State Taxes and Spatial Misallocation*

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Chicago Booth & NBER

November 2015

Abstract

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

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*We thank Costas Arkolakis, Dominick Bartelme, Lorenzo Caliendo, Arnaud Costinot, Klaus Desmet, Cecile Gaubert, Enrico Moretti, Nirupama Rao, Pat Kline, Ralph Ossa, Esteban Rossi-Hansberg, Aleh Tsyvinski, and Jon Vogel for helpful comments. Matt Panhans, Prab Upadrashta and John Wieselthier provided excellent research assistance. Suárez Serrato gratefully acknowledges support from the Kauffman Foundation. Zidar gratefully acknowledges support from the Kathryn and Grant Swick Faculty Research Fund and Booth School of Business at the University of Chicago.
1 Introduction

Tax policy varies widely across countries and across regions within countries. In 2012, the U.S. states collected roughly $800 billion in tax revenue relying on very different levels of sales, personal income, and corporate income taxes. Recent research studying dispersion in distortions across economic units – across firms, as in Hsieh and Klenow (2007), or across cities, as in Desmet and Rossi-Hansberg (2013) – suggests that this dispersion in tax rates may lower aggregate economic activity; indeed, policies that would move the state tax structure towards greater tax harmonization have been proposed in both academic and policy discussions.\(^1\) However, little is known about the aggregate effects of eliminating dispersion in tax rates, or, more generally, about how the state tax distribution impacts the U.S. economy.\(^2\)

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

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


\(^2\)The March 24, 2015 poll of members of the IGM Economic Experts Panel of Chicago Booth on Local Tax Incentives illustrates the disagreement and uncertainty among economists on questions related to this topic.

\(^3\)Our baseline analysis focuses on these three types of taxes as they account for the bulk of state tax revenue; see Section 2 for background on the U.S. tax system. In the counterfactuals, we inspect alternative ways of measuring these tax rates.
state spending – and in general equilibrium through the impact of taxes on prices and public-services’ provision. Specifically, our model implies that state taxes impact the allocation of firms, workers, and goods through their effect on “adjusted fundamentals,” defined as functions of actual state fundamentals (productivity, amenity, and trade costs), tax rates, and government spending. Given the level of government spending, higher income or sales taxes in one state are equivalent to a lower amenity level in that state, higher corporate taxes are equivalent to lower productivity, and changes in sales-apportioned corporate tax rates are equivalent to changes in trade costs. In general equilibrium, government spending varies with the size of each government’s budget; as a result, changes in tax rates in one state impact the adjusted fundamentals of every state.

To measure the effects of alternative state tax structures we need estimates of four structural parameters: the elasticities of worker and firm mobility, and the weight of public services in worker preferences and firm productivity. We identify these parameters using equilibrium relationships from our model and a longitudinal dataset on the distribution of workers and firms across states, state tax rates, and state government revenue from 1980 to 2010. Specifically, our model generates a worker-location equation that predicts each state’s employment share as a function of after-tax real wages and 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 government spending. Our estimation strategy uses taxes in other states to instrument for each state’s factor prices and government spending. We estimate a partial elasticity of state employment with respect to after-tax real wages of about 1, and with respect to government spending of about 0.2. Within our model, the ratio between these reduced-form coefficients identifies the preference for public services relative to private goods, and their level identifies the elasticity of worker mobility.⁴

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

Using the estimated model, we measure the effects of replacing the 2007 distribution of state tax rates with counterfactual distributions. Our main counterfactuals assess the impact of tax reforms that eliminate dispersion in tax rates across states. We define the spatial misallocation caused by the state tax distribution as the welfare and real-income gains (if they exist) that would result from eliminating the dispersion in each type of tax across states while keeping the size of state governments constant. We undertake two types of counterfactuals that differ in the measure of government size that is kept constant: we undertake a revenue-neutral counterfactual by simultaneously bringing the common tax rate for each type of tax to a level such that the tax revenue collectively raised by all states is the same as in the initial scenario; and we also under-

⁴These estimates are in the range of existing work that has estimated similar specifications, such as Bound and Holzer (2000), Notowidigdo (2011), Suárez Serrato and Wingender (2011), Diamond (2015), and Suárez Serrato and Zidar (2014). See Section 4.3 for details.
take a spending-neutral counterfactual by bringing the common tax rate for each type of tax to a level such that the tax revenue collectively raised by all states jointly with a system of cross-state transfers can finance the same level of government spending as in the initial scenario in every state. Dispersion in tax rates across states can be shown theoretically to reduce real income and welfare in restricted versions of our model that do not feature some forces such as spatial externalities through home-market effects and government spending. However, the model that we estimate and use as basis for our counterfactuals accounts for these forces, and therefore does not necessarily imply that eliminating tax dispersion must lead to real-income and welfare gains.

We find that a revenue-neutral harmonization of sales, income, and corporate taxes leads to aggregate real-income gains in the order of 0.7%, or roughly $110 billion in 2012, pointing to quantitatively important effects from dispersion in these taxes relative to their revenue share in GDP, i.e., about 4%. Welfare gains are also in the order of 0.7%. The spending-neutral elimination of tax dispersion leads to a 0.12% increase in welfare and to a similar increase in real GDP, pointing to the existence of spatial misallocation due to forces other than the changes in state government spending that a tax harmonization could imply. We inspect how these results would vary if the weight of government spending in worker preferences and productivity was lower than what our benchmark estimates imply, and if we allowed for heterogeneity across states in workers’ preferences for public services provided by state governments. We continue to find gains from eliminating dispersion in income, sales, and corporate tax rates in these cases. For example, in an extreme parametrization that assigns zero weight to government spending in preferences and productivity, both revenue- and spending-neutral counterfactuals lead to welfare gains of 0.2%. We also study counterfactuals under parametrizations corresponding to alternative estimation strategies and under different ways of measuring tax rates; e.g., adjusting corporate tax rates for state subsidies and incorporating progressivity in state and federal income tax schedules.

We also use the estimated model to gauge the effects of other policies which are often subject to public debate. In some states, lower taxes are said to help create jobs or attract businesses, but also to erode the provision of public services with little overall effect on employment. To inform the ongoing debate on the effects of lowering state taxes, we simulate a 1 percentage point reduction in the individual income tax in each state at a time. On average, this policy causes a loss of economic activity in the state enacting the tax change. General-equilibrium forces largely drive the effects: keeping goods prices, factor prices, and government spending constant, the tax reduction leads to an increase in economic activity in the state reducing taxes, but when these variables are allowed to adjust, activity in that state decreases. We find that this tax change leads to heterogeneous impacts across other states, with the states who export or import relatively more from the state lowering taxes experiencing a relatively smaller increase in economic activity. We also explore the implications of the sales apportionment of corporate taxes; i.e., the fact that business profits are allocated to states proportionally to sales to determine each firm’s effective corporate tax

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rate. In the model, the sales apportionment distorts sales decisions, leading firms to sell relatively more to states with lower sales-apportioned corporate taxes. We find aggregate losses from fully apportioning corporate taxes through sales instead of employment. We identify a relevant role for trade in driving this result: moving away from sales apportionment implies smaller gains under no heterogeneity in trade linkages across states, suggesting a complementarity between trade frictions and the distortions caused by the sales apportionment. To the best of our knowledge, this paper provides the first quantification of these often-debated policies using a general-equilibrium model fitted to the actual distribution of economic activity and tax rates across all U.S. states.

In terms of tools, the paper is related to a recent literature on quantitative economic-geography models including Ramondo et al. (2012), Redding (2012), Allen and Arkolakis (2014), Caliendo et al. (2014), Bartelme (2014), and Monte et al. (2015). Our question – the impact of state taxes on the U.S. economy – distinguishes our paper from this previous literature. This focus drives our modeling choices, estimation approach, and counterfactuals. Our model combines a number of ingredients already present in existing studies, plus a few new ones dictated by our research question. The new ingredients are imperfect firm mobility (in the form of idiosyncratic productivity draws across states), a tax structure that encompasses the main taxes used by U.S. states, and a government sector that uses these taxes to finance public services valued by workers and firms. Relative to this literature, a central feature of our analysis is the focus on performing counterfactuals with respect to policy variables that are directly observed (U.S. state tax rates) and the estimation of key parameters (elasticities of firm and worker mobility and preferences for government spending) using changes over time and space in those policies and in economic activity.

Our paper contributes to the literature on the aggregate effects of misallocation. A common approach in the literature consists in measuring distortions across firms as an implied wedge between an observed allocation and a model-implied undistorted allocation, as in Hsieh and Klenow (2007) and Restuccia and Rogerson (2008); a few papers have adopted a similar strategy to analyze misallocation across geographic units, such as Desmet and Rossi-Hansberg (2013), Hsieh and Moretti (2015), or Brandt et al. (2013). These wedges capture distortions that may be due to mul-

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

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

9Specifically, our model includes an endogenous number of monopolistically competitive firms as in Krugman (1991) and Helpman (1998), the use of differentiated products as intermediates as in Krugman and Venables (1995), and workers with idiosyncratic preferences across locations as in Tabuchi and Thisse (2002). These ingredients are present in different studies from the recent quantitative economic-geography literature, e.g., Redding (2012) includes free-entry and idiosyncratic preferences of workers, Caliendo et al. (2014) allow for a full set of input-output linkages across sectors, and Allen and Arkolakis (2014) model externalities which are isomorphic to some of these agglomeration forces.

10In this sense, our approach shares features with Caliendo and Parro (2014), who, in an international trade context, estimate trade elasticities using variation in tariffs. A few recent papers are also concerned with the impact of policies in models with labor mobility. Gaubert (2014) studies subsidies in a model with with heterogeneous firms and externalities from city size, Ossa (2015) studies the Nash equilibrium in state subsidies in a spatial model with home market effects, and Eeckhout and Guner (2014) study optimal taxes across cities under externalities from city size.
tiple sources. Rather than inferring distortions from wedges, we focus on the spatial misallocation 
generated by one specific type of distortion (state taxes) that we can directly observe in the data. 
While this literature typically focuses on the impact of distortions on TFP, we study the impact 
on real income and welfare.\textsuperscript{11}

Finally, our paper is also related to the literature that has analyzed the general equilibrium 
effects of tax changes. For example, Shoven and Whalley (1972), and Ballard et al. (1985) emphasize 
the importance of general equilibrium effects when analyzing large changes in policy. Also in a 
general equilibrium, Albouy (2009) study the distortions in the allocation of workers across U.S. 
cities caused by federal tax progressivity. The general-equilibrium effects implied by our analysis 
depend on the elasticities of firm and worker location with respect to taxes; evidence on the incidence 
of taxes on worker mobility includes Bartik (1991) and, more recently, Moretti and Wilson (2015); 
in terms of firm mobility, Holmes (1998) uses state borders to show that manufacturing activity 
responds to business conditions, and a large literature studies the impact of local policies on business 
location.\textsuperscript{12} Suárez Serrato and Zidar (2014) provide evidence on the impact of corporate taxes on 
worker and firm mobility, and Suárez Serrato and Wingender (2011) show that local economic 
activity responds to public spending. While these papers quantify the local effects of actual policy 
changes, our framework allows us to quantify how counterfactual policy changes in one or many 
states, such as tax harmonization, would impact outcomes in every state individually and in the 
U.S. economy as an aggregate through both partial- and general-equilibrium forces.

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

2 Background on the U.S. State Tax System

Our benchmark analysis focuses on three sources of tax revenue: personal income, corporate 
income, and sales taxes. The revenue raised by these taxes accounted, respectively, for 35\%, 5\%, 
and 47\% of total states' tax revenue in 2012, and collectively amounted to 4\% of U.S. GDP. In this 
section, we first describe how we measure each tax rate. We then present statistics that summarize

\textsuperscript{11}For any observed distribution of taxes, the quantitative economic-geography model that we adopt can rationalize 
the observed distribution of economic activity (wages, prices, employment, and trade) as an equilibrium outcome 
corresponding to some joint distribution of productivity, amenities, and trade costs. We do not introduce wedges 
in the model to save notation, but we note that, if introduced, they would not be separately identified from these fundamentals.

\textsuperscript{12}E.g., Devereux and Griffith (1998) estimate the effect of profit taxes on the location of production of U.S. 
multinationals, Goolsbee and Maydew (2000) estimate the effects of the labor apportionment of corporate income 
taxes on the location of manufacturing employment, Hines (1997) exploits foreign tax credit rules to show that 
investment responds to state corporate tax conditions, and Giroud and Rauh (2015) use establishment-level data to 
show that multi-state C-corporations reduce their activity on both the intensive and extensive margins when states 
increase corporate tax rates. Chirinko and Wilson (2008) and Wilson (2009) also provide evidence consistent with 
the view that state taxes affect the location of business activity.
the dispersion in tax rates across states. We conclude with evidence on the relationship between state tax revenue and government spending. Appendix F details the sources of the data discussed in this section.

2.1 Main State Taxes

**Personal Income Tax** States tax the personal income of their residents. The base for the state personal income tax includes both labor and capital income. In our benchmark analysis, we use a flat state income tax rate, and we then explore how our counterfactual results change if we account for the progressivity of income taxes at both the state and federal levels.\(^{13}\) 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.\(^{14}\) In 2010, the average across states was 3%; the states with the highest income tax rates were Oregon (6.2%), North Carolina (5.2%), and Hawaii (5.0%), while seven states had no income tax.

**Corporate Income Tax** 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.\(^{15}\) State tax authorities determine the share of a C-corporation’s national profits allocated to their state using apportionment rules, which aim to capture the corporation’s activity share within their state. To determine that activity share, states put different weight on three apportionment factors: payroll, property, and sales. Payroll and property factors depend on where goods are produced and typically coincide; the sales factor depends on where goods are consumed.\(^{16}\) In 2012, the average corporate income tax rate across states was 6.4%; the states with the highest corporate tax rates were Iowa (12%), Pennsylvania (10%), and Minnesota (10%), while six states 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.\(^{17}\) We also explore how our results change when we apply alternative corporate tax rates that adjust for the fraction of C-corporations

\(^{13}\)The schedule of state income tax rates tends to be progressive, but it is typically much flatter than the federal income tax schedule. We compare the progressivity of state and federal income tax rates when we introduce progressive income taxes in Section 5.4.

\(^{14}\)The fixed sample corresponds to actual 1984 tax returns. The features of the tax code taken into account by NBER TAXSIM include maximum and minimum taxes, alternative taxes, partial inclusion of social security, earned income credit, phasestofs of the standard deduction and lowest bracket rate. State tax liabilities are calculated using the data from the federal return. All items on the return are adjusted for inflation, so differences across tax years only reflect changes in tax laws.

\(^{15}\)Most states limit the tax base to profits earned within the “water’s edge”, i.e. profits from domestic activity.

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

\(^{17}\)C-corporations accounted for 66% percent of total business receipts in 2007 (PERAB, 2010).
in total revenue in each state, or that account for tax subsidies that some states grant to firms, reducing their effective corporate tax rate.

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

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

Both the tax base and the tax rates vary considerably across states. While most states collect both income and sales taxes, some rely almost exclusively on sales tax revenue, such as Texas and Nevada, while others are sales-tax free, like New Hampshire and Oregon. Panel (a) of Figure 1 shows the 2010 distribution of sales, income, corporate, and sales-apportioned corporate tax rates. For each tax, rates vary across states, corporate tax rates being the most dispersed. 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%.

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

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

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

20 Table A.2 in Appendix F.2 shows the state tax rates in 2007 for personal income taxes, general sales taxes, statutory corporate taxes and sales apportioned corporate taxes in all 50 states. Table A.1 shows the federal income, corporate and payroll tax rates in 2007.

