferences for government spending across states do not materially affect our results.[78]

7.5 Varying Tax Dispersion

The results reported in the previous section show that there are aggregate welfare and real GDP gains from eliminating the observed dispersion in tax rates across U.S. states. In this section, we study the welfare effects of implementing counterfactual distributions of taxes that partially reduce or increase the observed dispersion in taxes.

Figure 2 shows the impact on welfare of switching from the currently observed distribution of taxes to counterfactual distributions in which, for each type of tax, the standard deviation of tax rates across states is modified in the quantity indicated in the horizontal axis. The counterfactual change in taxes discussed in Section 7.4, in which we eliminate tax dispersion, corresponds to the leftmost point in spending-constant line of the figure. The figure is constructed using the same parametrization employed to compute the results in the first row of Table 4.

The main implication of Figure 2 is that welfare is maximized when tax dispersion is eliminated. This result implies that, among all the distributions of tax rates that preserve the current ranking of taxes across the U.S. states while also ensuring that the current level of government spending is feasible through cross-state transfers (i.e., among all the distributions of the form $\left(t_n^j\right)' = a^j + b * t_{n,2007}^j$ for $j = y, c, l, x$ satisfying the constraint (32)), eliminating tax dispersion maximizes worker welfare in our model.[79]

The second implication of the figure is that increasing the dispersion in taxes beyond what is currently observed in the US could generate potentially large welfare losses. Moving from the current scenario to one with twice as much dispersion as what is currently observed would reduce welfare by 0.4% keeping government spending constant, and by 1.2% if states' government spending change as their tax revenue change.

These results suggest that, in environments in which the observed spatial dispersion in taxes is much larger than in the US (e.g., Switzerland, the European Union), the welfare gains from eliminating such dispersion in taxes may be large. However, as the theoretical discussion in Section

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[78]We can also see that both welfare and real GDP gains are generally larger when, for the same counterfactual distribution of taxes, the system of transfers is not implemented and government spending is forced to change in reaction to the changes in tax revenue by state. The intuition for this difference follows from a similar logic to what we discussed in the context of the simple model introduced in Section 5. Once government spending is allowed to change, whether welfare and GDP changes are larger or smaller depends on how the implied changes in spending impact the distribution of state appeals v_n and the marginal product of labor, respectively.

[79]Computing the optimal level of taxes across all states would require allowing for changes in the ranking of taxes across U.S. states. Specifically, it would require allowing for constants $\{a_n^j\}_{j=y,c,l,x}$ that are state-specific. This optimization problem is much more numerically challenging that what we are currently implementing, as it would involve an optimization over 196 control variables (4 tax rates for each of the 49 states considered in the analysis).

5 indicates and the following section shows empirically, the exact welfare impact of eliminating tax dispersion in these other settings would also depend on the correlation between the different regional entities' fundamentals and their initial level of taxes.

Figure 2: Welfare Effects of Changes in Tax Dispersion
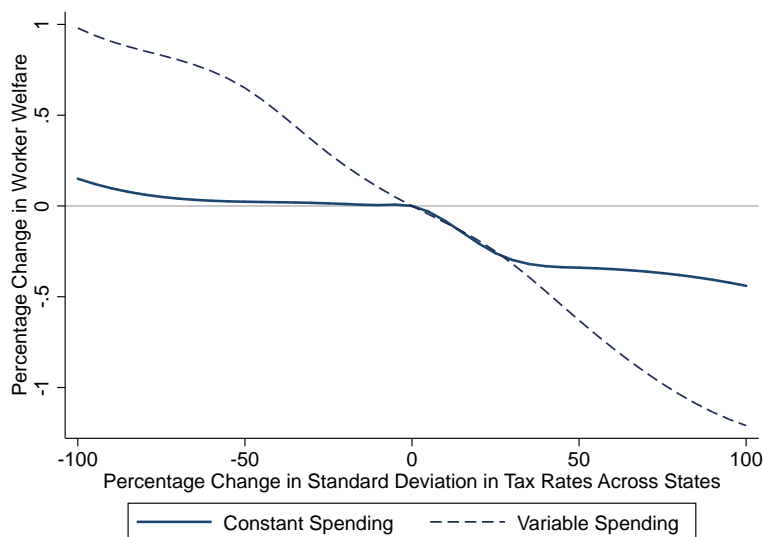
7.6 Alternative Distributions of Fundamentals

As the discussion in Section 5 suggests, the welfare and real GDP impact of eliminating dispersion in state taxes while keeping government spending constant depends on the joint distribution of initial state taxes and state fundamentals (such as state amenities and productivity). In this section, we demonstrate empirically the importance of measuring correctly these fundamentals, and we emphasize that the effects of eliminating tax dispersion across regions might be both qualitatively and quantitatively different in other countries.

Table 5 shows the results from eliminating tax dispersion in scenarios where wages, income, and trade flows across states are the same as those observed in 2007 but we reassign the data on employment shares across states. As discussed in Section 6.2, state fundamentals impact the system of equations used to compute the effect of counterfactual changes in taxes through a composite (analogous to the composite Z_n in the simpler model discussed in Section 5) that can be measured using information on the observed number of workers, wages, income, and trade flows across states. Therefore, exploring the effect of eliminating tax dispersion in a context in which the state fundamentals are different than those currently observed in the U.S. is equivalent to doing so in a setting in which the distribution of these variables is different.

As we increase the cross-state correlation between initial worker keep-tax rates and the total number of workers, the welfare effect of eliminating tax dispersion while keeping the provision of public goods in every state constant decreases. This relationship is consistent with the proposition

in Section 5.[80]   Therefore, through the lens of the simple model in Section 5, we can interpret the results in Table 5 as indicating that eliminating tax dispersion is more beneficial in contexts with a lower correlation between initial keep-tax rates and state fundamentals such as amenities or productivity.[81]   Therefore, whether a harmonized tax system that keeps government spending constant is superior to an observed spatial tax distribution depends on the specific country in question.

Table 5: Spending Constant Counterfactual under Alternative Distribution of Fundamentals

Case	Welfare	GDP
$RankCorr(1 - T_n, L_n) = -1$	0.42%	-0.14%
Benchmark	0.15%	0.12%
$RankCorr(1 - T_n, L_n) = 1$	-1.07%	0.64%

7.7 Progressive Income Taxes

The results reported in all previous sections approximate state and federal income tax schedules through a flat tax rate, set equal to the average effective tax rate from NBER TAXSIM. In practice, both the federal government and most states have progressive income tax schedules. In this section, we explore how our counterfactual results vary if we account for the progressivity of income taxes. Specifically, we implement two changes with respect to our benchmark: we take into account the progressivity in state and federal income taxes when defining the income tax rate applied to workers, and we allow the income tax rate on capital owners to differ from that on workers.[82]

In order to approximate the progressive state income tax schedules, we use data from NBER TAXSIM on average effective income tax rates by state, year, and income group and estimate the state-specific linear function of income that best fits the actual relationship between income and average tax rates in each state in 2007. Using the estimates $\{\hat{a}_n, \hat{b}_n\}_{n=1}^N$, we construct the income tax rate that workers in state n must pay if their wage were w as $t_n^{y,prog}(w) = \hat{a}_n + \hat{b}_n w$. Following the same procedure, we construct a federal income tax rate $t_{fed}^{y,prog}(w) = \hat{a}_{fed} + \hat{b}_{fed} w$.[83]   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 tax schedule in state n imposes (i.e., the income tax rate for the highest income bracket).[84]

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[80]In the context of the simple model described in that section, lower correlation between worker shares and worker keep-tax rates implies lower correlation between the function Z_n (which is increasing in productivity and in the supply of the immobile factor) and worker keep-tax rates.

[81]As mentioned above, the intuition for this result is that worker welfare is increasing in the dispersion of state-specific appeals $\{v_n\}$ and an elimination of tax dispersion increases dispersion in these state-specific appeals when initial states' worker tax rates are positively correlated with states' productivity, supply of the immobile factor or amenities.

[82]Albouy (2009) studies how federal tax progressivity impacts the allocation of workers across U.S. cities.

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

[84]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

Table 6: Removing Tax Dispersion under Progressive Income Taxes

$\alpha_{W,n}$	α_F	Welfare	GDP
A. State Progressive Only			
0.22	0.04	0.37%	0.11%
0.00	0.00	0.49%	0.10%
$\frac{R_n}{GDP_n}$	0.04	0.45%	0.11%
B. State and Federal Progressive			
0.22	0.04	0.42%	0.11%
0.00	0.00	0.55%	0.10%
$\frac{R_n}{GDP_n}$	0.04	0.51%	0.11%

The introduction of progressive tax schedules in our model allows state income tax rates to change as a result of changes in states' nominal wages. Specifically, accounting for progressive tax schedules implies that the observed heterogeneity in wages in 2007 translates into an implied dispersion in income tax rates across states that is larger than the dispersion implied by the flat income rates used in Section 7.4.

Table 6 reports the results for our spending-constant tax harmonization counterfactual. We bring the constant and slope of the state progressive tax income schedule in every state to the same values (and simultaneously eliminate dispersion in sales and corporate taxes) while keeping government spending constant in every state through inter-state transfers. Notice that, even though all income tax schedules are identical in the counterfactual, dispersion in nominal wages generates dispersion in the effective tax rate workers face in different states. In Panel A, the only departure from the benchmark model used to compute the results in Section 7.4 is progressivity in state income taxes; in Panel B, we allow for progressivity in both federal and state income taxes. The impact of eliminating tax dispersion on welfare is approximately three times larger than in our benchmark, which is consistent with the increased initial dispersion across states implied by the introduction of progressive tax schedules. Once we account for progressivity in state income tax schedules, additionally accounting for progressive federal income taxes has a relatively small effect.

7.8 Robustness

Alternative Definitions of Corporate Taxes

Table A.8 in Appendix E.2 reports the results of the spending constant counterfactuals where we eliminate dispersion in state taxes under two alternative ways of measuring corporate tax rates. First, we account for the fact that some states grant firms reductions in their corporate tax liabilities. These subsidies modify the effective corporate tax rate that firms face. To account for these subsidies, we scale down the statutory corporate tax rate, used in our benchmark analysis, by the ratio of corporate tax revenue net of subsidies to total corporate tax revenue in each state.[85] We find that this adjustment reduces the welfare effect of eliminating dispersion in state tax rates

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in the top-1%.

[85] We use data from the *New York Times* subsidy database. See Appendix F.1 for details.

slightly. The reason for the smaller impact of tax harmonization when accounting for subsidies is that subsidy-adjusted rates are less disperse. The lower dispersion in the initial tax distribution implies that the gains from tax harmonization are also smaller.

Second, in our benchmark model, all firms pay state corporate taxes on their profits and, additionally, firm owners pay income taxes on after-tax profits, matching the actual tax treatment of 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.[86] To account for the fact that not all firms are C-corporations, we scale down the statutory corporate tax rate used in our benchmark analysis by the share of establishments registered as C-corporations in each state in 2010 relative to the total number of establishments in that state.[87] This adjustment reduces the welfare and real-income effects of misallocation. The reason for the smaller impact of tax harmonization is analogous to that indicated above when discussing the impact of adjusting for subsidies: once we adjust for the share of C-corps, the dispersion in the corporate rates in the initial scenario is significantly smaller than in the benchmark and, therefore, this initial scenario is closer to the counterfactual scenario of complete tax harmonization.

Varying Congestion

Our benchmark parametrization assumes that the parameters χ_W and χ_F, which determine congestion in access to public services, equal one. These parameters govern the intensity of one source of agglomeration in the model: if χ_W and χ_F are smaller than one, the increase in the provision of public services caused by an increase in the number of workers or firms in a state translates into an increase in amenity and firm productivity, attracting additional workers and firms. Table A.9 in Appendix E.2 reports the results for χ_W and χ_F equal to zero. For each of these cases, we re-estimate the parameters ε_W, α_W, ε_F, and α_F under the same exogeneity assumptions discussed in Section 6.3.[88] The results are extremely similar to those obtained under the assumption that public goods enjoyed by firms and workers are rival.

State Tax Rates Adjusted for Local Taxes and Property Taxes

Given our focus on the spatial misallocation caused by state taxes, our benchmark analysis does not include local taxes. However, to account for the possibility that dispersion in effective state plus local tax rates may differ from the observed dispersion in state rates, we compute here adjusted tax rates that account for average local tax rates within each state. Specifically, we scale our baseline

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[86]Consistent with the taxation of S-corporations and partnerships, capital owners of pass-throughs pay personal income taxes on income generated by pass-through entities.

[87]Data on the share of establishments registered as C-corporations by state is obtained from the County Business Patterns. An alternative would be to adjust corporate tax rates by the share of employment in C-corporations in each state. C-corporations are on average much larger than S-corporations; adjusting by employment instead of by establishment count would therefore yield adjusted corporate tax rates that are closer to those employed in Section 7.4.

[88]See Table 1 for the estimates.

income, sales, and corporate tax rates by the ratio of state plus local to state tax revenue.[89] While property taxes are a minimal source of tax revenue for states, they are key for local entities; therefore, we also include consolidated local and property taxes in this version of the model, and model them as a tax on the return of the fixed factor in each state.[90] In this counterfactual, we interpret the budget constraint of each state government as the consolidated budget constraint of that state government and all local governments located in the same state. Table A.10 in Appendix E.2 shows that the results are similar to the baseline ones. The reason why the results are so similar is that the bulk of local taxes is accounted for by property taxes and, therefore, accounting for local taxes has a very small impact on the measures state income, corporate, and sales taxes. Within our framework, property taxes apply to a fixed factor and, therefore, they do not impact the allocation of workers other than through the government's budget constraint.[91]

8   Conclusion

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

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

We find that, in the U.S., tax dispersion leads to aggregate losses. Keeping government spending constant through a system of cross-state transfers, eliminating tax dispersion would increase real GDP and worker welfare by around 0.2% (relative to a 4% share of state taxes in GDP); when accounting for progressivity of state income taxes, this same elimination in dispersion leads to worker welfare gains that are twice as large.

We also find that the potential losses from greater tax dispersion can be sizable: moving from the current scenario to one in which state tax dispersion is twice as large would reduce worker welfare by 0.4%. Moreover, eliminating tax dispersion maximizes worker welfare among all of the

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[89]For example, if sales tax revenue at the local level were 20% of state plus local sales tax revenue in any given state, our resulting measure of the sales tax rate for that state would be 1.2 times the statutory state sales tax rate.

[90]I.e., we assume that owners of land of state n receive $(1 - \tau_n^H)r_n H_n$ before paying income taxes. We follow Cabral and Hoxby (2015) by measuring property taxes as the ratio of reported property taxes and property values in the CPS. We use state-level averages of this ratio by state in 2007 to compute τ_n^H.

[91]As discussed in footnote 29, in a framework in which housing supply elasticities vary across states, property taxes will have an additional effect on the allocation by altering the supply of housing. Heterogeneity in housing supply elasticities may be included in our analysis subject to the caveats discussed in that footnote.

distributions of tax rates that modify the overall spatial dispersion in taxes while preserving the current tax-rate ranking of U.S. However, we also find that the effects on worker welfare from a spending-constant tax harmonization are decreasing with the correlation between initial worker keep-tax rates and state amenities or productivity. Therefore, whether, keeping spending constant, a harmonized tax system is superior to an observed spatial tax distribution depends on the specific country in question.

The framework and estimation approach we introduce could be combined with data from European countries to inform ongoing debates concerning cross-country tax harmonization within the European Union, or with data from other countries featuring large tax dispersion across sub-national entities (e.g. Switzerland) to study the impact of tax dispersion in those contexts. It could also be used to study quantitatively other related questions, such as how the state tax structure affects states' responses to state- or aggregate-level shocks (e.g., productivity shocks), what the advantages and disadvantages of corporate-, sales-, or income-based tax systems are, or what the optimal state tax distribution is. Our framework could also be extended with multiple worker types to quantitatively address questions related to the distributional impacts of alternative tax schemes. We leave these questions for future research.