21 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.
2.3 Relationship Between State Taxes and Government Spending

State governments typically have balanced budgets (Poterba, 1994), so we assume in our model that changes in state tax revenue translate to changes in state government spending. Figure 2 shows that there is indeed a high correlation between the tax revenue from the taxes we consider in the analysis (i.e., personal income, corporate income, and sales taxes) and direct state spending during 1980-2012 both within states over time and across states in any given year. Direct expenditures include all government expenditures other than intergovernmental transfers.\(^{22}\)

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

\(^{22}\)The main direct-expenditure items include education, public welfare, hospitals, highways, police, correction, natural resources, parks and recreation, government administration, and utility expenditure.
3 Quantitative Trade Model with State Taxes and Public Goods

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

Each state $n$ is characterized by an endowment $H_n$ of fixed factors of production (land and structures), an amenity level $u_n$, and a productivity level $z_n$. There is an iceberg cost $\tau_{ni} \geq 1$ of shipping from state $i$ to state $n$ (if one unit is shipped from $i$ to $n$, $1/\tau_{ni}$ units arrive). Firms are single-plant and sell differentiated products. To produce, they use the fixed factor, workers, and intermediate inputs. Workers receive only labor income, which they spend in the state where they live. Firms and fixed factors are owned by immobile capital owners exogenously distributed across states.

State governments collect personal income taxes $t_n^y$, sales taxes $t_n^c$, and corporate income taxes apportioned through sales, $t_n^{sx}$, or through payroll and fixed factors, $t_n^{fl}$. Each state uses the tax revenue to finance the provision of public services, which enter as shifters of that state’s amenity and of the productivity of firms that locate in that state. The federal government collects personal income taxes $t_{fed}^y$, payroll taxes $t_{fed}^{fl}$, and corporate taxes $t_{fed}^{corp}$. Federal public spending is not valued by consumers or firms.  

\[\text{We could impose the alternative assumption that federal public spending shifts the utility of consumers independently from where they locate. In this case, our analysis would remain unchanged except that, for any counterfactual change in taxes, there would be an additional aggregate welfare effect through its impact on the size of the federal budget.}\]
3.1 Production Technologies

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

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

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

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

Each variety $j$ is produced by a different firm; to produce $q_{ni}^j$ in region $i$, firm $j$ uses its own productivity in that location, $z_{ij}^j$, and combines it with the fixed factor $h_j^i$, workers $l_j^i$ and intermediate inputs $i_j^i$ through a Cobb-Douglas technology:

$$q_{ni}^j = z_{ij}^j \left[ \frac{1}{\gamma_i} \left( \frac{h_j^i}{\beta_i} \right)^{\beta_i} \left( \frac{l_j^i}{1-\beta_i} \right)^{1-\beta_i} \right]^{\gamma_i} \left( \frac{i_j^i}{1-\gamma_i} \right)^{1-\gamma_i},$$

where $\gamma_i$ is the value-added share in production of every firm in state $i$, and where $1-\beta_i$ is the labor share in value added in state $i$. The existence of a fixed factor is one of the sources of congestion in the model; the higher the number of firms and workers located in a given state, the higher the relative price of this fixed factor. Production functions are allowed to vary by state; this flexibility is needed to match the heterogeneity in the shares of total payments to labor and intermediate inputs expenditures in states’ GDP observed in the data.\(^{24}\)

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

$$Q_n = C_n + I_n + G_n + G_{n,fed}^f.$$

3.2 Workers and Capital Owners

A continuum of workers $l \in [0,1]$ decide in which state to work and consume. The indirect utility of worker $l$ in state $n$ is $v_n^l = v_n \epsilon_n^l$, where the vector $\{\epsilon_n^l\}_{n=1}^N$ 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

\(^{24}\)This heterogeneity in the production function may be thought of as a way of capturing differences in sectoral composition across states; in the presence of multiple sectors, the labor and intermediate-input shares of each state would be endogenous and change in the counterfactuals, but abstract from this margin in our analysis.
component is

\[ v_n = u_n \left( \frac{G_n}{L_n^{\chi W}} \right)^{\alpha W} \left( 1 - T_n \right) \left( \frac{w_n}{P_n} \right)^{1 - \alpha W}, \]

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

\[ 1 - T_n \equiv \frac{(1 - t_{fed}^y)(1 - t_n^y) - t_{fed}^w}{1 + t_n^{fed}}. \]

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

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

\[ L_n = \left( \frac{v}{v_n} \right)^{\epsilon_W}, \]

where

\[ v = \left( \sum_n v_n^{\epsilon_W} \right)^{1/\epsilon_W}. \]

Under the Fréchet distribution, both the ex-ante expected utility of a worker before drawing \( \{ \epsilon_n \}_{n=1}^N \) and the average ex-post utility of agents located in any state are proportional to \( v \); hence, we adopt it as our measure of worker welfare. In the counterfactuals, we also report the change in real consumption (of both mobile workers and immobile capital-owners) and real GDP; we present the

25 Although we do not allow for direct consumption of land by workers, our model features congestion forces through the price index, as the fixed factor is used in production. We could generalize the framework to allow for an additional source of congestion by having housing in equation (5).

26 I.e., if we had an additional variable \( z^G \) representing the efficiency or quality of government spending, it would enter multiplicatively with \( u_n \).

27 Note that equation 6 takes into account that state income taxes can be deducted from federal taxes. We abstract from the non-linearity of the federal income tax scheme in the benchmark analysis; empirically, we set the value of the federal income tax rate \( t_{fed}^y \) to the average effective federal rate paid by U.S. residents. In section 5.4 we relax this assumption and allow the federal rate to be a function of state wages. As the federal income tax schedule is defined on nominal wages, it may lead to spatial distortions, as analyzed by Albouy (2009).

28 The constant of proportionality equals \( \Gamma \left( \frac{\epsilon_W - 1}{\epsilon_W} \right) \), where \( \Gamma(\cdot) \) is the gamma function.
A larger value of $\varepsilon_W$ implies that the idiosyncratic taste draws are less dispersed across states; as a result, locations become closer substitutes and an increase in the relative appeal of a location (an increase in $v_n/v$) leads to larger response in the fraction of workers that choose to locate there. From the definitions of $v_n$ and $L_n$ in (5) and (7), it follows that $\varepsilon_W (1 - \alpha_W)$ is the partial elasticity of the fraction of workers who locate in state $n$ with respect to after-tax real wages, $(1-T_n)(w_n/P_n)$, while $\varepsilon_W \alpha_W$ is the partial elasticity with respect to real government services per worker, $G_n/L_n^{\chi_W}$. We rely on these relationships to estimate $\{\varepsilon_W, \alpha_W\}$ in section 4.3.

Immobile capital owners in state $n$ own a fraction $b_n$ of a portfolio that includes all firms and fixed factors, independently of the state in which they are located. Therefore, their income is $b_n (\Pi + R)$, where $\Pi$ are national after-tax profits, $R$ are the national returns to land and structures. We do not need to specify the number of capital owners located in each state $n$ for our computations. We calibrate the ownership shares $b_n$ to match the observed trade imbalances across states. Capital owners spend their income locally, and pay sales taxes on consumption and both federal and income taxes on their income.

### 3.3 Firms

A continuum of firms $j \in [0, 1]$ decide in which state to locate and produce and how much to sell to every state. Each firm $j$ produces a differentiated variety and is endowed with a vector of productivities $\{z_j\}_{i=1}^N$ 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, which are common with standard models of international trade such as Melitz (2003).

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

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

where $t_i^j$ is the corporate tax rate of firm $j$ in state $i$, $x_{ni}^j = P_n Q_n^{\gamma} (q_{ni}^j)^{1-\frac{1}{\sigma}}$ are its sales to state $n$, and $c_i = (w_i^1 - \beta_i r_i^1) \gamma_i P_i^{1-\gamma_i}$ 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 $i$.\(^{29}\)

All firms face corporate taxes apportioned through sales, payroll, and land and structures.\(^{30}\) A

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\(^{29}\)Note that the definition of $c_i$ incorporates that, unlike consumers, firms do not face the sales tax when purchasing the final good to be used as an intermediate.

\(^{30}\)This assumption implies that we treat all companies as C-corporations. In practice, many companies are set up as S-corporations and partnerships. These companies are not subject to corporate income taxes. We ignore them in our baseline model because they represent a small fraction of U.S. business revenues – see our previous discussion in section 2.1. However, in Section 5.5 we perform a robustness check where corporate tax rates are adjusted by the
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 \( t_i^f \) times the pre-tax national profits in corporate income taxes apportioned through payroll and land and structures to state \( i \), and a rate \( t_{fed}^c \) in federal corporate income taxes. As a result, the corporate tax rate of firm \( j \) is:

\[
\tau_i^j = t_{fed}^c + t_i^f + \sum_{n=1}^{N} t_n^x s_{ni}^j. \tag{10}
\]

Due to the sales apportionment of corporate taxes, the decision of how much to sell to each state in (9) is not separable across states as in the standard CES maximization problems with constant marginal production costs in Krugman (1980) or Melitz (2003). When a firm increases the fraction of its sales to state \( n \) (i.e., when \( s_{ni}^j \) increases), the average tax rate changes depending on the sales-apportioned corporate tax in state \( n \), \( t_n^x \), relative to that in other states. Since the base of the corporate tax are national profits, firms trade off the marginal pre-tax benefit of exporting more to a given state against the potential marginal cost of increasing the corporate tax rate on its entire profits.

Despite this interaction in the sales decision, the firm problem retains convenient properties from the standard CES maximization problem that allow for aggregation; we describe these properties here and refer to Appendix B.1 for derivations. Specifically, all firms located in a state \( i \) have the same sales shares across destinations irrespective of their productivity, i.e., \( s_{ni}^j = s_{ni} \) for all firms \( j \) located in \( i \); from (10), this leads to a common corporate tax rate across firms, \( \tau_i^j = \bar{\tau}_i \). 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:

\[
p_{ni}(z) = \tau_{ni} \frac{\sigma}{\sigma - t_{ni}} \phi \frac{c_i}{z}, \tag{11}
\]

where

\[
\hat{\tau}_{ni} = \frac{t_n^x - \sum_{n'} t_{n'}^x s_{n'i}}{1 - \bar{t}_i}. \tag{12}
\]

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

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

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actual share of C-corporations in each state.
component of productivity is:

\[ z_i^0 = \left( \frac{G_i}{M_i^{\chi_F}} \right)^{\alpha_F} z_i^{1-\alpha_F}. \]

(13)

As in the case of amenities, this common component has an endogenous part that depends on the amount of public spending and an exogenous part, \( z_i \). The endogenous part equals real government spending \( G_i \) normalized by \( M_i^{\chi_F} \), where the parameter \( \chi_F \) captures rivalry among firms in access to public goods. The exogenous part captures both natural characteristics that impact productivity, like natural-resource availability, and the rate at which the government transforms real spending into services valued by firms. Using (9), the profits of firm \( j \) when it locates in \( i \) can be expressed as the product of a common and an idiosyncratic component:

\[ \pi_i^j(z_i^0) = \pi_i(z_i^0) \left( \epsilon_i^j \right)^{\sigma-1}. \]

(14)

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

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

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

(15)

where

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

(16)

Equation (15) says that the fraction of firms located in \( n \) depends on the common component of profits in \( n \), \( \pi_i(z_i^0) \), relative to that of other locations. The distributional assumption on the idiosyncratic productivity draw implies that both the ex-ante profits of a firm before drawing \( \{\epsilon_i^j\}_{i=1}^N \) and the average ex-post profits of firms located in any state are proportional to \( \bar{\pi} \).\footnote{The constant of proportionality is \( \Gamma\left(1 - \frac{\sigma-1}{\varepsilon_F}\right) \), where \( \Gamma(\cdot) \) is the gamma function.} 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 \( \pi_i(z_i^0) / \bar{\pi} \)) leads to a larger response in the fraction of firms that choose to optimally locate in that location.

**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 \( \bar{z}_i \) of 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 \( i \):\(^{32}\)

\[
\bar{z}_i = z_i^0 M_i^{-\frac{1}{e_F}}. \tag{17}
\]

The productivity of the representative state-\( i \) firm \( \bar{z}_i \) is larger than the unconditional average of the distribution of productivity draws, \( \bar{z}_i / z_i^0 > 1 \), 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 Aggregates** State-\( i \) outcomes can be constructed as if in equilibrium all the \( M_i \) firms located in state \( i \) had productivity \( \bar{z}_i \). Specifically, the share of aggregate expenditures in state \( n \) spent on goods produced in state \( i \) is

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

where \( p_{ni}(z) \) is the pricing function defined in (11). We construct the sales shares \( s_{ni} \), which are necessary to compute the corporate tax rate \( t_i \) in (10) and the pricing distortion \( \bar{t}_{ni} \) in (12), using the identity \( s_{ni} = \lambda_{ni} P_n Q_n / X_i \), where \( P_n Q_n \) are aggregate expenditures on final goods in state \( n \).

By definition, aggregate sales by firms located in state \( i \) are:

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

Because of Cobb-Douglas technologies and CES demand, aggregate payments to intermediate inputs, labor and fixed factors in state \( i \) are constant fractions of \( X_i \).\(^{33}\) As a result, spatial interactions drive local effects: larger expenditures \( P_n Q_n \) in state \( n \) act as a factor-demand shifter in state \( i \) through \( X_i \), and its impact depends on the intensity of the trade linkage \( \lambda_{ni} \). Aggregate pre-tax profits \( \bar{\Pi}_i \) are also proportional to sales:

\[
\bar{\Pi}_i = \frac{X_i}{\sigma}, \tag{20}
\]

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

**Contrast with Models with Free Entry** This structure has similar implications to standard monopolistic competition models with free entry, in the sense that in both types of models the

\(^{32}\)By definition, \( \bar{z}_i = \left( \int_{z_i}^{\bar{z}_i} (\bar{z}_i)^{\sigma-1} d\bar{z}_i \right)^{1/\sigma} \). To reach (17), we use that the Fréchet assumption on the distribution of productivity draws implies \( \pi(\bar{z}_i) = \tilde{\pi} \) in every state together with (15) and the relationship \( \pi_i(z_i^0) / \pi_n(\bar{z}_i) = (z_i^0 / \bar{z}_i)^{\sigma-1} \), implied by (14).

\(^{33}\)See the expressions (A.6) to (A.8) in Appendix B.2.
number of firms by location is endogenous and proportional to sales. From (20) and the distribu-
tional assumption on the productivity draws, it follows that the number of firms in state \( i \) can be expressed as:

\[
M_i = \frac{1 - \bar{t}_i X_i}{\bar{\pi}}. \tag{21}
\]

This condition determines the number of firms in each region similarly to a standard free-entry condition in monopolistic competition models such as Krugman (1980).\textsuperscript{34} However, we prefer the micro-foundation of equation 21 described above for three reasons: first, it allows us to use data on patterns of firm mobility to estimate the parameter \( \varepsilon_F \), see Section 4.3; second, it is similar to existing work which has estimated elasticities of firm location with respect to taxes in the public-finance literature such as Suárez Serrato and Zidar (2014); third, it allows us to treat mobility of workers and firms symmetrically.\textsuperscript{35}

3.4 State Government

State governments use tax revenue \( R_n \) to finance spending in public services. Total government spending and revenue in state \( n \) is:

\[
P_n G_n = R_n = R_n^{\text{corp}} + R_n^y + R_n^c, \tag{22}
\]

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

\[
R_n^{\text{corp}} = t_x^{\pi} \sum_{n'} s_{nn'}^n \tilde{\Pi}_{n'} + t_l^{\pi} \tilde{\Pi}_n, \tag{23}
\]

\[
R_n^y = t_y^n (1 - t_{y^{\text{fed}}}) [w_n L_n + b_n (\Pi + R)], \tag{24}
\]

\[
R_n^c = t_c^n P_n C_n. \tag{25}
\]

The base for corporate tax profits are the pre-tax profits from every state, defined in (20), adjusted by the proper apportionment weights. Equation (24) shows that the base for state income taxes is the income of both workers and capital-owners who reside in \( n \) net of federal income taxes. The base for the sales tax in (25) is the total personal consumption expenditure of workers and capital owners, \( P_n C_n \).\textsuperscript{36}

\textsuperscript{34}If, instead of firm mobility, we had assumed free-entry of homogeneous firms in each state with entry cost equal to \( f_i \) units of the factors and inputs bundle, the number of firms in state \( i \) in our model would be: \( M_i = \frac{1 - \bar{t}_i X_i}{\bar{\pi}} \).