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A   Appendix to Section 3 (Background)
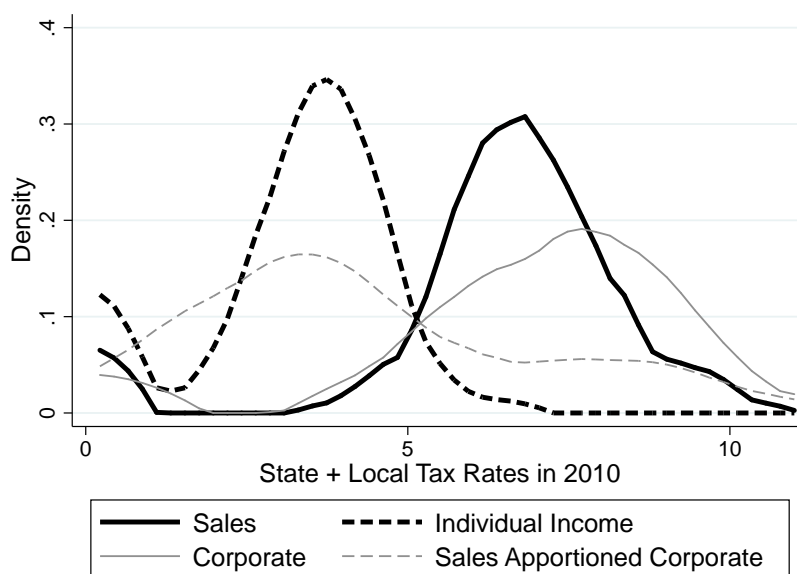
Figure A.1: Dispersion in State + Local Tax Rates in 2010

Table A.1: Federal Tax Rates from 2007

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

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

Table A.2: State Tax Rates from 2007

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

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

B   Appendix to Section 4 (Model)

B.1   Firm Maximization

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

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

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

$$\frac{\partial \tilde{\pi}_i^j}{\partial q_{ni}^j} = \frac{\sigma - 1}{\sigma} E_n^{1/\sigma} P_n^{1-1/\sigma} \left(q_{ni}^j\right)^{-1/\sigma} - c_i \frac{\tau_{ni}}{z_i^j},$$

$$\frac{\partial \bar{t}_i^j}{\partial q_{ni}^j} = \frac{\sigma - 1}{\sigma} \left(t_n^x - \sum_{n'} t_{n'}^x s_{n'i}^j\right) \frac{p_{ni}^j}{x_i^j}.$$

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

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

where

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

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

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

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

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

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

B.2   Additional State-Level Variables

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

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

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

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

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

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

After-tax profits therefore are:

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

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

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

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

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

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

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

Aggregate real GDP is defined as the aggregate state GDP's deflated using the price index of the final good,

$$GDP^{real} = \sum_n \frac{GDP_n}{P_n} \tag{A.13}$$

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

$$\widehat{GDP}^{real} = \sum_n \frac{\frac{\gamma_n(\sigma-1)+1}{(1-\beta_n)\gamma_n(\sigma-1)} \frac{w_n L_n}{P_n}}{\sum_{n'} \frac{\gamma_{n'}(\sigma-1)+1}{\left(1-\beta_{n'}\right)\gamma_{n'}(\sigma-1)} \frac{w_{n'} L_{n'}}{P_{n'}}} \frac{\widehat{w_n L_n}}{\widehat{P_n}}. \tag{A.14}$$

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

$$P_n C_n = P_n C_n^W + \frac{\left(1 - t_{fed}^y\right)\left(1 - t_n^y\right)}{1 + t_n^c} b_n \left(\Pi + R\right). \tag{A.15}$$

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:

$$\widehat{C^W} = \sum_n \left(\frac{\left(1 - T_n\right)\frac{w_n L_n}{P_n}}{\sum_{n'}\left(1 - T_{n'}\right)\frac{w_{n'} L_{n'}}{P_{n'}}}\right) \hat{C}_n^W. \tag{A.16}$$

$$\widehat{C^K} = \sum_n \left(\frac{\frac{1-t_n^y}{1+t_n^c}\frac{b_n}{P_n}}{\sum_{n'}\frac{1-t_n^y}{1+t_n^c}\frac{b_{n'}}{P_{n'}}}\right) \hat{C}_n^K. \tag{A.17}$$

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

$$R_n^{corp} = t_n^x \sum_{n'} s_{nn'}\tilde{\Pi}_{n'} + t_n^l \tilde{\Pi}_n, \tag{A.18}$$

$$R_n^y = t_n^y(1 - t_{fed}^y)\left[w_n L_n + b_n\left(\Pi + R\right)\right], \tag{A.19}$$

$$R_n^c = t_n^c P_n C_n. \tag{A.20}$$

The base for corporate tax profits are the pre-tax profits from every state, defined in (A.9), adjusted by the proper apportionment weights. Equation (A.19) shows that the base for state income taxes is the income of both workers and capital-owners who reside in n net of federal income taxes; in that expression, $\Pi = \sum_i \Pi_i$ and $R = \sum_i r_i H_i$ are national after-tax profits and returns to land and structures, respectively. The base for the sales tax in (A.20) is the total personal consumption expenditure of workers and capital owners, $P_n C_n$ defined in Equation (A.15).

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

$$T_{n,fed} = \left(t^y_{fed} + t^w_{fed}\right) w_n L_n + b_n t^y_{fed}\left(\Pi + R\right) + b_n t^{corp}_{fed}\sum_{n'}\tilde{\Pi}_{n'}. \tag{A.21}$$

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

Trade Imbalances   Three reasons give rise to differences between aggregate expenditures $P_n Q_n$ and sales X_n of state n, and therefore create trade imbalances. First, differences in the ownership rates b_n lead to differences between the gross domestic product of state n, GDP_n, and the gross income of residents of state n, GSI_n. Second, differences in ownership rates b_n and in sales-apportioned corporate taxes t^x_n across states create differences between the corporate tax revenue raised by state n's government (R^{corp}_n) and the corporate taxes paid by residents of state n (TP^{corp}_n). Third, there may be differences between taxes paid by residents of state n to the federal government ($T_{n,fed}$) and the expenditures made by the federal government in state n in either transfers to the state government in n ($T^{fed\to st}_n$) or purchases of the final good produced in state n ($G_{n,fed}$). As a result, the trade imbalance in state n, defined as difference between expenditures and sales in that state, can be written as follows:[92]

$$P_n Q_n - X_n = (GSI_n - GDP_n) + (R^{corp}_n - TP^{corp}_n) + \left(P_n G_{n,fed} + T^{fed\to st}_n - T_{n,fed}\right). \tag{A.22}$$

Letting $R = \sum_n r_n H_n$ and $\tilde{\Pi} = \sum_n \tilde{\Pi}_n$ be the pre-tax returns to the national portfolio of fixed factors and firms , we can rewrite some of the components of (A.22) as follows:[93]

$$GSI_n = b_n\left(\tilde{\Pi} + R\right) + w_n L_n, \tag{A.23}$$

$$R^{corp}_n = \frac{1}{\sigma}\left(t^x_n P_n Q_n + t^l_n X_n\right), \tag{A.24}$$

$$TP^{corp}_n = b_n\sum_{n'}\left(\bar{t}_{n'} - t^{corp}_{fed}\right)\tilde{\Pi}_{n'}. \tag{A.25}$$