\textsuperscript{35}The cost of not using the free-entry model is that changes in taxes do not affect the total number of firms in the economy. We note, however, that in both models the fraction of the total number of firms located in each state is determined independently from the total number of firms (here normalized to 1); as such, the aggregate-entry margin would not affect the part of welfare changes that corresponds to the spatial distribution of economic activity which is the focus of our analysis. However, it would be possible to carry out our analysis using the free-entry model to assess this additional margin.

\textsuperscript{36}\( P_n C_n \) is defined in Equation (A.11) in Appendix B.2. As mentioned above, taxes are also collected by the federal government. Expression (A.14) in Appendix B.2 shows the expression for total taxes levied by the federal government in state \( n \).
3.5 General Equilibrium

**Definition** A general equilibrium of this economy consists of distributions of workers and firms \{L_n, M_n\}_{n=1}^{N}, aggregate quantities \{Q_n, C_n, I_n, G_n, G_{fed}^n\}_{n=1}^{N}, wages and rents \{w_n, \tau_n\}_{n=1}^{N}, and prices \{P_n\}_{n=1}^{N} such that: i) final-goods producers optimize, so that final-goods prices are given by (2); ii) workers make consumption and location decisions optimally, as described in Section 3.2; iii) firms make production, sales, and location decisions optimally, as described in Section 3.3; iv) government budget constraints hold, as described in Section 3.4; v) goods markets clear in every location, i.e. (4) holds for all \(n\); vi) the labor market clears in every state, i.e. labor supply (7) equals labor demand (A.7) for all \(n\); vii) the land market clears in every location, i.e. (A.8) holds; and viii) the national labor market clears, i.e. \(\sum_n L_n = 1\).

**Adjusted Fundamentals** Appendix B.3, presents a system of equations that characterizes the general equilibrium solution for wages and employment in every state, \{w_n, L_n\}_{n=1}^{N}, and welfare, \(v\), as function of the model’s primitives. In this system, wages, employment and welfare are affected by state taxes \{t^c_n, t^p_n, t^f_n, t^n\}_{n=1}^{N} only through their impact on the *adjusted fundamentals* in every state, \{\{A\}_{i=1}^{N}, z^A_n, u^A_n\}_{n=1}^{N}:

\[
\begin{align*}
\tau^A_{in} &= \frac{\sigma}{\sigma - i_{in}} \tau_{in}, \\
\tau^A_{in} &= \left(1 - \bar{T}_n\right) 1 - \alpha F \left(\frac{P_n G_n}{GDP_n}\right)^{\alpha F} z^{1-\alpha F}_n, \\
\tau^A_{in} &= \left(1 - T_n\right) 1 - \alpha W \left(\frac{P_n G_n}{GDP_n}\right)^{\alpha W} u_n,
\end{align*}
\]

where \(P_n G_n/GDP_n\) is the share of state government spending, defined in (22), to GDP. We can express this share as

\[
P_n G_n \frac{GDP_n}{GDP_n} = \frac{P_n G_n}{X_n} + t^c_n + \left(1 - t^p_n\right) t^f_n \frac{G_{fed}^n}{G_{fed}^n + \frac{1 - \bar{T}_n}{\bar{T}_n} + \frac{1}{\bar{T}_n}} + \left(\frac{1 - \bar{T}_n}{\bar{T}_n} + \frac{t^f_n}{\bar{T}_n}\right) (1 - \beta_n) \gamma_n (\sigma - 1),
\]

where \(P_n Q_n/X_n\) is the share of state expenditures to sales (i.e., a measure of state trade deficit).\(^{37}\)

The adjusted fundamentals are functions of state fundamentals (productivity \(z_n\), amenity \(u_n\), and trade costs \(\tau_{in}\)), tax rates and government size. State-\(n\) taxes impact the adjusted fundamentals in state \(n\) through their effect on the price distortion \{\bar{I}_{in}\}_{i=1}^{N}, the corporate tax rate \(\bar{T}_n\), the keep-tax rate \(1 - T_n\), and government size relative to GDP. State-\(n\) taxes also affect the adjusted fundamentals in states other than \(n\) through their impact on the price distortion, the corporate tax rate and government size relative to GDP in these other states.

Consider the effect of sales-apportioned corporate taxes, \{\tau^s_{i1}\}_{i=1}^{N}. These taxes impact the adjusted trade costs in state \(n\), \(\tau^A_{in}\), through the pricing distortion \{\bar{I}_{in}\}_{i=1}^{N}. Because of this distortion,

\(^{37}\)Equation (A.19) in Appendix B.2 shows the expression for \(P_n Q_n/X_n\). To reach (29), first replace \(P_n C_n\) from (A.11), \(R^p_n\) from (24), and \(R^n_{cor}\) from (A.17) into the government budget constraint (A.14), and then normalize by GDP using (A.9).
markups are higher to importing states with higher sales-apportioned corporate taxes $t^x_n$, and from states with higher average tax rates, $\bar{t}_n$. Hence, sales-apportioned corporate taxes are similar to trade costs: given government sizes and trade deficits, the equilibrium outcomes can be rationalized without sales-apportioned corporate taxes ($t^x_n = 0$ for all $n$) but with a different distribution of trade costs (equal to $\tau^A_n$). To clarify the role of the remaining taxes, it is useful to focus on a case without pricing distortion ($t^x_n = t^x$ for all $n$) and without cross-ownership of assets across states.\footnote{This corresponds to ownership rates $b_n = (\Pi_n + r_nH_n)/(\Pi + R)$.}

In this case, the effective corporate tax is exogenous, $\bar{t}_n = t^x + t^l_n$, and government size relative to GDP in a state $n$, $P_nG_n/GDP_n$, becomes a function of state $n$ taxes only. State taxes $\{t^c_n, t^h_n, t^l_n, t^x\}$ then affect the allocation exclusively through the adjusted productivities $\{z^A_n\}$ and the adjusted amenities $\{u^A_n\}$. Individual income and sales taxes are similar to amenities: given government sizes relative to GDP, the equilibrium outcomes can be rationalized with no individual income or sales taxes, but with a different distribution of amenities $u_n$ (equal to the adjusted amenities $u^A_n$). In the same way, corporate taxes are similar to productivity: given government size relative to GDP, the equilibrium outcomes can be rationalized without corporate taxes, but with a different distribution of productivities (equal to $z^A_n$).

**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 (who 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; as long as $\chi_W < 1$ or $\chi_F < 1$, this means that larger market size leads to higher utility per worker (see (5)) or firm productivity (see (13)). At the same time our model features congestion through the use of an immobile factor (land and structures) in production, leading to a higher marginal production cost when employment increases (as implied by (A.8) in Appendix B.2). It also features congestion through selection of heterogeneous firms, leading to a lower average firm productivity in a state when the number of firms located in that state increases (as implied by (17)), and through the presence of immobile capital-owners who spend their income where they live.

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

4 Data and Parametrization

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

4.1 Data

For the calibration in Section 4.2, we use measures by state of employment $L_n$, wages $w_n$, total sales $X_n$, intermediate-input expenditures $P_n I_n$, and total expenditures $P_n Q_n$. As detailed in Appendix F.2, these variables are drawn from the Economic Census of the United States. We also use information from a recently available dataset from the B.E.A. on Personal Consumption Expenditures as an input to calculate a measure of aggregate expenditures by state, $P_n C_n$. Finally, we use information on bilateral trade flows $X_{ni}$ from the Commodity Flow Survey. Information on state corporate tax rates is obtained from Suárez Serrato and Zidar (2014). All these variables correspond to the year 2007.

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. Intermediate-input expenditures $P_n I_n$ are constructed as the difference between state sales and GDP; total

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39 Changing one parameter at a time, we find that these sufficient conditions for uniqueness are violated if the elasticities of firm and labor mobility ($\varepsilon_F$ and $\varepsilon_W$) or the importance of government spending for firms and workers ($\alpha_F$ and $\alpha_W$) are sufficiently high, or if congestion in the provision of public goods ($\chi_W$ and $\chi_F$) or if the elasticity of substitution $\sigma$ are sufficiently low. When computing the counterfactuals, we experiment with different starting values of our algorithm and find always the same results, suggesting that the system of equations has indeed a unique solution.

40 To measure states exports, we use the total value of all merchandise exported to the rest of the world from the U.S. Department of Commerce International Trade Administration’s TradeStats Express dataset.
expenditures $P_nQ_n$ are constructed by adding up personal consumption expenditures, intermediate-goods expenditures, and government expenditures. In order to construct bilateral sales shares $s_{in}$ and expenditure shares, we define own-state sales as the difference between total sales and trade flows to every other state, $X_{ii} = X_i - \sum_n X_{ni}$.\(^{41}\)

For the estimation in Section 4.3, we use information for all states and years between 1980 and 2010 on number of workers and firms, hourly wage, total tax revenues, price indices, and personal income, corporate income and sales tax rates. Because Economic Census data are available infrequently, we use data on the number of workers and establishments from the County Business Patterns (CBP). The information on number of workers and establishments reported in the CBP is consistent with that reported by the Census in those years when both are available. We use the Current Population Survey to construct an hourly wage measure by state. We use regional price indices from the Bureau of Labor Statistics. As detailed in Appendix F.1, the data on tax rates and total tax revenues are drawn from the US Census, NBER TAXSIM, the Book of States, and Suárez Serrato and Zidar (2014). State spending on public services $P_nG_n$ is set equal to the sum of tax revenues across the three types of taxes considered in the model.

### 4.2 Calibrated Parameters

**Technologies** We set the state-specific value-added shares, $\gamma_n$, and shares of labor in value added, $1 - \beta_n$, so that the intermediate-input and employment shares predicted by the model in (20), (A.6) and (A.7) match their empirical counterparts for each state in the year 2007.\(^{42}\) The averages across states of our calibrated parameters are: $N^{-1}\sum_n 1 - \gamma_n = 0.62$ and $N^{-1}\sum_n 1 - \beta_n = 0.68$.

**Fundamentals** The system of equations that characterizes the general equilibrium impact of counterfactual changes in taxes, described in Appendix B.5, is a function of the value of all fundamentals (endowments of land and structures $H_n$, productivities $z_n$, amenities $u_n$, and trade costs $\tau_{in}$) for every state or pair of states. However, these fundamentals affect the outcomes from the counterfactuals only through the composite $A_{in}$ defined in (A.26) in Appendix B.3. In order to calibrate this composite, we match $A_{in}$ to the function of expenditure shares, wages, and employment described in equation (A.24). We therefore do not need to separately identify the value of all fundamentals.\(^{43}\) As a result, the parametrized model exactly matches the distributions of bilateral expenditure shares, bilateral sales shares, wages, and employment across states in 2007.

---

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

42 I.e.: $1 - \gamma_n = \frac{\sigma}{\sigma - 1} \frac{P_nI_n}{X_n}$ and $1 - \beta_n = \frac{\sigma}{\sigma - 1} \frac{w_nL_n}{\gamma_nX_n}$. To perform this calculation, we use the value of $\sigma$ described below.

43 This feature of our model is shared by the existing 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 separately identify all the fundamentals.
Ownership Rates. We set the ownership rates, $b_n$, to match the ratio of expenditures to sales in each state. Expression (A.21) in Appendix B.2 shows that the set of parameters $\{b_n\}_{n=1}^N$ are uniquely identified as a function of observables, technology parameters in state $n$, and the parameter $\sigma$. As a result, the the parametrized model exactly matches the distribution of trade imbalances across states in 2007.\footnote{The ownership rates $b_n$ that we obtain are positively correlated with the share of national dividend, interest, and rental income earned in state $n$ in 2007 from BEA regional data on personal incomes (CA 30). In particular, in 2007, we estimate that $b_n = .14 + 1.36 \times SHARE_n$ where the standard errors for the intercept and slope are 0.018 and 0.28, respectively.}

Other Parameters. As shown in the next section, the firm- and labor mobility elasticities $\{\varepsilon_F, \varepsilon_W\}$ are not separately identified from the congestion parameters $\{\chi_W, \chi_F\}$. In the benchmark specification we set $\chi_W = 1$ and $\chi_F = 1$, corresponding to a case where government goods and services are rival, as in, for example, Wildasin (1991). We inspect how the counterfactual predictions change when we assign values between 0 and 1 to $\chi_W$ and $\chi_F$. The elasticity of substitution across varieties $\sigma$ is set to 4, which is to a central value in the range of estimates of the demand elasticity across differentiated products computed in the international trade literature; see Head and Mayer (2013).\footnote{Standard procedures to estimate $\sigma$ in the international trade literature rely on information on tariffs across countries (e.g. see Caliendo and Parro (2014)). No tariff applies to the exchange of goods between U.S. states, complicating the estimation of $\sigma$ in our context.}

4.3 Estimated Parameters

Table 1 contains the estimates of the remaining parameters. The labor supply elasticity, $\varepsilon_W$, and the share of public goods in preferences, $\alpha_W$, are estimated using the worker-location equation, as described in Section 4.3.1. The elasticity of firm mobility, $\varepsilon_F$, and the weight of government spending in productivity, $\alpha_F$, are estimated using the firm-location equation, as described in Section 4.3.2. Appendix C.4 shows that our estimates for these parameters are in line with previous estimates which rely on different identification assumptions.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor supply elasticity</td>
<td>$\varepsilon_W$</td>
<td>1.49</td>
<td>Section 4.3.1</td>
</tr>
<tr>
<td>Share of public goods in preferences</td>
<td>$\alpha_W$</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Firm mobility elasticity</td>
<td>$\varepsilon_F$</td>
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<td></td>
</tr>
<tr>
<td>Share of public goods in technology</td>
<td>$\alpha_F$</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Elasticities and Preference for Government Spending

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

Combining the labor supply equation in (7), the definition of the state effect in (5), and the government budget constraint in (22), we obtain the following expression for the share of labor
located in state $n$ at time $t$:

$$
\ln (L_{nt}) = a_0 \ln (\tilde{w}_{nt}) + a_1 \ln (\tilde{R}_{nt}) + \psi^L_n + \xi^L_n + \nu^L_{nt},
$$

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

Our model predicts that ordinary least squares (OLS) estimates of $a_0$ and $a_1$ are asymptotically biased due to the dependence of real wages and government spending in state $n$ and year $t$ on the unobserved amenities or government efficiency in the same state and year, which are accounted for in the term $\nu^L_{nt}$. Specifically, our model predicts amenities in a state to be negatively correlated with after-tax real wages and positively correlated with real government spending. Intuitively, higher amenities in a state attract workers, shift out the labor supply curve, and lower wages. Similarly, an increase in the number of workers raises the tax revenue and thus increases government spending. Our model thus predicts that the OLS estimate of $a_0$ is biased downwards, and the OLS estimate of $a_1$ is biased upwards.