Replacing (A.12) and (A.23) to (A.25) into (A.22), and using (A.7) and (A.9) to express labor payments and pre-tax profits as function of sales, we obtain:

$$\frac{P_n Q_n}{X_n} = \frac{1}{\sigma - t^x_n}\left((\sigma - 1)(1 - \beta_n\gamma_n) + t^l_n + \frac{P_n G_{n,fed} + T^{fed\to st}_n - T_{n,fed}}{\tilde{\Pi}_n} + \frac{b_n}{\tilde{\Pi}_n / \left(\Pi + R + t^{corp}_{fed}\tilde{\Pi}\right)}\right), \tag{A.26}$$

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[92]To reach this relationship, first impose goods market clearing (5) to obtain $P_n Q_n = P_n\left(C_n + G_{n,fed} + G_n + I_n\right)$. Then, note that personal-consumption expenditures can be written as $P_n C_n = GSI_n - (R^y_n + R^c_n + TP^{corp}_n) - T_{n,fed}$, where the terms between parentheses are tax payments made by residents of state n to state governments and $T_{n,fed}$ are taxes paid to the federal government. Combining these two expressions and using the state's government budget constraint (17) gives $P_n Q_n = (GDP_n + P_n I_n) + (GSI_n - GDP_n) + (R^{corp}_n - TP^{corp}_n) + \left(P_n G_{n,fed} + T^{fed\to st}_n - T_{n,fed}\right)$. Adding and subtracting GDP_n and noting that by definition $GDP_n = X_n - P_n I_n$ gives (A.22).

[93](A.23) and (A.25) are by definition. For (A.24), combine (A.18) with (A.32) and (A.9).

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

$$\frac{\tilde{\Pi}_n}{\Pi + R + t_{fed}^{corp}\tilde{\Pi}} = \frac{X_n}{\sum_i \left(1 - t_n^l - \bar{t}_n + \beta_i \gamma_i \left(\sigma - 1\right)\right) X_i}. \tag{A.27}$$

Expression (A.26) 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:[94]

$$b_n = \frac{\tilde{\Pi}_n}{\Pi + R + t_{fed}^{corp}\tilde{\Pi}} \left[\left(\sigma - t_n^x\right)\left(\frac{P_n Q_n}{X_n}\right) - \left(\sigma - 1\right)\left(1 - \beta_n \gamma_n\right) - t_n^l\right]. \tag{A.28}$$

Share of State Taxes and Spending in GDP Replacing $P_n C_n$ from (A.15), R_n^y from (A.19), and R_n^{corp} from (A.24) into the government budget constraint (A.21), and then normalizing by GDP using (A.12), we reach

$$\frac{R_n}{GDP_n} = \frac{t_n^x \frac{P_n Q_n}{X_n} + t_n^l + \left(1 - t_{fed}^y\right)\frac{t_n^c + t_n^y}{1 + t_n^c}\frac{b_n}{\tilde{\Pi}_n/(\Pi + R)} + \left(\left(1 - t_{fed}^y\right)\frac{t_n^c + t_n^y}{1 + t_n^c} - \frac{t_n^c}{1 + t_n^c}t_{fed}^w\right)\left(1 - \beta_n\right)\gamma_n\left(\sigma - 1\right)}{\gamma_n\left(\sigma - 1\right) + 1}, \tag{A.29}$$

where $P_n Q_n / X_n$ is the share of state expenditure in aggregate sales (i.e., a measure of state trade deficit) derived in (A.26) . The state government budget constraint (17) then implies a share of state spending in GDP:

$$\frac{P_n G_n}{GDP_n} = \left(1 + s_n^{fed \rightarrow st}\right)\frac{R_n}{GDP_n}. \tag{A.30}$$

B.3   General-Equilibrium Conditions

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

$$\sum_n \lambda_{in} = 1 \text{ for all } i. \tag{A.31}$$

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

$$X_i = \sum_n \lambda_{ni} P_n Q_n. \tag{A.32}$$

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

$$\sum_i s_{in} = 1 \text{ for all } n. \tag{A.33}$$

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:

$$\lambda_{in} = A_{in}\left(\frac{w_n}{\bar{\pi}}\right)^{1 - \kappa_1} L_n^{1 - \kappa_{2n}}\left(\frac{w_i}{\bar{\pi}}\right)^{\sigma - 1} L_i^{-\kappa_3}, \tag{A.34}$$

$$s_{in} = \lambda_{in}\frac{P_i Q_i}{X_i}\frac{(w_i/\bar{\pi}) L_i}{(w_n/\bar{\pi}) L_n}\frac{(1 - \beta_n)\gamma_n}{(1 - \beta_i)\gamma_i}, \tag{A.35}$$

where A_{in} is given by

$$A_{in} = \left(\frac{H_n^{\beta_n \gamma_n}\Theta_{1n} z_n^A}{\frac{\sigma}{\sigma - 1}\tau_{in}^A}\frac{\left(\Theta_{2i} u_i^A\right)}{\left(\Theta_{2n} u_n^A\right)^{1 - \gamma_n + \alpha_F}}v^{\alpha_F - \gamma_n}\right)^{\sigma - 1}, \tag{A.36}$$

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

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

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

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

The parameters $\{\kappa_1, \kappa_{2n}, \kappa_3\}$ in (A.34) and (A.35) are given by:

$$\kappa_1 = (\sigma-1)\left(\frac{1}{\varepsilon_F} + \alpha_F \chi_F + 1\right), \tag{A.37}$$

$$\kappa_{2n} = (\sigma-1)\left[\left(\frac{1}{\varepsilon_F} - \alpha_F(1-\chi_F) + \beta_n \gamma_n\right) - (1-\gamma_n+\alpha_F)\left(\frac{1}{\varepsilon_W} - \alpha_W(1-\chi_W)\right)\right], \tag{A.38}$$

$$\kappa_3 = (\sigma-1)\left(\frac{1}{\varepsilon_W} - (1-\chi_W)\alpha_W\right). \tag{A.39}$$

Equations (A.31) to (A.36), together with (9), (A.26), and (A.29) give the solution for import shares $\{\lambda_{in}\}$, export shares $\{s_{in}\}$, employment shares $\{L_n\}$, wages relative to average profits $\{w_n/\bar{\pi}\}$, government sizes $\{P_n G_n/GDP_n\}$, relative trade imbalances $\{P_n Q_n/X_n\}$, and utility v.[95] The endogenous variables not included in this system (e.g., the fraction of firms, M_n) can be recovered using the remaining equilibrium equations of the model.

B.4 Uniqueness

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

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

$$\gamma_n = \overline{A}_n^{\sigma-1} w_n^{1-\kappa_1} L_n^{1-\kappa_2}, \tag{A.40}$$

$$\delta_i = \left(\frac{\overline{u}_i}{\overline{\overline{W}}}\right)^{\sigma-1} w_i^\sigma L_i^{1-\kappa_3}, \tag{A.41}$$

where

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

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

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

Using these definitions and the definition of import shares in (A.34), 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.40) and (A.41) 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.40) and (A.41), and (A.7) allows us to write

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$\bar{\lambda}^{1+a} = \sum_n C_n \gamma_n^d \delta_n^e$, 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.31) to (A.33):

$$\frac{\sigma - (1 - \kappa_3)}{\sigma(1 - \kappa_2) - (1 - \kappa_3)(1 - \kappa_1)} > 1, \tag{A.42}$$

$$\frac{\kappa_1 - \kappa_2}{\sigma(1 - \kappa_2) - (1 - \kappa_3)(1 - \kappa_1)} > 1, \tag{A.43}$$

where κ_1 to κ_3 are defined in (A.37) to (A.39). These steps hold taking as given the value of $\bar{\pi}$; since (the inverse of) $\bar{\pi}$ enters as a proportional shifter of wages, the condition applies to the solution of $\left\{L_n, \frac{w_n}{\bar{\pi}}, v\right\}$.

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 $\{(t_n^y)', (t_n^c)', (t_n^x)', (t_n^l)'\}_{n=1}^N$. As we discussed in section 4.9, implementing counterfactuals in our framework requires simultaneously accounting for a mapping from changes in adjusted fundamentals to changes in outcomes and for a mapping from changes in taxes and in general-equilibrium outcomes to changes in adjusted fundamentals. The first mapping is given by equations (A.44) to (A.49) below, and the second is given by equations (A.50) to (A.52).

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.31) and (A.33) hold:

$$\sum_n \lambda_{in} \hat{\lambda_{in}} = 1 \text{ for all } i, \tag{A.44}$$

$$\sum_i s_{in} \hat{s_{in}} = 1 \text{ for all } n, \tag{A.45}$$

where, using (A.34) and (A.35),

$$\hat{\lambda_{in}} = \hat{A_{in}} \hat{w_n}^{1-\kappa_1} \hat{L_n}^{1-\kappa_{2n}} \hat{w_i}^{\sigma-1} \hat{L_i}^{-\kappa_3}, \tag{A.46}$$

$$\hat{s_{in}} = \hat{\lambda_{in}} \left(\frac{\hat{P_i Q_i}}{X_i}\right) \frac{\hat{w_i} \hat{L_i}}{\hat{w_n} \hat{L_n}}, \tag{A.47}$$

where using (A.36),

$$\hat{A_{in}} \propto \left(\frac{\hat{z_n^A}}{\hat{\tau_{in}^A}} \frac{\hat{u_i^A}}{\left(\hat{u_n^A}\right)^{(1-\gamma_n)+\alpha_F}} \hat{v}^{\alpha_F - \gamma_n}\right)^{\sigma-1}, \tag{A.48}$$

Additionally, labor shares must add up to 1 :

$$\sum_n L_n \hat{L_n} = 1. \tag{A.49}$$

From (19) to (21), the changes in the adjusted fundamentals are

$$\hat{\tau_{in}^A} = \frac{\sigma - \tilde{t}_{in}}{\sigma - (\tilde{t}_{in})'}, \tag{A.50}$$

$$\hat{z_n^A} = \left(\frac{1 - (\bar{t}_n)'}{1 - T_n}\right)^{\frac{1}{\sigma-1} - \left(\frac{1}{\varepsilon_F} + \alpha_F \chi_F\right)} \left(\frac{\hat{P_n G_n}}{GDP_n}\right)^{\alpha_F}, \tag{A.51}$$

$$\hat{u_n^A} = \left(\frac{1 - T_n'}{1 - T_n}\right)^{1-\alpha_W} \left(\frac{\hat{P_n G_n}}{GDP_n}\right)^{\alpha_W}. \tag{A.52}$$

The variables $\left\{\frac{\hat{P_n Q_n}}{X_n}, \frac{\hat{P_n G_n}}{GDP_n}, T_n', (\bar{t}_n)', (\tilde{t}_{in})'\right\}_{n=1}^N$ entering in (A.50) to (A.52) can be expressed as function of the original taxes $\{t_n^y, t_n^c, t_n^x, t_n^l\}_{n=1}^N$, the new tax distribution $\{(t_n^y)', (t_n^c)', (t_n^x)', (t_n^l)'\}_{n=1}^N$, and the new export shares

$\{s\hat{}_{in}s_{in}\}_{n,i=1}^{N}$ using (7), (11), (13), (A.26), and (A.29). Hence, these equations, together with (A.44) to (A.49), give the solution for $\left\{\hat{\lambda}_{in}, \hat{s}_{in}, \hat{L}_n, \hat{w}_n\right\}$ and $\hat{v}$.[96]

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

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

$$\left(\frac{z_n^0}{\gamma_n}\right)^{1/\gamma_n} \left(\frac{H_n}{\beta_n}\right)^{\beta_n} \left(\frac{L_n}{1-\beta_n}\right)^{1-\beta_n}. \tag{A.53}$$

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

$$v_n = u_n \left(\frac{G_n}{L_n^{\chi_W}}\right)^{\alpha_{W,n}} \left((1-T_n)\,w_n\right)^{1-\alpha_{W,n}}. \tag{A.54}$$

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

$$MPL_n = Z_{n,0}L_n^{-\beta_n}, \tag{A.55}$$

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

$$L_n^*(v) = \left(\frac{(Z_n(1-T_n))^{1-\alpha_{W_n}}}{v}\right)^{\frac{1}{1/\varepsilon_W+\alpha_{W,n}\chi_W+\left(1-\alpha_{W,n}\right)\beta_n}} \tag{A.56}$$

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

$$v = \left(\sum (Z_n(1-T_n))^\zeta\right)^{1/\varepsilon_W+\alpha_W\chi_W+(1-\alpha_W)\beta}. \tag{A.57}$$

Let v' be welfare under a distribution of taxes where every tax rate is brought to the mean of the initial distribution, $T_n' = \frac{1}{N}\sum T_n$ for all n. Then, $v' > v$ if

$$E\left[Z_n^\zeta\right](E[1-T_n])^\zeta > cov\left[Z_n^\zeta, (1-T_n)^\zeta\right] + E\left[Z_n^\zeta\right]E\left[(1-T_n)^\zeta\right] \tag{A.58}$$

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

$$\frac{\mathbb{E}\left[1-T_n\right]^\zeta - \mathbb{E}\left[(1-T_n)^\zeta\right]}{sd\left((1-T_n)^\zeta\right)} > cv\left(Z_n^\zeta\right) corr\left[Z_n^\zeta, (1-T_n)^\zeta\right] \tag{A.59}$$

where cv and sd denote the coefficient of variation and the standard deviation. The results of parts i) and ii) follow

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

by inspection of this last equation. Parts iii) and iv) follows from the examples and discussion in Section 5.

D   Appendix to Section 6.3 (Estimated Parameters)

D.1   Construction of Covariates

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

Constructing unit costs also requires data on the price of structures r_{nt}, which is is not available at an annual frequency. Therefore, to construct an annual series of unit costs, we set the local price of structures equal to the local price index, resulting in the following measure of unit costs: $c_{nt} = \left(w_{nt}^{1-\beta_n} P_{nt}^{\beta_n} \right)^{\gamma_n} P_{nt}^{1-\gamma_n}.$[97]

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

We also need information on expenditures $P_{nt}Q_{nt}$ to build MP_{nt}. Since expenditures are not observed in every year, we follow the predictions of the model and construct a proxy for $P_{nt}Q_{nt}$ as a function of state GDP by combining equations (A.7), (A.12), and (A.26) to obtain

$$P_{nt}Q_{nt} = \frac{(\sigma - 1)(1 - \beta_n \gamma_n) + a_{nt} + t_n^l}{\sigma - t_n^x} \frac{\sigma}{\gamma_n (\sigma - 1) + 1} GDP_{nt}, \tag{A.60}$$

where $a_{nt} \equiv \frac{b_n}{\bar{\Pi}_n / \left(\Pi + R + t_{fed}^{corp} \tilde{\Pi} \right)}$. 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.[98]

D.2   Construction of Instrument for Market Potential

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

$$MP_{nt}^* = \sum_{n' \neq n} E_{n't}^* \left(\frac{\tau_{n'nt}}{P_{n't}^*} \frac{\sigma}{\sigma - \tilde{t}_{n'nt}^*} \frac{\sigma}{\sigma - 1} \right)^{1-\sigma}. \tag{A.61}$$

To implement this expression, we need to construct measures of the variables E_{nt}^*, P_{nt}^*, and $\tilde{t}_{n'nt}^*$. We construct E_{nt}^* using (A.60) with lagged GDP instead of period $t's$ GDP.[99] We set $P_{n,t}^* = 1 + t_{n,t}^c$. We construct $\tilde{t}_{n'nt}^*$ using the expression for $\tilde{t}_{ni}$ in (13) evaluated at hypothetical export shares defined as relative inverse log distances: $s_{int}^* = \frac{\ln(dist_{in})^{-1}}{\sum_{i \neq n} \ln(dist_{in})^{-1} + 1} \; \forall t, i \neq n$ and $s_{iit}^* = \frac{1}{\sum_{i \neq n} \ln(dist_{in})^{-1} + 1} \; \forall t$.

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[97] 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.

[98] 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.