Consequently, we estimate $a_0$ and $a_1$ using two different two-stage least squares (TSLS) estimators. In both cases, we account for the terms $\psi^L_n$ and $\xi^L_n$ using time and state dummies, respectively. In the first TSLS estimator, we instrument both the after-tax real wage and the real government spending in state $n$ at period $t$ using two vectors of tax rates: a vector of state-$n$ taxes in period $t$, $Z^L_{nt} \equiv (1-T_{nt}, 1-t^\text{corp}_{nt})$, and a vector of tax rates in states other than $n$ at period $t$, $Z^{L*}_{nt} \equiv (t^c_{nt}, t^x_{nt}, t^y_{nt})$. The vector $Z^L_{nt}$ includes the worker keep-tax rate $1-T_n$ defined in (6) (which account for state-$n$ sales and income taxes) and the corporate keep-tax rate $1-t^\text{corp}_{nt}$. The components of vector $Z^{L*}_{nt}$ are “external” taxes, defined as an inverse-distance to state $n$ weighted average of sales, income, and sales-apportioned corporate tax rates in every state other than $n$:

$$
t^z_{nt} \equiv \sum_{i \neq n} \omega_{ni} t^z_{it}, \quad \text{with} \quad \omega_{ni} = \frac{\ln (\text{dist}_{ni})^{-1}}{\sum_{i \neq n} \ln (\text{dist}_{nv})^{-1}} \quad \text{for} \quad z = c, x, y.
$$

Using standard asymptotics in panel data models, we assume that our panel data is fixed in the time dimension. In this case, the TSLS estimator that uses both $Z^L_{nt}$ and $Z^{L*}_{nt}$ as instruments for $\tilde{w}_{nt}$ and $\tilde{R}_{nt}$ assumes that $\nu^L_{nt}$, which represents the amenity level and the quality or the efficiency of government spending in state $n$ and period $t$, is mean independent of the functions of taxes included in either the vector $Z^L_{nt}$ or the vector $Z^{L*}_{nt}$ in any time period, after controlling for year

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46 We have normalized total employment to 1. Time variation in aggregate labor supply leads to changes in $v_t$, hence $\psi^L_t$ captures changes in aggregate labor supply.
and state effects. Formally, \( E[\nu_n^L | Z_n^L, Z_n^{L*}, \xi_n^L, \psi_t^L] = 0 \), where \( Z_n^L = (Z_{n1}^L, \ldots, Z_{nt}^L, \ldots, Z_{nT}^L) \) and analogously for \( Z_n^{L*} \).

### Table 2: TSLS Estimates of Local Labor Supply Parameters

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

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 \( \tilde{w}_{nt} \) and real government expenditures \( \tilde{R}_{nt} \) – 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 clustered by state are in parentheses and *** \( p<0.01 \), ** \( p<0.05 \), * \( p<0.1 \).

An implication of this assumption is that income, sales and corporate tax rates in state \( n \) must affect state \( n \) employment shares only through their effect on real wages and the provision of public goods in that state. In order to alleviate potential concerns arising from correlation between changes in a state \( n \) and its own taxes, we also present estimates from a TSLS estimator that exclusively relies on the vector of external taxes \( Z_{nt}^{L*} \) as instruments for \( \tilde{w}_{nt} \) and \( \tilde{R}_{nt} \). Under the assumption that changes in taxes in any state \( n \) will not react to idiosyncratic shocks to amenities or government efficiency in states other than \( n \), excluding the vector \( Z_{nt}^L \) from the vector of instruments eliminates any possible bias in the TSLS estimates. Formally, the TSLS estimator that exclusively uses \( Z_{nt}^{L*} \) as instruments for \( \tilde{w}_{nt} \) and \( \tilde{R}_{nt} \) assumes that \( E[\nu_n^L | Z_n^{L*}, \xi_n^L, \psi_t^L] = 0 \).

Appendix C.1 describes the the first-stage estimates. The estimation results appear in Table 2. Column (1) shows the OLS estimates, which indicate that higher levels of real government spending and after-tax real wages are correlated with higher supply of labor. Columns (2) and (3) show the TSLS estimates; column (2) uses own-state and external taxes as instruments, while column (3) uses only external taxes. Compared to the TSLS estimates, the OLS estimates imply a lower elasticity of labor supply with respect to after-tax real wages and a larger one with respect to real government spending. This difference between the OLS and the TSLS estimates is consistent.
with our model’s predictions that amenities in any given state \( n \) being negatively correlated with after-tax real wages in \( n \) and positively correlated with real government spending in \( n \).

As indicated above, the orthogonality restriction needed for consistency of the TSLS is weaker in the case in which we exclusively rely on taxes in states other than \( n \) as instruments. Therefore, we choose the specification in column (3) as our preferred one. It implies a preference for government spending of 0.17 and, given a value \( \chi_W = 1 \), a labor supply elasticity \( \varepsilon_W \) of roughly 1.5. These results line up well with the existing literature which uses different shocks to identify local labor elasticities (see Appendix C.4 for details).

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

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

\[
\ln M_{nt} = b_0 \ln \left((1 - \tilde{t}_n) MP_{nt}\right) + b_1 \ln(\tilde{R}_{nt}) + b_2 \ln c_{nt} + \psi^M + \xi^M_n + \nu^M_{nt},
\]

where \( b_0 \equiv (\varepsilon_F / (\sigma - 1)) / (1 + \chi_F \alpha_F (\sigma - 1)) \), \( b_1 \equiv \varepsilon_F \alpha_F / (1 + \chi_F \alpha_F (\sigma - 1)) \), and \( b_2 \equiv -\alpha_F b_1; \psi^M \) is a time effect, and \( \xi^M_n + \nu^M_{nt} \) accounts for state effects and deviations from state and year effects in log productivity, \( \ln(z_{nt}) \).

The term \( MP_{nt} \) is the market potential of state \( n \) in year \( t \),

\[
MP_{nt} = \sum_{n'} E_{n't} \left( \frac{\tau_{n'n't}}{P_{n't}} \frac{\sigma}{\sigma - t_{n'n't} \sigma - 1} \right)^{1-\sigma},
\]

where \( E_{n't} \equiv P_{n't}Q_{n't} \) denotes aggregate expenditures in state \( n' \) and unit costs are given by

\[
c_{nt} = (u_{nt}^{1-\beta_n} \bar{r}_{nt}^{\beta_n})^{\gamma_n} P_{nt}^{1-\gamma_n}.
\]

Details on how we construct measures of all the covariates entering the right-hand side of (33) are contained in Appendix C.2. Given identification of the reduced-form parameters \( b_0, b_1 \) and \( b_2 \), the impact of government spending on productivity is identified as \( \alpha_F = -b_2 / b_1 \). The parameters \( \varepsilon_F \) and \( \chi_F \) are not separately identified; therefore, we present estimates for \( \varepsilon_F \) given values of \( \chi_F \in \{0, 0.5, 1\} \). Given an assumed value for \( \chi_F \), equation 32 contains three reduced form parameters (i.e. \( b_0, b_1 \) and \( b_2 \)) that jointly identify the two structural parameters \( \varepsilon_F \) and \( \alpha_F \). Therefore, we use a GMM estimator to directly estimate the parameter vector \( (\varepsilon_F, \alpha_F) \).

Our model predicts that estimates of \( (\varepsilon_F, \alpha_F) \) resulting from a GMM estimator that assumes that deviations from year and state effects in log-productivity in state \( n \), \( \nu^M_{nt} \), are mean independent of the market potential, real government spending and marginal production costs in the same state \( n \) are asymptotically biased. Therefore, we implement instead a GMM estimator that uses as instruments a vector of state and year effects, tax rates in both state \( n \) and in other states, and a shifter for market potential. Specifically, we use own-state corporate keep-tax rates \( Z^M_{nt} \equiv 1 - t_{nt}^{corp} - t_{fed,t}' \) a vector \( Z^M_{nt} = (t_{sc,t}^{f}, t_{sc,t}^{fx}, t_{nt}' \nu_Y) \) of external taxes already defined in (31), and an exogenous shifter \( MP^*_{nt} \) of the market potential term defined in (A.44). The exogenous shifter of

\[
\psi^M = (-\varepsilon_F / (\sigma - 1)) \ln(\sigma_{nt}) / (1 + \chi_F \alpha_F (\sigma - 1)) \text{ and } \xi^M_n + \nu^M_{nt} = (1 - \alpha_F) \varepsilon_F / (1 + \chi_F \alpha_F (\sigma - 1)) \star \ln(z_{nt}).
\]
market potential $MP_{nt}$ is constructed similarly to market potential, $MP_{nt}$, (see equation (33)), but differs from it in that we substitute the components $E_{nt}$, $P_{nt}$, and $\{\ell_{nt'}\}^N_{n'=1}$, which according to our model are correlated with $\nu^M_{nt}$, with functions of exogenous covariates. Appendix C.2 presents the precise definition of $MP^*_n$.

<table>
<thead>
<tr>
<th></th>
<th>A. All IVs</th>
<th>B. External IVs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fix $\sigma = 4$</td>
<td>Fix $\sigma = 5$</td>
</tr>
<tr>
<td>$\chi_F = 0$</td>
<td>$\varepsilon_F$</td>
<td>$\alpha_F$</td>
</tr>
<tr>
<td></td>
<td>2.4***</td>
<td>.1</td>
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<td></td>
<td>(.4)</td>
<td>(.09)</td>
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<tr>
<td>$\varepsilon_F = 0.5$</td>
<td>$\varepsilon_F$</td>
<td>$\alpha_F$</td>
</tr>
<tr>
<td></td>
<td>2.77***</td>
<td>.1</td>
</tr>
<tr>
<td></td>
<td>(.54)</td>
<td>(.09)</td>
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<td>$\chi_F = 1$</td>
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</tr>
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<td></td>
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</tr>
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<td></td>
<td>(.82)</td>
<td>(.09)</td>
</tr>
</tbody>
</table>

Notes: This table shows the GMM estimates for firm mobility parameters. The dependent variable is log of state establishments $\ln M_{nt}$. The data are at the state-year level. Each column has 661 observations. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total US population. After-tax market potential is based on $s_{int}$ and the instrument for market potential is $MP^*_n$, which excludes own state components and is described in more detail in Appendix C.2. Every specification includes state and year fixed effects. Robust standard errors clustered by state are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

Using standard asymptotics in panel data models, we assume that our panel data is fixed in the time dimension. The GMM estimator that uses $Z^M_{nt}$, $Z^M_{nt'}$, and $MP^*_n$ as instruments assumes that $\nu^M_{nt}$, which represents the productivity level and the quality or the efficiency of government spending in state $n$ and period $t$, is mean independent of the functions of taxes included in $Z^M_{nt}$, $Z^M_{nt'}$, and $MP^*_n$ in any time period, after controlling for year and state effects. Formally, $E[\nu^M_{nt}|Z^M_n, Z^M_{n'}, MP^*_n, \psi^M_t] = 0$, where $Z^M_n = (Z^M_{n1}, \ldots, Z^M_{nt}, \ldots, Z^M_{n'T})$ and analogously for $Z^M_{nt'}$ and $MP^*_n$. An implication of this assumption is that corporate tax rates in state $n$ must affect that state’s number of establishments only through their effect on the real government spending, unit production costs, and market potential of that state. The orthogonality conditions necessary
for consistency of our GMM estimator are weaker when we only rely on state fixed effects, year
fixed effects, and the vectors $Z_{nt}^M$ and $MP_{nt}^*$ to construct moments. In this case, the resulting
GMM estimates are consistent even if corporate taxes in state $n$ react to changes in the unobserved
productivity of state $n$, as captured in the composite $v_{nt}^M$.

Table 3 presents the GMM estimates. Columns (1) and (2) show the results using the vector of
instruments $(Z_{nt}^M, Z_{nt}^M, MP_{nt}^*)$, and columns (3) and (4) show the results using only the vector of
external instruments $(Z_{nt}^M, MP_{nt}^*)$. The estimates that rely on the later vector of instruments are
consistent even in the case in which states react to productivity shocks by changing their corporate
tax rate; therefore, we choose the specification in column (3) as our preferred specification. For the
pair $(\sigma, \chi_F) = (4, 1)$, it yields estimates $\varepsilon_F = 3.08 (1.04)$ and $\alpha_F = 0.04 (0.09)$. These estimates
are broadly consistent with alternative estimates found in the existing literature (see Appendix C.4
for details).

4.4 Over-Identification Checks

We study the implications of the estimated model for moments not targeted by the parametriza-
tion described above.

First, Panels (a) and (b) of Figure A.2 in Appendix C.3 compare the model implications for
the share of state $n$ in national GDP and in the total number of establishments against the data in
2007. 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.48

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

Third, panels (d) to (f) of Figure A.2 compare the model-implied share in tax revenue for each
type of tax against the the actual shares observed in the data.49 We see a positive correlation
between the data and the model-implied shares, although the model tends to over-predict the
importance of corporate income taxes and under-predict the importance of individual income taxes.
These differences are due in part to the use of average (rather than progressive) income rates for
each state and to the model assumption that all companies are C-corporations and therefore pay
corporate taxes. In robustness checks, we verify how the results change when we use alternative
tax rates that account for progressivity of the income tax and adjust corporate tax rates for the

48From (A.9) in Appendix B.2, the share of state $n$ in national GDP in the model is $GDP_n/GDP = (\gamma_n(\sigma - 1) + 1)X_n / \left( \sum_{n'} (\gamma_n'(\sigma - 1) + 1)X_n' \right)$.

49The revenue shares are constructed in the data using the same variables as in the model, e.g., panel (d) cor-
responding to the sales tax shows the distribution of $R_n/R_n = R_n^c / (R_n + R_n^c + R_n^{corp})$ both in the model and
data.
5 Measuring the Spatial Misallocation from State Taxes

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

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

$$\hat{v} = \left( \sum_n L_{n,2007} \hat{v}_n^{\epsilon W} \right)^{\frac{1}{\epsilon W}},$$

where, from (5), $\hat{v}_n$ depends on the change in after-tax real wages and real government spending in state $n$.\footnote{Specifically, $\hat{v}_n = \left( \frac{1-T_n^{\epsilon W}}{1-T_n^{\epsilon W},2007} \frac{\hat{w}_n}{\hat{w}_n^{\epsilon W}} \right)^{1-\alpha W} \left( \frac{\hat{G}_n}{\hat{G}_n^{\epsilon W}} \right)^{\alpha W}$.} The change in welfare is an employment-weighted average of the changes in each state’s appeal, as captured by the $v_n$’s. This measure excludes the gains or losses accruing to firms and fixed factors. Therefore, as a second aggregate measure, we also consider the change in the aggregate real income of all factors. Aggregate real income is defined as the aggregation of real state GDP’s: $GDP^{real} = \sum_n GDP_n / P_n$. Equation (A.10) in Appendix B.2 shows the expression for real GDP in the counterfactual relative to the initial scenario.