[99] 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.61) is independent over time.

D.3 Supplemental: 2SLS Estimates of Worker Parameters

This section presents both OLS and 2SLS estimates the auxiliary parameters a_0 and a_1 in 23. When computing the 2SLS estimator, we rely on the vector of external tax rates $\boldsymbol{Z}_{nt}^L = (t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$ as instruments for after-tax real wages, $\tilde{w}_{nt}$, and real government spending, $\tilde{R}_{nt}$.

As mentioned in the main text, our model predicts that OLS estimates of a_0 and a_1 are asymptotically biased due to the dependence of real wages and government spending on unobserved amenities or government efficiency accounted for in the term ν_{nt}^L. Specifically, our model predicts that amenities in a state are negatively correlated with its after-tax real wages and positively correlated with its real government spending. Intuitively, higher amenities in a state attract workers, shift out the labor supply curve, and lower wages. This increase in the number of workers also 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. Therefore, if the instrument vector $\boldsymbol{Z}_{nt}^L$ were to be valid, we should should obtain 2SLS estimates of a_0 and a_1 that are, respectively, higher and lower than their OLS counterparts.

Table A.3 provides the estimates of the first-stage regression corresponding to the 2SLS estimation of a_0 and a_1. Column (1) shows the estimates of a regression of after-tax real wages on the instrument vector $\boldsymbol{Z}_{nt}^L$ and state and year fixed effects. Column (2) does the same thing for real government services $\tilde{R}_{nt}$. 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 state is "close" to high income tax states. The F-statistics of joint significance of the instruments conditional on state and year fixed effects are 16 in column (1) and 12 in column (2). Additionally, the Cragg-Donald Wald F-statistic is 14.7 and the Kleibergen-Paap Wald F-statistic is 8.7. Therefore, we can conclude that the instruments are strong enough for standard inference procedures to be valid.

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

	$\ln(\tilde{w}_{nt})$	$\ln(\tilde{R}_{nt})$
	(1)	(2)
t_{nt}^{*c}	4.1***	0.8
	(0.6)	(2.0)
t_{nt}^{*y}	1.1*	-8.6***
	(0.6)	(1.5)
t_{nt}^{*x}	-0.3	0.5
	(0.3)	(0.7)
Observations	712	712
F-stat:	15.76	11.86

NOTES: This table shows the first stage estimates for labor supply. The dependent variables are after-tax real wages and real government expenditures in column (1) and (2), respectively. The data are at the state-year level. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total US population. Every specification includes state and year fixed effects. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

Table A.4 presents OLS and 2SLS estimates of a_0 and a_1. 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) shows the 2SLS estimates. Compared to the 2SLS 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 2SLS 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.

Table A.4: OLS and 2SLS Estimates of Local Labor Supply Parameters

	(1) OLS	(2) 2SLS
$\ln(\tilde{w}_{nt})$	0.42***	1.09***
	(0.14)	(0.29)
$\ln \tilde{R}_{nt}$	0.41***	0.30**
	(0.06)	(0.13)
Structural Parameters		
ε_W for $\chi_W = 0$	.84***	1.39***
	(.17)	(.35)
ε_W for $\chi_W = 1$	1.66***	2.01**
	(.24)	(.79)
α_W	.49***	.22***
	(.07)	(.07)

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. The Cragg-Donald Wald F statistic is 14.7 and the Kleibergen-Paap Wald F statistic is 8.7 for the 2SLS specification in column (2). Every specification includes state and year fixed effects. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

D.4 Supplemental: 2SLS Estimates of Firm Parameters

This section presents both OLS and 2SLS estimates of the auxiliary parameters b_0, b_1, and b_2 in (26). When computing the 2SLS estimator, we instrument for after-tax market potential, unit costs, and real government services using the instrument vector of external tax rates $\boldsymbol{Z}_{nt}^M = (t_{nt}^{*c}, t_{nt}^{*x}, t_{nt}^{*y})$ and MP_{nt}^*.

As mentioned in the main text, our model predicts that OLS estimates of b_0, b_1, and b_2 are asymptotically biased due to the dependence of after-tax market potential, costs, and government spending in state n and year t on unobserved productivity or government efficiency in the same state and year, which are accounted for in the term ν_{nt}^M.

Table A.5 provides the estimates of the first-stage regression corresponding to the 2SLS estimation of b_0, b_1, and b_2. The first three columns show how after tax market potential, unit costs, and real government spending relate to the instruments. To mimic the variation used to estimate ε_F in those cases in which we calibrate the value of α_F, we also report first-state estimates for the combinations of after tax market potential, unit costs, and real government spending used to identify ε_F in these cases. Specifically, in the case in which we assume that $\alpha_F = 0.05$, we can write the right hand side of equation (26) as $b_0 \times RHS_{nt}$, where $RHS_{nt} \equiv \ln((1 - \bar{t}_{nt})MP_{nt}) - (\sigma - 1)\ln c_{nt} + 0.05(\sigma - 1)\ln(\tilde{R}_{nt})$, and σ is calibrated to equal 4. Similarly, in the case in which we assume that $\alpha_F = 0$, we can write the right hand side of equation (26) as $b_0 \times RHS_{nt}$, where $RHS_{nt} \equiv \ln((1 - \bar{t}_{nt})MP_{nt}) - (\sigma - 1)\ln c_{nt}$. Columns (4) and (5) report the first stage estimates for RHS_{nt} for these two possible calibrations of the parameter α_F.

Table A.6 presents OLS and 2SLS estimates of b_0, b_1, and b_2. Columns (1)-(3) present OLS estimates and (4)-(6) present 2SLS estimates. Column (1) shows that higher after-tax market potential and real government services tend to attract firms and that higher costs are unattractive. Recall that $(\varepsilon_F, \alpha_F)$ are overidentified, but that the ratio of b_2/b_1 identifies α_F. Intuitively, firm location is $0.55/0.09 = 6.1$ times as responsive to unit costs as to real government

57

Table A.5: First Stage of Firm-Location Equation

	(1) $\ln((1-\bar{t}_{nt})MP_{nt})$	(2) $\ln c_{nt}$	(3) $\ln(\tilde{R}_{nt})$	(4) RHS with $\alpha_F = .05$	(5) RHS with $\alpha_F = 0$
t_{nt}^c	0.46	-1.33***	1.73	4.73***	4.47***
	(1.96)	(0.46)	(1.64)	(1.54)	(1.41)
t_{nt}^y	3.11**	0.13	-1.28	2.54**	2.73**
	(1.57)	(0.41)	(1.50)	(1.11)	(1.07)
t_{nt}^x	2.27**	0.31	-1.04	1.19**	1.35**
	(0.96)	(0.22)	(0.63)	(0.57)	(0.53)
$\ln MP_{n,t}$	2.65***	0.25***	0.88***	2.04***	1.91***
	(0.39)	(0.07)	(0.25)	(0.29)	(0.27)
F-stat:	12.51	7.605	4.685	15.92	17.31

NOTES: This table shows the first stage estimates for firm mobility equation. The dependent variables are after-tax market potential, unit cost, and real government expenditures in columns (1)-(3), respectively. Columns (4) and (5) show two versions of the variable RHS is $\ln((1-\bar{t}_{nt})MP_{nt}) - (\sigma-1)\ln c_{nt} + \alpha_F(\sigma-1)\ln(\tilde{R}_{nt})$. Column (4) shows estimates for the sum of after-tax market potential, $(\sigma-1) = 3$ times unit costs, and $\alpha_F \times (\sigma-1) = .05 \times 3$ times real government expenditures (which results in common coefficients in the model). Similiarly, column (5) is column (4) with $\alpha_F = 0$, so the sum is just of after-tax market potential and 3 times unit costs. 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. Each row has 609 observations. Robust standard errors are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

spending, and $\alpha_F = 1/6.1 = .16$ reflects the inverse of this relative responsiveness. Columns (2) and (3) show the OLS estimate of b_0 in the cases in which we either assume that ε_F is equal to the cross-state average R_n/GDP_n or we set it to 0; the resulting estimate of b_0 is very similar to that in column (1). Our model predicts that these OLS estimates are asymptotically biased estimates of the parameters b_0, b_1, and b_2, the reason being that after-tax market potential, production costs and real government services are likely correlated with unobserved state productivity and government efficiency.