Impact of Tax Dispersion on Real Income and Welfare In specific parametrizations of our model, dispersion in tax rates across states can be shown to reduce real income and welfare. This is the case, for example, if there are no trade costs, no trade imbalances, government spending does not change with taxes, workers are perfectly mobile, the number of firms in each state is exogenously fixed, and there is no dispersion in amenities.\footnote{In that case, the production side of our model collapses to the structure in Hsieh and Klenow (2007), with dispersion in tax rates across states in our model playing a similar role to dispersion in wedges across firms in theirs.} However, more generally it is theoretically unclear whether eliminating tax dispersion improves welfare and real income. A first reason is that, keeping government spending constant, unobserved amenities imply that real income is not maximized under homogeneous taxes. Second, as we have already mentioned, our model features agglomeration forces through home-market effects, whereby the returns to locating in a state increase with the number of workers and firms located in that state and in close-by states. Additionally, when government...
spending is allowed to change with taxes, the number of workers located in each state impacts the provision of public services in that state and in other states through each state’s government budget constraint. Because of these spatial externalities, the market allocation is not generically efficient and, therefore, distortions that make the equilibrium different from the market allocation are not generally welfare and real-income reducing. As a result, the assumptions embedded in our model do not impose an answer for whether eliminating tax dispersion leads to welfare gains.\textsuperscript{52}

\textbf{Definition of Spatial Misallocation} Taxes impact aggregate outcomes through two channels: the allocation of labor, firms and trade flows across regions, and the allocation of aggregate spending between public services provided by the government and final consumption goods provided by the private sector. As our focus is on the first channel, we engineer an elimination of tax dispersion such that spending in public services remains unaffected. Specifically, we define the spatial misallocation caused by the US state tax distribution as the welfare and real-income gains (if they exist) that would result from eliminating the observed dispersion in tax rates across states in a way that keeps government size constant. We use two measures of state government size. We undertake a \textit{revenue-neutral} counterfactual by bringing each tax to a percentile of its distribution such that the aggregate tax revenue collectively raised by all states is the same as in the initial scenario; i.e., in the \textit{R-neutral} scenario,\textsuperscript{28} $\sum_{n=1}^{N} R'_{n} = \sum_{n=1}^{N} R_{n}$, where $R'_{n}$ is the tax revenue of state $n$ in the counterfactual scenario, and $R_{n}$ is defined in (22). We also undertake a \textit{spending-neutral} counterfactual by bringing each tax to a percentile of its distribution such that the aggregate tax revenue collectively raised by all states jointly with a system of cross-state transfers allows each state to keep government spending constant at its initial level; i.e., in the \textit{S-neutral} scenario, \textsuperscript{53}$\sum_{n=1}^{N} R'_{n} = \sum_{n=1}^{N} P'_{n} G_{n}$, and $G'_{n} = G_{n}$ for all $n$. In both counterfactuals, dispersion tax rates across states is eliminated by bringing taxes to some percentile of their initial distribution; in the revenue-neutral counterfactual, there is a redistribution of real government spending from initially high-tax states to initially low-tax states, while in the spending-neutral counterfactual real government spending is kept constant in all states.

5.1 Benchmark

Table 4 presents the results for the spatial-misallocation counterfactual using the benchmark parametrization and definitions of tax rates. The first row shows the results for the case in which we eliminate the dispersion in all taxes simultaneously; the remaining rows show the results for the elimination of the dispersion in one type of tax at a time. The columns labeled “S-neutral” show the results from the spending-neutral counterfactual described above, and the columns labeled “R-neutral” show the results from the revenue-neutral counterfactual described above.\textsuperscript{53}

\textsuperscript{52}Eeckhout and Guner (2014) find that heterogeneity in income taxes across cities may be welfare-maximizing in a setup with externalities from city size.

\textsuperscript{53}When dispersion in all taxes is eliminated, the revenue-neutral counterfactual is implemented if each tax rate is brought to the 43th percentile of their respective distributions. Eliminating dispersion only in income, sales, or corporate taxes is revenue-neutral when the corresponding tax rate is brought to the 28th, 53th, and 54th percentile of its distribution across states, respectively. These percentiles also implement the spending-neutral counterfactual.
The direct welfare effect of these tax changes, defined as their impact on worker welfare keeping prices, government spending, and employment constant at their initial values, is negligible: because some tax rates increase and others decrease, the real consumption does not change at the initial prices.\footnote{We measure the direct welfare effect of tax changes keeping prices, government spending and allocations constant by evaluating (34) at the state-specific effects $\tilde{v}_n^{\text{direct}} = \left( (1 - T'_n) / (1 - T_{n, 2007}) \right)^{1 - \alpha W}$ instead of the full $\tilde{v}_n$ effects defined in footnote 50.}

Eliminating of dispersion in all taxes in the spending-neutral way leads to a welfare gain of 0.12%, pointing to the existence of distortionary effects from heterogeneity in taxes. The welfare gains are 0.69% in the revenue-neutral counterfactual, with similar gains in terms of real GDP.\footnote{We also undertake an alternative counterfactual in which, for each type of tax, we replace the tax rate in every state with its average across states. In this case, the welfare and real-income gains are 0.79% and 0.60%, respectively. While this counterfactual happens to be nearly revenue-neutral, the direct effect from this tax change keeping prices, government spending, and employment constant at their initial values is 0.24%; i.e., while some tax rates increase and others decrease, the change in the distribution is such that consumers end up paying lower taxes at the initial prices, leading to higher welfare.}

Simultaneously harmonizing all taxes is important to reach welfare gains; e.g., only eliminating dispersion in sales taxes in a revenue-neutral way leads to a slight welfare losses. We also compute changes in real consumption of workers and capital-owners; in the revenue-neutral counterfactual, the real consumption of workers increases by 0.3% and consumption of capital owners increases by 0.4%.\footnote{(A.12) and (A.13) in Appendix B.2 show the expressions used to compute the change in aggregate real consumption.}

We recall that these gains correspond to revenue- or spending- neutral changes in taxes whose aggregate tax revenue only adds up to 4% of GDP. Therefore, the results point to considerable distortionary effects from tax dispersion relative to the initial levels of tax revenue in GDP.

### Table 4: Removing Tax Dispersion: Benchmark

<table>
<thead>
<tr>
<th>Counterfactual</th>
<th>Welfare</th>
<th>Real GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-neutral</td>
<td>R-neutral</td>
</tr>
<tr>
<td>All state taxes</td>
<td>0.12%</td>
<td>0.69%</td>
</tr>
<tr>
<td>Income Taxes</td>
<td>0.13%</td>
<td>0.49%</td>
</tr>
<tr>
<td>Sales Taxes</td>
<td>0.01%</td>
<td>-0.08%</td>
</tr>
<tr>
<td>Corporate Taxes</td>
<td>0.08%</td>
<td>0.55%</td>
</tr>
</tbody>
</table>

\footnote{For the case of the trade-cost adjustment, the counterfactual distribution is degenerate at 1. Eliminating tax dispersion does not eliminate dispersion in the endogenous components of productivity and amenities because government spending over GDP, $P_n G_n / GDP_n$, is part of these adjustment and varies with the technology parameters of each state – see (29).}
to lower welfare, the welfare and GDP gains from eliminating tax dispersion must be associated with the reductions in dispersion in the adjusted fundamentals and not with changes in the levels of their distributions.

**Role of Trade Frictions** To explore the impact that trade costs have on the potential welfare gains from tax harmonization, we re-compute the revenue-neutral elimination of dispersion in all taxes starting from a different parametrization that, instead of matching the actual distribution of bilateral spending and sales shares across states (as done in the benchmark parametrization, see Section 4.2), assumes a world in which each state’s spending and sales shares on other states is proportional to the size of the origin and destination states, respectively. In the absence of corporate taxes, these symmetric shares would be the equilibrium outcomes of a model like that presented in Section (3) if there were no trade costs. Hence, this parametrization explores how our counterfactual results would differ in an environment in which trade costs are smaller. We find the welfare gain from the revenue-neutral elimination of tax dispersion to be larger (1.01%) in this case, pointing to a complementarity between reducing tax dispersion and eliminating barriers to trade.

### 5.2 Heterogeneous Preferences for Government Spending Across States

The benchmark model assumes that the preference for government spending $\alpha_W$ is the same across states. We study here how allowing for heterogeneity across states in workers’ preferences for government services affects our results. Preferences for publicly provided services might be different across states if there exists a complementarity of state-specific features and government services. For instance, spending in state parks will have a higher value in states that are rich in natural amenities.

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

We construct a second measure of heterogeneous preferences using the ratio of government spending to GDP to proxy for $\alpha_{W,n}$, as in Michaillat and Saez (2015); i.e. $\alpha_{W,GDP}^{R/GDP} = R_n/GDP_n$. This approach takes the stand that there might be multiple reasons why workers in different states might have different preferences for public goods (e.g., differences in skill level, differences in state

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

\[ \text{We find } \hat{\alpha}_0 = 0.17 (0.07) \text{ and } \hat{\alpha}_1 = -0.003 (0.025), \text{ which implies that states with higher Republican party vote have a smaller preference parameter for government spending. However, the small value of the estimate of } \hat{\alpha}_1 \text{ implies that preferences for public goods do not seem to vary much across states with the political index } POL_n. \text{ For details on the estimation procedure employed to estimate } \varepsilon_W, \alpha_0 \text{ and } \alpha_1, \text{ see Appendix D.2.} \]
characteristics that make every worker prefer a larger provision of public goods in one state than
in another) and that most of these reasons might be unobservable but that, no matter what these
reasons are, they are reflected in the observed ratio of government spending to GDP. To isolate
the effect of cross-state dispersion in the \( \alpha \)'s, we rescale the distribution of \( \alpha_{W,n}^{R/GDP} \) so that the mean of
its distribution coincides with the benchmark value of 0.17. This measure yields estimates of \( \alpha_{W,n} \)
between 0.147 and 0.218.

Table 5 reports the results from the spending-neutral and revenue-neutral counterfactuals under
each of these alternatives measures, and compares them with the benchmark. The first measure
of heterogeneous \( \alpha_{W,n} \) produces similar welfare and real-income effects as our benchmark. For the
second measure, we observe that allowing for heterogeneity across states moderately reduces the
revenue-neutral welfare effects (to 0.49% from the 0.69% in benchmark), but has not impact on the
predictions for real-income or the spending-neutral counterfactual.

Table 5: Removing Tax Dispersion Under Heterogeneous Preferences Across States

<table>
<thead>
<tr>
<th>Counterfactual</th>
<th>Welfare</th>
<th>Real GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-neutral</td>
<td>R-neutral</td>
</tr>
<tr>
<td>Benchmark</td>
<td>0.12%</td>
<td>0.69%</td>
</tr>
<tr>
<td>Political Heterogeneity</td>
<td>0.12%</td>
<td>0.67%</td>
</tr>
<tr>
<td>Revenue/GDP</td>
<td>0.11%</td>
<td>0.49%</td>
</tr>
</tbody>
</table>

5.3 Lower Weights of Government Spending in Preferences and Productivity

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

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

<table>
<thead>
<tr>
<th>Counterfactual</th>
<th>Welfare</th>
<th>Real GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-neutral</td>
<td>R-neutral</td>
</tr>
<tr>
<td>Benchmark</td>
<td>0.12%</td>
<td>0.69%</td>
</tr>
<tr>
<td>Lower ( \alpha )'s by 25%</td>
<td>0.14%</td>
<td>0.49%</td>
</tr>
<tr>
<td>Lower ( \alpha )'s by 50%</td>
<td>0.15%</td>
<td>0.34%</td>
</tr>
<tr>
<td>Lower ( \alpha )'s by 75%</td>
<td>0.17%</td>
<td>0.24%</td>
</tr>
<tr>
<td>( \alpha_W = \alpha_F = 0 )</td>
<td>0.19%</td>
<td>0.19%</td>
</tr>
</tbody>
</table>
5.4 Progressive Income Taxes

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

We use data from NBER TAXSIM for the period 1980-2010 on average effective income tax rates by state, year, and income group to estimate a linear function of income that best fits the actual relationship between income and average tax rates. We use OLS to estimate the parameters of the linear projection \( t_{y,2007}(y) = a_n + b_n y + \varepsilon_n \) and, using the estimates \( \{\hat{a}_n, \hat{b}_n\}_{n=1}^N \), we construct the income tax rate that a worker with income \( w \) living in state \( n \) must pay as \( t_{y,prog}^n(w) = \hat{a}_n + \hat{b}_n w \). We follow the same procedure using information on federal income tax rates, and construct a federal income tax rate in state \( n \) in our model as \( t_{y,prog}^{fed}(w) = \hat{a}_{fed} + \hat{b}_{fed} w \). The introduction of these progressive tax schedules in our model generalizes our benchmark results by allowing state income tax rates to change as a result of changes in state nominal wages. Because our model does not specify the number of capital owners living in a state and, therefore, does not yield a measure of capital income per capita, we assume that every capital owner in a state \( n \) pays the highest average income tax rate that the progressive tax schedule in state \( n \) imposes (i.e., the income tax rate for the highest income bracket).60

Table 7 reports the results. The first line shows the outcome of eliminating tax dispersion when the only departure from the benchmark is that federal income taxes are allowed to be progressive, the second line allows for progressivity in state income taxes, and the third line does so in the context of progressive federal and state income taxes.62 The results show that accounting for tax progressivity increases the welfare gains from both spending- and revenue-neutral tax harmonization.63 The spending-neutral effects on real GDP do not change with the introduction of income tax progressivity.

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

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

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

63 In the revenue-neutral case, the bulk of the increase in spatial misallocation is due to the introduction of progressive federal income taxes. This is consistent with results in Albouy (2009), who studied misallocation across U.S. cities due to federal income taxes.
Table 7: Removing Tax Dispersion under Progressive Income Taxes

<table>
<thead>
<tr>
<th>Counterfactual</th>
<th>Welfare</th>
<th>Real GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-neutral</td>
<td>R-neutral</td>
</tr>
<tr>
<td>Benchmark</td>
<td>0.12%</td>
<td>0.69%</td>
</tr>
<tr>
<td>Federal Progressive Only</td>
<td>0.14%</td>
<td>1.62%</td>
</tr>
<tr>
<td>State Progressive Only</td>
<td>0.40%</td>
<td>1.27%</td>
</tr>
<tr>
<td>State and Federal Progressive</td>
<td>0.45%</td>
<td>1.58%</td>
</tr>
</tbody>
</table>

5.5 Alternative Definitions of Corporate Taxes

Table 8 reports the results of the revenue- and spending-neutral elimination in dispersion in all taxes under 2 alternative ways of defining corporate taxes:

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

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

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

<table>
<thead>
<tr>
<th>Counterfactual</th>
<th>Welfare</th>
<th>Real GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-neutral</td>
<td>R-neutral</td>
</tr>
<tr>
<td>Benchmark</td>
<td>0.12%</td>
<td>0.69%</td>
</tr>
<tr>
<td>Corporate Taxes Adjusted for Tax Subsidies</td>
<td>0.10%</td>
<td>0.61%</td>
</tr>
<tr>
<td>Corporate Taxes Adjusted for Share of C-Corps</td>
<td>0.06%</td>
<td>0.42%</td>
</tr>
</tbody>
</table>

Data on the share of employment in C-corporations by state is obtained from the County Business Patterns.
5.6 Other Parametrizations

Our benchmark parametrization sets the value $\sigma = 4$ and assumes that the congestion parameters $\chi_W$ and $\chi_F$ equal 1. Table 9 reports the results for $\sigma = 5$ and for different congestion levels between 0 and 1. In each case, we use the estimates arising from the estimation strategies based on assuming that changes in state amenities and productivities are mean independent of external taxes.\(^{65}\) The last row uses the estimates of the structural parameters $\varepsilon_W$, $\alpha_W$, $\varepsilon_F$ and $\alpha_F$ that rely on imposing the assumption that changes in state amenities and productivities are mean independent not only of external taxes but also from own-state taxes. The results from spending-neutral counterfactuals change little across all these parametrizations. In the revenue-neutral case, misallocation decreases somewhat under larger $\sigma$, and is non-monotone with the congestion parameters. The estimation strategy that relies on assuming that each state’s changes in taxes are mean independent from their changes in amenities and productivity delivers considerably larger welfare and real-income effects in the revenue-neutral counterfactual, largely due to the higher value of the preference parameter for government spending implied by this estimate.

\section*{Table 9: Removing Tax Dispersion under Alternative Parametrizations}

\begin{tabular}{lll|ll}
<table>
<thead>
<tr>
<th>Counterfactual</th>
<th>Welfare</th>
<th>Real GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-neutral</td>
<td>R-neutral</td>
</tr>
<tr>
<td>Benchmark</td>
<td>0.12%</td>
<td>0.69%</td>
</tr>
<tr>
<td>Higher demand elasticity</td>
<td>0.08%</td>
<td>0.59%</td>
</tr>
<tr>
<td>Medium congestion</td>
<td>0.12%</td>
<td>0.78%</td>
</tr>
<tr>
<td>No congestion</td>
<td>0.13%</td>
<td>0.63%</td>
</tr>
<tr>
<td>All IV’s</td>
<td>0.09%</td>
<td>2.35%</td>
</tr>
</tbody>
</table>
\end{tabular}

6 Other Policies

6.1 Changes in Tax Rates in a Single State

In this section we try to answer the question: What are the effects of tax changes in one state on this same state and on other states? With this aim, we simulate a 1 percentage point reduction in the income tax of each state.\(^{66}\) Each counterfactual corresponds then to reduction in taxes in one state. We run each of these counterfactuals twice: keeping government spending exogenously constant, and allowing it to change according to each state’s budget constraint. Table 10 reports average percentage changes in employment, number of firms, real wage, real GDP, and real government spending across the fifty counterfactuals, both in the state enacting the tax change (“Own”) and on average in other states (“Rest of the U.S.”).

Keeping government spending constant, reducing income taxes increases welfare for the repre-

\(^{65}\)See Tables 2 and 3 for the specific estimates. In the cases in which the theoretical $\varepsilon_F > \sigma - 1$ condition is violated, we re-estimate $\varepsilon_F$ and $\alpha_F$ imposing the restriction that $\varepsilon_F > \sigma - 1$. This approach results in estimates of $\alpha_F$ between 0.03 and 0.05, which are similar to the unconstrained estimates.

\(^{66}\)In states where the average income tax is less than 1 percent we set its value equal to zero.
sentative U.S. worker. From (28), higher tax keep rates, i.e., $1 - T_n$, are similar to an increase in amenities, which raises the number of workers in the state lowering taxes in detriment of the rest of the U.S. This increase in labor supply reduces the wage in that state. Firms are also attracted to the state lowering taxes, leading to an increase in the set of varieties produced in that state. This increase in varieties partially offsets the real-wage decline through a reduction in the price index. After-tax real wages and rents increase; the combined effect of factor inflow and higher prices boost GDP, which increases in real terms; in the rest of the U.S., the effects on real wages and GDP have the opposite sign due to the reallocation of workers.

When government spending adjusts in every state to satisfy each states’ government budget constraint, government revenue in the state lowering income taxes falls. This reduction in tax revenue reduces the provision of public goods in that state state, which in turn reduces both labor supply and labor demand. As a result, both employment and real GDP fall in the state lowering taxes, and the welfare of the representative U.S. worker decreases.

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

$$\ln \left( \hat{L}_n \right) = 0.99 \times \ln \left( \frac{1 - T_n}{1 - T_n,2007} \right) + 0.99 \times \ln \left( \frac{\hat{w}_n}{\hat{P}_n} \right) + 0.20 \times \ln \left( \hat{G}_n \right) - 1.18 \times \ln \left( \hat{v} \right),$$

(35)

where the bar over each variable denotes an average across the fifty counterfactual changes in taxes, each corresponding to a 1 percentage point reduction in the income tax in a different state $n$. The first term in the right-hand side of (35) is the direct effect from the tax change keeping all general-equilibrium variables constant; given the estimate of $a_0$ in (30) and the average change in worker keep tax rates, it leads on average to an increase in employment. However, in general

\[\text{Table 10: State-by-state Reduction in Income Tax by 1 Percentage Point}\]

<table>
<thead>
<tr>
<th>Average Change in</th>
<th>G Constant</th>
<th>Total Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Own</td>
<td>Rest of U.S.</td>
</tr>
<tr>
<td>Aggregate Welfare</td>
<td>0.02%</td>
<td>-0.05%</td>
</tr>
<tr>
<td>Employment</td>
<td>0.70%</td>
<td>-0.01%</td>
</tr>
<tr>
<td>Firms</td>
<td>1.12%</td>
<td>-0.02%</td>
</tr>
<tr>
<td>Real Wage</td>
<td>-0.37%</td>
<td>0.01%</td>
</tr>
<tr>
<td>Real GDP</td>
<td>0.33%</td>
<td>-0.01%</td>
</tr>
<tr>
<td>Real Government Spending</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

\[\text{sentative U.S. worker. From (28), higher tax keep rates, i.e., } 1 - T_n, \text{ are similar to an increase in amenities, which raises the number of workers in the state lowering taxes in detriment of the rest of the U.S. This increase in labor supply reduces the wage in that state. Firms are also attracted to the state lowering taxes, leading to an increase in the set of varieties produced in that state. This increase in varieties partially offsets the real-wage decline through a reduction in the price index. After-tax real wages and rents increase; the combined effect of factor inflow and higher prices boost GDP, which increases in real terms; in the rest of the U.S., the effects on real wages and GDP have the opposite sign due to the reallocation of workers.} \]

\[\text{When government spending adjusts in every state to satisfy each states’ government budget constraint, government revenue in the state lowering income taxes falls. This reduction in tax revenue reduces the provision of public goods in that state state, which in turn reduces both labor supply and labor demand. As a result, both employment and real GDP fall in the state lowering taxes, and the welfare of the representative U.S. worker decreases.} \]

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

\[\ln \left( \hat{L}_n \right) = 0.99 \times \ln \left( \frac{1 - T_n}{1 - T_n,2007} \right) + 0.99 \times \ln \left( \frac{\hat{w}_n}{\hat{P}_n} \right) + 0.20 \times \ln \left( \hat{G}_n \right) - 1.18 \times \ln \left( \hat{v} \right), \]

(35)

\[\text{where the bar over each variable denotes an average across the fifty counterfactual changes in taxes, each corresponding to a 1 percentage point reduction in the income tax in a different state} n. \text{ The first term in the right-hand side of (35) is the direct effect from the tax change keeping all general-equilibrium variables constant; given the estimate of } a_0 \text{ in (30) and the average change in worker keep tax rates, it leads on average to an increase in employment. However, in general} \]

\[\text{To reach this expression we use (5) and the labor supply equation (7).} \]

\[\text{Note that this is different from the 0.7% change in own employment in the G-constant counterfactual reported in Table 10 because that number includes both the direct effect and the general-equilibrium effects through prices and aggregate welfare, i.e., the second and fourth components in the right-hand side of (35).} \]
equilibrium, the reduction in real wages and in the provision of public goods more than offsets the positive direct effect of the increase in the keep tax rate, leading to an overall fall in employment in the state reducing income taxes, with a large part of the reversal being driven by the change in government spending.

**Heterogeneous Impact Across States** The impact of a change in taxes in one state on states other than the state changing taxes is heterogeneous. For illustration purposes, we focus on the reduction in the income tax in one large state, California. Figure A.4 in Appendix E shows the heterogeneous response across states in terms of real wages, real GDP, employment, and number of firms. When government spending in every state is kept constant, employment in California grows and it shrinks in every other state, but the negative employment effect is smaller in states that trade more with California. The effects are reversed when government spending adjusts: economic activity in California shrinks and states in the East Coast gain more in terms of employment and number of firms relative to states with stronger trade links with California. This heterogeneity across states is caused by heterogeneity in trade flows between California and every other state, which affect the parametrized model through the spending and sales shares. Figure A.5 in Appendix E shows the employment change by state when government spending is allowed to adjust as a function of each state’s sales share to CA (left panel) and share of spending in goods coming from CA (right panel). Employment increases relatively less in states that rely more on California as either an export market or a source of imported products. Figure A.6 in Appendix E reproduces the same figure averaging across all counterfactuals, and it implies that the pattern in Figure A.5 is indeed representative of what happens when a typical U.S. state reduces the income tax.69

### 6.2 Changes in Apportionment Rules

According to some views, payroll-based apportionment tends to be more distortionary than sales-based apportionment. Table 11 reports the effects of moving to either 0%, 50%, or 100% sales-apportionment of corporate taxes simultaneously in every state. As shown in Table A.2, most states use sales-apportionment rates of 33% or 50%. Moving to no-sales-apportionment increases welfare by 0.22%, while moving fully into sales apportionment reduces welfare. In our model, sales apportionment may cause larger distortions because it impacts both the adjusted productivities in (26) and the adjusted trade costs in (27), while payroll-based apportionment only impacts the adjusted productivities. A way to assess the extra role of the trade-cost distortion is to repeat the counterfactual under a different parametrization that assumes frictionless trade. In this alternative

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69 These heterogeneous effects are driven by heterogeneity in trade linkages across states. A natural extension would be to allow for heterogeneity in linkages through labor mobility. This force can be introduced in our model by allowing for spatial correlation in the idiosyncratic amenity draws, for bilateral mobility similarly to how migration or commuting flows are introduced in Tombe et al. (2015), Monte (2014), or Monte et al. (2015), or for state-of-birth parameters in utility as in Diamond (2015).

70 Because of their expected distortionary effects, some authors propose shifting away from income- and into sales-based state tax state systems. For example, see Auerbach (2013), Zucman (2014), and Auerbach and Devereux (2015) for a discussion of these ideas.
parametrization, sales and spending shares are assumed to be independent from the identity of the exporter. In this case, the welfare gains of moving away from sales apportionment are considerably smaller. The smaller welfare loss from moving into sales apportionment under low trade costs suggests a complementarity between trade frictions and the distortions caused by the sales apportionment in causing reduction in welfare.

<table>
<thead>
<tr>
<th>Sales Apportionment</th>
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<th>G Constant</th>
<th>Total</th>
<th>Low Trade Costs</th>
</tr>
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<td></td>
<td>0.05%</td>
<td>0.22%</td>
<td>0.08%</td>
</tr>
<tr>
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<td></td>
<td>-0.03%</td>
<td>-0.11%</td>
<td>-0.01%</td>
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7 Conclusion

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

Our results suggest quantitatively important effects on aggregate real income and welfare (around 0.7%) from a revenue-neutral harmonization of sales, income, and corporate taxes, whose aggregate tax revenue across all states amount to 4% of U.S. GDP. In our model, these effects are largely driven by reallocations of workers, firms, and trade across states. Our results also highlight the importance of accounting for general-equilibrium forces when studying the effects of a tax change in one state on that same state, and of accounting for trade frictions when studying the impact that such a change in taxes may have on other states.

Our paper contributes to the ongoing debate about the impacts of the state tax structure in the U.S., but has also implications for similar debates taking place within the European Union.\textsuperscript{71} We also believe that a similar approach that combines a quantitative spatial equilibrium model with an estimation of key parameters using data on tax rates could be used to tackle questions related to taxation rules of multinational corporations.\textsuperscript{72} These questions are left for future research.

\textsuperscript{71}E.g., see Bénassy-Quéré et al. (2014) and Bettendorf et al. (2010).
\textsuperscript{72}E.g., see “Taxing the foreign profits of multinational firms,” VOX, Michael Devereaux, Clements Fuest, and Ben Lockwood, June 12, 2015, and Auerbach and Devereux (2015)
References


Appendices for Online Publication

A Appendix to Section 2 (Background)

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

Table A.1: Federal Tax Rates from 2007

<table>
<thead>
<tr>
<th>Type</th>
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<tr>
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</tr>
<tr>
<td>Payroll Tax $t_{fed}^w$</td>
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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 Disability Insurance and Medicare’s Hospital Insurance Program. See section F.1 for additional details.
Table A.2: State Tax Rates from 2007

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Notes: This table shows state tax rates in 2007 for personal income, general sales, corporate, and sales-apportioned corporate taxes, which is the product of the statutory corporate tax rate and the state’s sales apportionment weight. See the section 2.1 for details.
B  Appendix to Section 3 (Model)

B.1 Firm Maximization

The first-order condition of (9) with respect the quantity sold to \( n \) is:

\[
\frac{\partial \pi^j_i}{\partial q^j_{ni}} = \left(1 - \bar{\ell}^j_i\right) \frac{\partial \tilde{\pi}^j_i}{\partial q^j_{ni}} - \frac{\partial \bar{\ell}^j_i}{\partial q^j_{ni}} \tilde{\pi}^j_i = 0, \tag{A.1}
\]

where \( \tilde{\pi}^j_i \equiv \sum_{n=1}^{N} x^j_{ni} - \frac{\tau_{ni} \epsilon_{ni}}{z^j_i} q^j_{ni} \) are pre-tax profits, and where:

\[
\frac{\partial \tilde{\pi}^j_i}{\partial q^j_{ni}} = \frac{\sigma - 1}{\sigma} p^j_n \bar{P}^{1/\sigma} \bar{P}^{(\sigma - 1)/\sigma} (q^j_{ni})^{-1/\sigma} - c_i, \quad \text{(A.2)}
\]

\[
\frac{\partial \bar{\ell}^j_i}{\partial q^j_{ni}} = \frac{\sigma - 1}{\sigma} \left( t^j_i - \sum_n t^j_{ni} s^j_{ni} \right) \bar{p}^j_n / x^j_i. \tag{A.3}
\]

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

\[
p^j_{ni} = \frac{1}{1 - \bar{\ell}^j_i (\tilde{\pi}^j_i / x^j_i)} \frac{\sigma - 1}{\sigma} \frac{\tau_{ni} \epsilon_{ni}}{z^j_i}, \tag{A.2}
\]

where

\[
\bar{\ell}^j_i = \frac{\tilde{\ell}^j_i - \sum_n t^j_{ni} s^j_{ni}}{1 - t^j_i}. \tag{A.3}
\]

Expressing pre-tax profits as \( \tilde{\pi}^j_i \equiv \sum_{n=1}^{N} x^j_{ni} \left(1 - \frac{\tau_{ni} \epsilon_{ni}}{z^j_i} \bar{p}^j_n / p^j_{ni}\right) \), replacing (A.2) and using that \( \sum_n s^j_{ni} t^j_{ni} = 0 \) yields \( \tilde{\pi}^j_i = x^j_i / \sigma \). This implies

\[
p^j_{ni} = \frac{\sigma}{\sigma - \bar{\ell}^j_i} \frac{\sigma - 1}{\sigma} \frac{\tau_{ni}}{z^j_i}. \tag{A.4}
\]

Finally, note that export shares are independent of productivity, \( z^j_i \):

\[
s^j_{ni} = \frac{E_n \left( \bar{p}^j_n \right)^{1 - \sigma}}{\sum_{n' = 1}^{N} E_{n'} \left( \bar{p}^j_{n'} \right)^{1 - \sigma}} = \frac{E_n \left( \frac{\sigma - t^j_n}{\tau_{ni}} \right)^{\sigma - 1}}{\sum_{n' = 1}^{N} E_{n'} \left( \frac{\sigma - t^j_{n'}}{\tau_{n'i}} \right)^{1 - \sigma}}. \tag{A.5}
\]

Equations (A.3) and (A.5) for \( n = 1, \ldots, N \) define a system for \( \{\bar{\ell}^j_i\} \) and \( \{s^j_{ni}\} \) whose solution is independent from \( z^j_i \). Therefore, \( \bar{\ell}^j_i = \tilde{\ell}^j_i \) and \( s^j_{ni} = s_{ni} \) 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 \( X_i \):

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

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

\[
\tau_i H_i = \beta_i \gamma_i \frac{\sigma - 1}{\sigma} X_i. \tag{A.8}
\]