Column (4) in Table A.6 shows that the 2SLS estimates are larger than the OLS estimates for the coefficients on after-tax market potential and real government services and smaller than the corresponding OLS estimate for the coefficient on unit costs. The coefficient on real government services is estimated imprecisely: this shows that the identification of the structural parameters ε_F and α_F in our GMM estimation approach comes mainly from the auxiliary parameters b_0 and b_1. Furthermore, as columns (5) and (6) illustrate, conditional on calibrated values of α_F, the 2SLS estimate of parameter ε_F is estimated with a high degree of precision. Specifically, column (4) shows an estimate of 0.9 for the 2SLS estimate of the parameter b_0 . Given that $b_0 \equiv (\varepsilon_F/(\sigma-1))/(1+\chi_F\alpha_F\varepsilon_F)$, an estimate of 0.9 for b_0 implies that $\hat{\varepsilon}_F = ((\sigma-1)(\hat{b}_0))/(1-\chi_F\alpha_F(\sigma-1)) = (3 \times .9)/(1-.9 \times .05 \times 3) = 3.12$. This estimate of $\hat{\varepsilon}_F = 3.12$ is precise: $\hat{\varepsilon}_F$ is a linear function of $\hat{b}_0$ and the 2SLS standard error on the estimate of b_0 is 0.44. Similarly, the 2SLS estimate of $\hat{\varepsilon}_F$ under the assumption that $\alpha_F = 0$ is also precisely estimated. Moreover, the estimates in columns (4) and (5) are not affected by weak instrument problems. The Cragg-Donald Wald F statistic is 15.97 and the Kleibergen-Paap Wald F statistic is 14.06 for the 2SLS specification in column (4) and 18.5 and 17.0, respectively, for the specification in column (5).
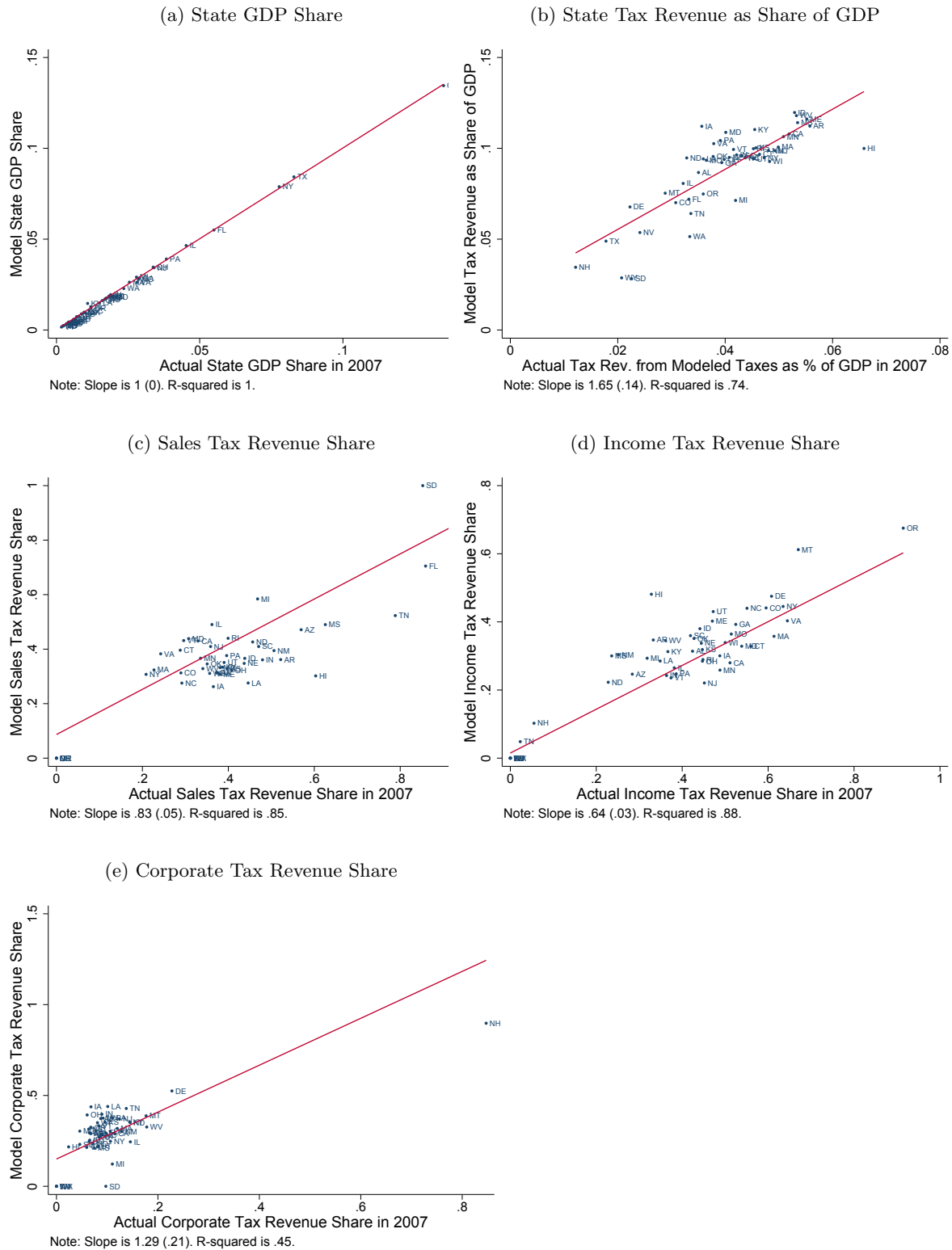
Table A.6: OLS and 2SLS Estimates of Firm-Location Parameters

	OLS			2SLS		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln((1-\bar{t}_{nt})MP_{nt})$	0.41***			0.77		
	(0.06)			(0.58)		
$\ln c_{nt}$	-0.55**			-11.51		
	(0.20)			(19.80)		
$\ln(\tilde{R}_{nt})$	0.09			1.05		
	(0.06)			(2.22)		
RHS with $\alpha_F = .05$		0.38***			0.90***	
		(0.07)			(0.11)	
RHS with $\alpha_F = 0$			0.38***			0.89***
			(0.08)			(0.11)

NOTES: This table shows OLS and 2SLS estimates. The dependent variable in each column is log of the numner of establishments $\ln M_{nt}$. The data are at the state-year level. Each column has 609 observations. The dependent variables are after-tax market potential, unit cost, and real government expenditures. RHS is $\ln((1-\bar{t}_{nt})MP_{nt}) - (\sigma-1)\ln c_{nt} + \alpha_F(\sigma-1)\ln(\tilde{R}_{nt})$. Real variables – 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.

D.5 Appendix Figure to Section 6.4 (Over-Identification Checks)

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

(a) State GDP Share

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

(b) State Tax Revenue as Share of GDP

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

(c) Sales Tax Revenue Share

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

(d) Income Tax Revenue Share

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

(e) Corporate Tax Revenue Share

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

D.6 Comparison with Existing Estimates

Researchers have previously estimated regressions similar to (23) and (26) using sources of variation different from ours to identify the labor and firm mobility elasticities. Table A.7 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 numbers of $\varepsilon_W = 1.39$ ($\chi_W = 0$) and $\varepsilon_W = 2.01$ ($\chi_W = 1$) reported in the first row of Table 1 are 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,[100] while others focus on the productivity effects of large investment projects.[101] However, very few papers estimate specifications similar to (23) and (26). The estimates of the effects of variation in federal spending at the local level from Suárez Serrato and Wingender (2014) imply $\alpha_F = 0.10$ and $\alpha_W = 0.26$.

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

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[100] 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.