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

\[
GDP_n = (\gamma_n (\sigma - 1) + 1) \bar{H}_n. \tag{A.9}
\]
From (A.9) and 20, aggregate real GDP in the counterfactual relative to the initial scenario is:

\[
\tilde{GDP}^{real} = \sum_n \left[ \frac{-\gamma_n(\sigma-1)+1}{(1-\beta_n)\gamma_n(\sigma-1)} \frac{w_n L_n}{P_n} \tilde{w}_n L_n P_n \right].
\]  

(A.10)

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

\[
P_n C_n = P_n C^n_W + \frac{(1-t^n_{fed})(1-t^n_t)}{1+t^n_t} b_n (\Pi + R),
\]  

(A.11)

where \(C^n_W = (1 - T_n) \frac{w_n L_n}{P_n}\) is the consumption of workers and \(C^n_K = \frac{(1-t^n_{fed})(1-t^n_t)}{1+t^n_t} b_n (\Pi + R)\) 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:

\[
\tilde{C}^W = \sum_n \left[ \frac{(1 - T_n) \frac{w_n L_n}{P^n_n}}{\sum_n' (1 - T_n') \frac{w_{n'} L_{n'}}{P_{n'}}} \right] C^n_W.
\]  

(A.12)

\[
\tilde{C}^K = \sum_n \left[ \frac{\frac{1-t^n_{fed}}{1+t^n_{fed}} b_n}{\sum_n' \frac{1-t^n_{fed}}{1+t^n_{fed}} b_{n'}} \right] C^n_K.
\]  

(A.13)

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

\[
P_n G_{n,fed} = (t^n_{fed} + t^n_t) w_n L_n + b_n t^n_{fed} (\Pi + R) + b_n t^n_{corp} \sum_{n'} \tilde{\Pi}_{n'}.
\]  

(A.14)

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

**Trade Imbalances** Aggregate expenditures \(P_n Q_n\) and sales \(X_n\) of state \(n\) may differ for two reasons. First, differences in the ownership rates \(b_n\) lead to differences between the gross domestic product of state \(n\), \(GDP_n\), and the gross income of residents of state \(n\), \(GSI_n\). Second, differences in ownership rates \(b_n\) and in sales-apportioned corporate taxes \(t^n_{corp}\) across states create differences between the corporate tax revenue raised by state \(n\)’s government \((R^n_{corp})\) and the corporate taxes paid by residents of state \(n\) \((TP^n_{corp})\). As a result, the trade imbalance in state \(n\), defined as difference between expenditures and sales in that state, can be written as follows:73

\[
P_n Q_n - X_n = (GSI_n - GDP_n) + (R^n_{corp} - TP^n_{corp}).
\]  

(A.15)

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

---

73To reach this relationship, first impose goods market clearing (4) to obtain \(P_n Q_n = \tilde{P}_n (C_n + G_{n,fed} + G_n + I_n)\). Then, note that personal-consumption expenditures can be written as \(P_n C_n = \tilde{GSI}_n - (R^n_t + R^n_{corp} + TP^n_{corp}) - P_n G_{n,fed}\), where the terms between parentheses are tax payments made by residents of state \(n\) to state governments and \(P_n G_{n,fed}\) are taxes paid to the federal government. Combining these two expressions and using the state’s government budget constraint (22) gives \(P_n Q_n = (GDP_n + \tilde{P}_n I_n) + (GSI_n - GDP_n) + (R_n - TP_n)\). Adding and subtracting \(GDP_n\) and noting that by definition \(GDP\) gives (A.15).
we can write each component of (A.15) other than GDP as follows:\footnote{\ref*{(A.16)} and (A.18) are by definition. For (A.17), combine (23) with (19) and (20).}

\[ GSI_n = b_n \left( \hat{\Pi} + \hat{R} \right) + w_n L_n, \]  
\[ R_{n \text{corp}} = \frac{1}{\sigma} \left( t^*_n P_n Q_n + t^*_n X_n \right), \]  
\[ TP_{n \text{corp}} = b_n \sum_{n'} \left( \bar{t}_{n'} - t^*_{n \text{fed}} \right) \hat{\Pi}_{n'}. \]  

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

\[
\frac{P_n Q_n}{X_n} = \frac{1}{\sigma - t^*_n} \left( (\sigma - 1) (1 - \beta_n \gamma_n) + t^*_n + \frac{b_n}{\Pi_n / \left( \Pi + R + t^*_{f \text{ed}} \hat{\Pi} \right)} \right), \quad \text{(A.19)}
\]

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

\[
\frac{\hat{\Pi}_n}{\Pi + R + t^*_{f \text{ed}} \hat{\Pi}} = \frac{X_n}{\sum_i \left( 1 - t^*_n - t^*_n + \beta_i (\sigma - 1) \right) X_i}. \quad \text{(A.20)}
\]

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

\[
b_n = \frac{\hat{\Pi}_n}{\Pi + R + t^*_{f \text{ed}} \hat{\Pi}} \left[ (\sigma - t^*_n) \left( \frac{P_n Q_n}{X_n} \right) - (\sigma - 1) (1 - \beta_n \gamma_n) - t^*_n \right]. \quad \text{(A.21)}
\]

**B.3 General-Equilibrium Conditions**

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

\[
\sum_n \lambda_{in} = 1 \quad \text{for all } i. \quad \text{(A.22)}
\]

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

\[
\sum_i s_{in} = 1 \quad \text{for all } n. \quad \text{(A.23)}
\]

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

\[
\lambda_{in} = A_{in} \left( \frac{w_n}{\bar{\pi}} \right)^{1 - \kappa_i} L_n^{1 - \kappa_n} \left( \frac{w_i}{\bar{\pi}} \right)^{\sigma - 1} L_i^{-\kappa_3}, \quad \text{(A.24)}
\]

\[
s_{in} = \lambda_{in} \frac{P_n Q_n}{X_i} \left( \frac{w_n}{\bar{\pi}} \right) L_n \left( 1 - \beta_i \gamma_i \right), \quad \text{(A.25)}
\]

where \( A_{in} \) is given by

\[
A_{in} = \left( H_n^{\beta_n \gamma_n \Theta_{1n}} \Theta_{1n} \frac{w_n}{\bar{\pi}^{\gamma_n}} \left( \frac{\Theta_{2n} u^A}{\bar{\pi}^{\gamma_n}} \right)^{\sigma - 1} \right)^{\gamma_n + \alpha^p \gamma_n}, \quad \text{(A.26)}
\]
where \( \{ z_A^n, r_A^n, u^n_A \} \) are defined in (26) to (28) in the text, and where \( \{ \Theta_1n, \Theta_2n \} \) are functions of parameters:

\[
\Theta_1n = \left( \frac{1 - \beta_n}{\beta_n} \right)^{\gamma_n} \left( \frac{1}{(1 - \beta_n) \gamma_n (\sigma - 1)} \right)^{\frac{1}{\sigma F}} \left( \frac{\gamma_n (\sigma - 1) + 1}{(1 - \beta_n) \gamma_n (\sigma - 1)} \right)^{\frac{1}{\alpha F}},
\]

\[
\Theta_2n = \left( \gamma_n (\sigma - 1) + 1 \right)^{\alpha W} \left( \frac{1}{(1 - \beta_n) \gamma_n (\sigma - 1)} \right)^{\alpha W}.
\]

The parameters \( \{ \kappa_1, \kappa_2n, \kappa_3 \} \) in (A.24) and (A.25) are given by:

\[
\kappa_1 = (\sigma - 1) \left( \frac{1}{\varepsilon_F} + \alpha_F \chi_F + 1 \right),
\]

\[
\kappa_2n = (\sigma - 1) \left[ \left( \frac{1}{\varepsilon_F} - \alpha_F (1 - \chi_F) + \beta_n \gamma_n \right) - (1 - \gamma_n + \alpha_F) \left( \frac{1}{\varepsilon_W} - \alpha_W (1 - \chi_W) \right) \right],
\]

\[
\kappa_3 = (\sigma - 1) \left( \frac{1}{\varepsilon_W} - (1 - \chi_W) \alpha_W \right).
\]

Equations (A.22) to (A.26), together with (8), (A.19), and (29) give the solution for import shares \( \{ \lambda_{in} \} \), export shares \( \{ s_{in} \} \), employment shares \( \{ L_n \} \), wages relative to average profits \( \{ w_n \} \), government sizes \( \{ P_n G_n / GDP_n \} \), relative trade imbalances \( \{ P_n Q_n / X_n \} \), and utility \( v \). 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 \( (\beta_n = \beta, \gamma_n = \gamma) \) for all \( n \); ii) there is no dispersion in sales-apportioned corporate taxes across states \( (t^*_n = \tau^* \text{ for all } n) \); 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 (28) and (26) are primitives (exogenous functions of fundamentals and own-state taxes). Define:

\[
K_{1n} = \tau_{in}^{1-\sigma},
\]

\[
\gamma_n = \bar{A}_n^{s-1} w_n^{1-\kappa_1} L_n^{1-\kappa_2},
\]

\[
\delta_i = \left( \bar{\pi}_i / \bar{W} \right)^{\sigma-1} u_i^{\gamma} L_i^{1-\kappa_3},
\]

where

\[
\bar{A}_n = \frac{1}{\beta^\frac{\sigma}{\sigma + 1} (1 - \gamma) + \alpha_F},
\]

\[
\bar{\pi}_i = \frac{u_i^{\gamma}}{(\beta^\frac{\sigma}{\sigma + 1} (1 - \gamma) + \alpha_F)},
\]

\[
\bar{W} = v^{\gamma - \alpha F}.
\]

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

\[
X_n = \frac{1}{\bar{A}_n} \gamma_n^{\frac{\sigma - (1 - \kappa_3)}{(1 - \kappa_2) + (1 - \kappa_1)}} \delta_i^{\frac{(1 - \kappa_2) - (1 - \kappa_3)}{(1 - \kappa_2) + (1 - \kappa_1)}}.
\]

---

75 The terms \( u^n_A, r^n_A, \) and \( z^n_A \) which enter in (A.26) are function of the export shares \( \{ s_{in} \} \) and government sizes \( \{ P_n G_n / GDP_n \} \). Government sizes and trade deficits also depend on the terms \( \{ \Pi_n, \Pi, \Pi + R \} \). These variables can be expressed as a function of export shares, labor compensation and parameters.
for a constant $B_n$ that is a function $\bar{X}_n$, $\pi_n$, and parameters, and where $\bar{X} = \sum_{n} C_n^{d} d_{n}^{\sigma}$. Second, using that labor shares add up to 1, the solution for $w_n$ from (A.30) and (A.31), and (A.7) allows us to write $\bar{X}_n^{1+\alpha} = \sum_{n} C_n^{d} d_{n}^{\sigma}$, for some constants $a$, $d$, and $e$ which are functions of $\sigma$, $\kappa_1$, $\kappa_2$ and $\kappa_3$. This satisfies Condition 4', so that we can apply their Corollary 2 to reach a uniqueness condition for the system of equations in $\{L_n, w_n, v\}$ in (A.22) to (A.23):

$$\frac{\sigma - (1 - \kappa_3)}{\sigma (1 - \kappa_2) - (1 - \kappa_3) (1 - \kappa_1)} > 1,$$

$$\frac{\kappa_1 - \kappa_2}{\sigma (1 - \kappa_2) - (1 - \kappa_3) (1 - \kappa_1)} > 1,$$

where $\kappa_1$ to $\kappa_3$ are defined in (A.27) to (A.29). These steps hold taking as given the value of $\pi$; since (the inverse of) $\pi$ enters as a proportional shifter of wages, the condition applies to the solution of $\{L_n, w_n, v\}$.

### 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, $(t_{n}^{n'}, t_{n}^{e}, t_{n}^{c}, t_{n}^{l})_{n=1}^{N}$, to a new distribution $(\hat{t}_{n}^{n'}, \hat{t}_{n}^{e}, \hat{t}_{n}^{c}, \hat{t}_{n}^{l})_{n=1}^{N}$. Letting $\hat{x} = x' / x$ be the counterfactual value of $x$ relative to its initial value, we have that the changes in import shares, export shares, employment shares, and wages $(\hat{\lambda}_{n}, \hat{s}_{n}, \hat{L}_{n}, \hat{w}_{n})_{n=1}^{N}$ as well as the welfare change $\hat{v}$ must be such that conditions (A.22) and (A.23) hold:

$$\sum_{n} \lambda_{in} \lambda_{in} = 1 \text{ for all } i,$$

$$\sum_{i} s_{in} s_{in} = 1 \text{ for all } n,$$

where, using (A.24) and (A.25) and normalizing $\hat{\tau} = 1$,

$$\hat{\lambda}_{in} = \frac{A_{in} \hat{w}_{n}^{1-\kappa_1} \hat{L}_{n}^{1-\kappa_2} \hat{w}_{n}^{\sigma-1} \hat{L}_{n}^{\kappa_3}}{A_{in}},$$

$$\hat{s}_{in} = \frac{\hat{P}_{i} Q_{i}}{\hat{w}_{n} L_{n}}$$

and where using (A.26)

$$\hat{A}_{in} \propto \left( \frac{\hat{z}_{n}^{A}}{\tau_{in}^{A}} \right)^{(1-\gamma_{n})+\alpha F \gamma_{n}} \left( \frac{u_{n}^{\alpha F}}{\hat{w}_{n}^{\alpha F}} \right)^{\sigma-1}$$

and where, from (27) to (28),

$$\tau_{in}^{A} = \frac{\sigma - \hat{t}_{in}}{\sigma - (\hat{t}_{in}),}$$

$$\hat{z}_{n}^{A} = \left( \frac{1 - (\hat{t}_{n}^{e})^{\gamma_{n}}}{1 - T_{n}} \right)^{\frac{1}{\alpha F}} \left( \frac{P_{n}^{F} G_{n}}{GDP_{n}} \right)^{\alpha F},$$

$$\hat{u}_{n}^{A} = \left( \frac{1 - T_{n}}{1 - \alpha W_{n}} \right)^{1-\alpha W} \left( \frac{P_{n}^{W} G_{n}}{GDP_{n}} \right)^{\alpha W}. $$

Additionally, labor shares must add up to 1 :

$$\sum_{n} L_{n} \hat{L}_{n} = 1.$$
C Appendix to Section 4.3 (Estimated Parameters)

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

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

Note that the new government sizes and trade deficits also depend on the new values of $\Pi'$ and $\Pi + R$; these variables can be expressed as a function of initial conditions and changes in the endogenous variables, $\Pi' = (1/\sigma) \sum_i w_i L_i (\hat{\bar{w}}_i \hat{L}_i)$ and $\Pi' + R' = (1/\sigma) \sum_i (1 - (\hat{\bar{t}}_i \gamma_i (\sigma - 1)) w_i L_i (\hat{\bar{w}}_i \hat{L}_i)$.
### Table A.3: First Stage of Labor-Supply Equation

<table>
<thead>
<tr>
<th></th>
<th>ln($\tilde{w}_{nt}$)</th>
<th>ln($R_{nt}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(1 − $T_{nt}$)</td>
<td>1.0*</td>
<td>-7.2***</td>
</tr>
<tr>
<td></td>
<td>(0.6)</td>
<td>(2.2)</td>
</tr>
<tr>
<td>ln $Z_{nt}^{corp}$</td>
<td>-1.0***</td>
<td>-0.1</td>
</tr>
<tr>
<td></td>
<td>(0.2)</td>
<td>(0.5)</td>
</tr>
<tr>
<td>ln $t^c_{nt}$</td>
<td>2.4**</td>
<td>4.1***</td>
</tr>
<tr>
<td></td>
<td>(1.1)</td>
<td>(0.6)</td>
</tr>
<tr>
<td>ln $t^y_{nt}$</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>(0.4)</td>
<td>(0.5)</td>
</tr>
<tr>
<td>ln $t^x_{nt}$</td>
<td>0.7***</td>
<td>-0.1</td>
</tr>
<tr>
<td></td>
<td>(0.3)</td>
<td>(0.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observations</th>
<th>796</th>
<th>796</th>
<th>796</th>
<th>796</th>
</tr>
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<tbody>
<tr>
<td>F-stat:</td>
<td>17.49</td>
<td>18.35</td>
<td>12.15</td>
<td>13.64</td>
</tr>
</tbody>
</table>

**Notes:** This table shows the first stage estimates for labor supply. The dependent variables are after-tax real wages and real government expenditures in columns (1)-(2) and (3)-(4), respectively. The data are at the state-year level. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total US population. Every specification includes state and year fixed effects. Robust standard errors are in parentheses and *** p < 0.01, ** p < 0.05, * p < 0.1.