[101] 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.7: 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 (23) and (26) found in the previous literature. Whenever needed, we assume the values used in our baseline parametrization of $\sigma = 4$, $\chi_W = 1$, $\chi_F = 1$, and $\alpha_W = 0.17$ in recovering structural parameters. When the effects are only reported separately for skilled and unskilled workers we use a share of skilled workers of 33% to average the effects.

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

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

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

[d]The parameters a_0 and a_1 come from Table 10 in Suárez Serrato and Wingender (2014) by manipulating the structural parameters as follows: $a_0 = 1/\sigma^i$ and $a_0 = \psi^i/\sigma^i$ for each skill group. The parameter b_1 comes from using the effect of spending on firm location 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).
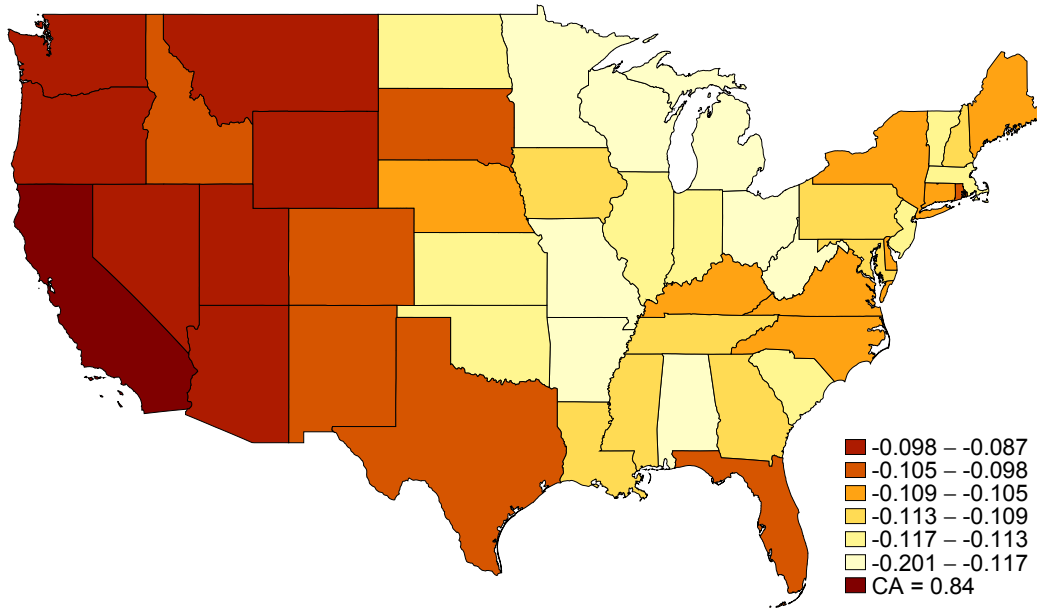
[h]Giroud and Rauh (2015) report an elasticity of number of establishment with respect to corporate taxes of 0.4.
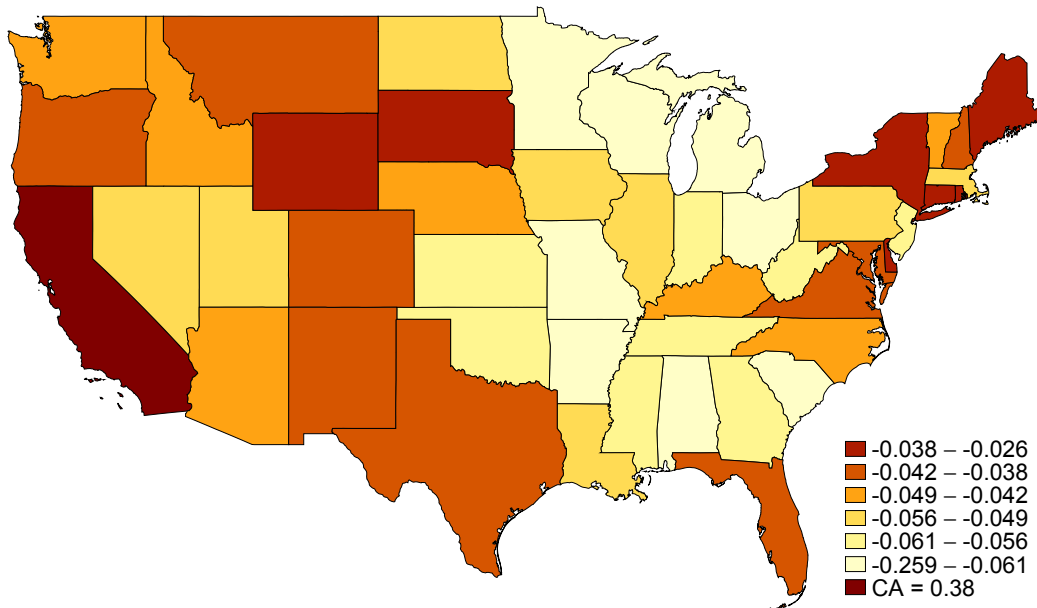
62

E   Appendix to Section 7 (Measuring Spatial Misallocation)

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

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

(a) Percent Change in Employment

(b) Percent Change in Number of Firms

Note: The first panel shows the percent change in employment and the second panel shows the percent change in the number of firms by state resulting from a 1 percent point reduction in the average income tax in CA from 3.6% to 2.6% keeping constant the provision of public services in every state.

E.2 Appendix Tables To Section 7.8 (Robustness)

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

$\alpha_{W,n}$	α_F	Welfare	GDP
A. Corporate Taxes Adjusted for Tax Subsidies			
0.22	0.04	0.10%	0.09%
0.00	0.00	0.14%	0.07%
$\frac{R_n}{GDP_n}$	0.04	0.11%	0.09%
B. Corporate Taxes Adjusted for Share of C-Corps			
0.22	0.04	0.06%	0.05%
0.00	0.00	0.09%	0.04%
$\frac{R_n}{GDP_n}$	0.04	0.07%	0.05%

Table A.9: Removing Tax Dispersion: No Congestion ($\chi_W = \chi_F = 0$)

$\alpha_{W,n}$	α_F	Welfare	GDP
0.22	0.04	0.16%	0.10%
$\frac{R_n}{GDP_n}$	0.04	0.19%	0.11%
$\frac{R_{n'}}{GDP_{n'}}$ of random $n' \neq n$	0.04	0.19%	0.11%
0.00	0.00	0.20%	0.10%
0.22	0.00	0.16%	0.10%
0.00	0.04	0.20%	0.10%

Table A.10: Removing Tax Dispersion with State and Local Taxes

$\alpha_{W,n}$	α_F	Welfare	GDP
0.22	0.04	0.15%	0.07%
0.00	0.00	0.18%	0.03%
$\frac{R_n}{GDP_n}$	0.04	0.18%	0.07%

F Data Sources

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

F.1 Government Finances

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

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

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

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

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

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

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

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

- Corporate taxes adjusted for subsidies (for Section 7.8): 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.[102] We first calculate an effective corporate tax rate by state by dividing corporate tax revenues by total pre-tax profits, which are given in A.12 by $\tilde{\Pi}_n = GDP_n / (\gamma_n(\sigma - 1) + 1)$. Since these effective rates are smaller than statutory tax rates, we adjust them by the ratio of statutory corporate rates to effective corporate rates in order to match the statutory rates. We next compute a subsidy rate by dividing state subsidies by the same tax base as above, and further multiply this ratio by the same adjustment factor as above. The net-of-subsidy, effective corporate tax rate is then the difference between the adjusted effective corporate rate and the adjusted subsidy rate.

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

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

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

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

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

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

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

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

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

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

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

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

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

F.3 Estimation (Section 6.3)

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

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

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

- Wages from CPS w_n^{CPS}: Source: IPUMS; Dataset: March Current Population Survey (CPS); Definition: we run the following regression, $\log wage_{int} = \mu_{nt} + \epsilon_{int}$ where i is individual, n is state, and t is year, and then use 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)