### Table A.4: GMM Estimates of Labor Mobility Parameters

<table>
<thead>
<tr>
<th></th>
<th>A. All IVs</th>
<th>B. External IVs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>$\chi W = 0$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon W$</td>
<td>1.31***</td>
<td>1.24***</td>
</tr>
<tr>
<td></td>
<td>(.23)</td>
<td>(.32)</td>
</tr>
<tr>
<td>$\alpha W$</td>
<td>.26***</td>
<td>.17*</td>
</tr>
<tr>
<td></td>
<td>(.07)</td>
<td>(.09)</td>
</tr>
<tr>
<td>$\chi W = 0.5$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon W$</td>
<td>1.57***</td>
<td>1.39***</td>
</tr>
<tr>
<td></td>
<td>(.33)</td>
<td>(.42)</td>
</tr>
<tr>
<td>$\alpha W$</td>
<td>.26***</td>
<td>.17*</td>
</tr>
<tr>
<td></td>
<td>(.07)</td>
<td>(.09)</td>
</tr>
<tr>
<td>$\chi W = 1$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon W$</td>
<td>1.97***</td>
<td>1.57***</td>
</tr>
<tr>
<td></td>
<td>(.56)</td>
<td>(.58)</td>
</tr>
<tr>
<td>$\alpha W$</td>
<td>.26***</td>
<td>.17*</td>
</tr>
<tr>
<td></td>
<td>(.07)</td>
<td>(.09)</td>
</tr>
</tbody>
</table>

**Notes:** This table shows the GMM estimates for structural parameters entering the labor mobility equation. The dependent variable is log state employment, ln $L_{nt}$. The data are at the state-year level. Each column has 712 observations. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total US population. Every specification includes state and year fixed effects. Robust standard errors are in parentheses and *** p < 0.01, ** p < 0.05, * p < 0.1.
C.2 Appendix to Section 4.3.2 (Firm-Mobility Elasticity)

C.2.1 Construction of Covariates

To construct measures of market potential $MP_{nt}$, real government services $\tilde{R}_{nt}$ and unit costs $c_{nt}$, we need data on prices: we use the consumer price index from the Bureau of Labor Statistics.\(^{77}\)

Constructing unit costs also requires data on the price of structures $r_{nt}$, which 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 expression of unit costs: $c_{nt} = \left( w_{nt}^{1-\beta_n} P_{nt}^{\beta_n} \right)^{\gamma_n} P_{nt}^{1-\gamma_n}.\(^{78}\)

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

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

$$P_{nt}Q_{nt} = \frac{(\sigma - 1)(1-\beta_n\gamma_n) + a_{nt} + \bar{t}_{nt}}{\sigma - \bar{t}_{nt}} \frac{\sigma}{\gamma_n(\sigma - 1) + 1} \text{GDP}_{nt},$$

(A.43)

where $a_{nt} \equiv \frac{b_0}{\bar{n}_n/(\bar{n}_nt + \text{dist}_{n\prime nt})}$. 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: $a_{nt} = a_{nt, 2007}$ for all $t$.\(^{79}\)

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

We define the instrument $MP_{nt}^*$ as a variable that has a similar structure to market potential $MP_{nt}$ in (33), but that differs from it in that we substitute the components $E_{nt}$, $P_{nt}$, and $\bar{E}_{nt}'$ that might potentially be correlated with $\nu_{nt}^M$ with functions of exogenous covariates that we respectively denote as $E_{nt}^*$, $P_{nt}^*$, and $\bar{E}_{nt}'^*$. We define $MP_{nt}^*$ as

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

(A.44)

In order to implement this expression, we need to construct measure of the variables $E_{nt}^*$, $P_{nt}^*$, and $\bar{E}_{nt}'^*$. We construct $E_{nt}^*$ using (A.43) with lagged GDP instead of period $t$’s GDP.\(^{80}\) We set $P_{nt}^* = 1 + t_{nt}^*$. We construct $\bar{E}_{nt}'^*$ using the expression for $\bar{E}_{nt}$ in (12) evaluated at hypothetical export shares defined as relative inverse log distances:

$$s_{int}^* = \frac{\ln(\text{dist}_{n\prime nt})^{-1}}{\sum_{n\prime \neq n} \ln(\text{dist}_{n\prime nt})^{-1} + 1} \forall t, i \neq n$$

We explore alternative ways to define the variable $MP_{nt}^*$ in Table A.5. Columns (1), (2), (5) and (6), use a measure of $MP_{nt}^*$ that differs from that described above in that $P_{nt}^*$ is set to equal 1. The results are very similar to those obtained in the baseline definition of $MP_{nt}^*$, using $P_{nt}^* = 1 + t_{nt}^*$. Columns (3), (4), (7) and (8) present

\(^{77}\)This is the same price data that is used in the estimation of the labor equation to construct measures of real government spending and real wages.

\(^{78}\)Projecting the decadal data on rental prices $r_{nt}$ on wages and local price indices, $w_{nt}$ and $P_{nt}$, and using the projection estimates in combination with annual data on $w_{nt}$ and $P_{nt}$ to compute predicted rental prices, $\tilde{r}_{nt}$, and predicted unit costs, $c_{nt} = \left( w_{nt}^{1-\beta_n} P_{nt}^{\beta_n} \right)^{\gamma_n} P_{nt}^{1-\gamma_n}$.\(^{78}\)

\(^{79}\)Using an alternate definition of $P_{nt}Q_{nt}$, i.e., $P_{nt}Q_{nt} = \text{constant} \times \text{GDP}_{nt}$, 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.

\(^{80}\)I.e., $E_{nt}^* = \frac{(\sigma - 1)(1-\beta_n\gamma_n) + a_{nt} + \bar{t}_{nt}}{\sigma - \bar{t}_{nt}} \frac{\sigma}{\gamma_n(\sigma - 1) + 1} \text{GDP}_{nt-1}$. A sufficient condition for an instrument that depends on lagged GDP to be exogenous is that the error term in equation (A.44) is independent over time.
estimates that use a measure of $MP^*_nt$, in which, for the construction of the terms $\tilde{t}^*_nt$, we use hypothetical export shares $\tilde{t}^*_nt$ constructed as the average over the observed export shares observed in the two periods that precede those used to construct $MP^*_nt$, $\tilde{t}^*_nt = \frac{s_{in,1993} + s_{in,1997}}{2}$. All these approaches produce similar estimates of the parameters.

Table A.5: Robustness of Firm Mobility Parameters

<table>
<thead>
<tr>
<th></th>
<th>A. All IVs</th>
<th>B. External IVs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Using $P^*_nt = 1$</td>
<td>Using $s_{in}$</td>
</tr>
<tr>
<td>Fix $\sigma = 4$</td>
<td>Fix $\sigma = 5$</td>
<td>Fix $\sigma = 4$</td>
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<td>$\chi^F = 0$</td>
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<td>$\varepsilon_F$</td>
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<td>3.11***</td>
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<tr>
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<td>.07</td>
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<td>(.08)</td>
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<td>$\chi^F = 0.5$</td>
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<td>3.56***</td>
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<td></td>
<td>(.09)</td>
<td>(.08)</td>
</tr>
<tr>
<td>$\chi^F = 1$</td>
<td>3.17***</td>
<td>4.02***</td>
</tr>
<tr>
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<td>(.8)</td>
<td>(1.25)</td>
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<tr>
<td>$\alpha_F$</td>
<td>.1</td>
<td>.07</td>
</tr>
<tr>
<td></td>
<td>(.09)</td>
<td>(.08)</td>
</tr>
</tbody>
</table>

Notes: This table shows the GMM estimates for firm mobility parameters using alternate definitions of the instrument for market potential $MP^*_nt$. The dependent variable is log state establishments in $M^*_nt$. The data are at the state-year level. Each column has 661 observations. Real variables are divided by a price index variable from BLS that is available for a subset of states which collectively amount to roughly 80 percent of total US population. Every specification includes state and year fixed effects. Each specification in the first four columns uses all instruments in $Z^M_{nt}$. Each specification in the last four columns, which are labeled external instruments, do not use the own-state tax instruments in $Z^M_{nt}$. Robust standard errors clustered by state are in parentheses and *** p<0.01, ** p<0.05, * p<0.1.
C.3 Appendix Figure to Section 4.4 (Over-Identification Checks)

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

(a) State GDP Share

(b) Share of Establishments

(c) State Tax Revenue as Share of GDP

(d) Sales Tax Revenue Share

(e) Income Tax Revenue Share

(f) Corporate Tax Revenue Share

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

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

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

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

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

Note: Slope is 1.65 (.14). R-squared is .74.
C.4 Comparison with Existing Estimates

Researchers have previously estimated regressions similar to (30) and (32) using sources of variation different from ours to identify the labor and firm mobility elasticities. Table A.6 compares our estimates of $\varepsilon_W$, $\alpha_W$, $\varepsilon_F$, and $\alpha_F$ to those that we would have constructed if we had used estimates of the elasticity of labor and firms with respect to after-tax wages and public expenditure from six recent studies. The parameter that is most often estimated is the elasticity of labor with respect to real wages; this previous literature implies estimates of $\varepsilon_W$ with mean value of 1.79. Our benchmark number of $\varepsilon_W = 1.49$ is within the range of these estimates. The firm-mobility parameter reported in Suárez Serrato and Zidar (2014) corresponds to $\varepsilon_F = 5.33$. 81

Concerning $\alpha_W$ and $\alpha_F$, there is substantial evidence that public expenditures have amenity and productivity value for workers and firms, respectively, which is consistent with $\alpha_W > 0$ and $\alpha_F > 0$. Some studies infer positive amenity value for government spending from land rents, 82 while others focus on the productivity effects of large investment projects. 83 However, very few papers estimate specifications similar to (30) and (32). The estimates of the effects of variation in federal spending at the local level from Suárez Serrato and Wingender (2011) imply $\alpha_F = 0.10$ and $\alpha_W = 0.26$.

Of course, all these comparisons are imperfect due to differences in the source of variation, geography, and time dimension; for example, all of these studies use smaller geographic units than states. Additionally, not all specifications include the same covariates as our estimating equations (30) and (32). These differences notwithstanding, our structural parameters are close to those in the literature.

81 Note that Suárez Serrato and Zidar (2014) focus on variation across local areas rather than across states, resulting in a higher amount of mobility.
82 E.g., Bradbury et al. (2001) show that local areas in Massachusetts with lower increases in government spending had lower house prices, and Cellini et al. (2010) show that public infrastructure spending on school facilities raised local housing values in California. Their estimates imply a willingness to pay $1.50 or more for each dollar of capital spending. Chay and Greenstone (2005) and Black (1999) also provide evidence of amenity value from government regulations on air quality and from school quality, respectively.
83 Kline and Moretti (2014) find that infrastructure investments in 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.
This table reports the values of our structural parameters implied by estimates of specifications similar to (30) and (32) 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.

- 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.
- This parameter comes from Table 3 in Notowidigdo (2011) and results from taking the ratio of columns (1) and (6). Note that these specifications also control for quadratic effects. We employ marginal effects around 0.
- This number is directly reported in Suárez Serrato and Zidar (2014) in Table 9.
- The parameters $a_0$ and $a_1$ come from Table 10 in Suárez Serrato and Wingender (2011) by manipulating the structural parameters as follows: $a_0 = 1/\sigma^i$ and $a_0 = \psi^i/\sigma^i$ for each skill group. The parameter $b_1$ comes from noting in Equation 21 that the effect of spending on firm location equals that of labor demand and by noting that this effect is equal to $1 - (\kappa^i_{GS} + (1 - \kappa^i_{GS})/(1 - \alpha_i)) \partial W^i/\partial F^i$ in Suárez Serrato and Wingender (2011). The parameters $\alpha^i, \kappa^i_{GS}$, and $\partial W^i/\partial F^i$ are reported in Tables 9 and 10 by skill group in Suárez Serrato and Wingender (2011). We then average these effects by the college share above.
- 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.
- We construct $a_0$ from Table 6, Panel (c) in Suárez Serrato and Zidar (2014) by taking the ratio of the effects on Population and Wages.
- We construct $a_0$ from Table 6, Panel (c) in Suárez Serrato and Zidar (2014) by taking the ratio of the effects on Population and Wages. $b_0$ is reported in Table 6, Panel (c).
- Giroud and Rauh (2015) report an elasticity of number of establishment with respect to corporate taxes of 0.4.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Estimates</th>
<th>Implied Values of</th>
<th>Source of Variation</th>
<th>Level of Variation</th>
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<td></td>
<td></td>
<td>$\varepsilon_W$</td>
<td>$\alpha_W$</td>
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<tr>
<td>Bound and Holzer (2000)</td>
<td>$a_0 = 1.26^a$</td>
<td>1.16</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>$a_0 = 1.58^c$</td>
<td>1.44</td>
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<tr>
<td>Suárez Serrato and Wingender (2011)</td>
<td>$a_0 = 2.9, a_1 = 1.02, b_1 = 0.26^d$</td>
<td>1.94</td>
<td>0.26</td>
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<td></td>
<td>$a_0 = 1.28^f$</td>
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<tr>
<td>Suárez Serrato and Zidar (2014)</td>
<td>$a_0 = 2.63, b_0 = 3.35^g$</td>
<td>2.06</td>
<td>5.33</td>
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<tr>
<td>Giroud and Rauh (2015)</td>
<td>$b_0 = 0.40^h$</td>
<td>1.34</td>
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</tbody>
</table>
D Appendix to Section 5 (Spatial Misallocation)

D.1 Appendix Figure to Section 5.1 (Benchmark)

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

(a) Amenity Adjustment

(b) Productivity Adjustment

(c) Trade Cost Adjustment

Notes: panels (a), (b) and (c) show, respectively, the distributions of $(1 - T_n)^{1 - \alpha_W} \Gamma_n^{\alpha_W}$, $(1 - \tilde{t}_n)^{1 - \alpha_F} \chi^{\alpha_F} \Gamma_n^{\alpha_F}$, and $\frac{\sigma}{\sigma - \tilde{t}_n}$ which enter in the adjusted fundamentals in (27) to (28) under the initial parametrization and in the counterfactual without tax dispersion. In Panel (c), the counterfactual distribution is degenerate at 1 because $\tilde{t}_n = 0$ for all $i, n$. 
D.2 Appendix to Section 5.2 (Heterogeneous Preferences for Government Spending)

For this counterfactual, we assume that $\alpha_{W,n} = \alpha_0 + \alpha_1 POL_n$, where $POL_n$ is a standardized political index constructed by Caesar and Saldin (2005). In order to estimate $\alpha_0$ and $\alpha_1$, we re-write the estimating labor-supply equation 30 substituting the term $\alpha_W$ by the function $\alpha_0 + \alpha_1 POL_n$. Now, the parameters $a_0$ and $a_1$ in 30 vary across states:

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

Under the assumption that $POL_n$ is independent of the amenity shocks in state $n$ and the exogeneity assumptions described in Section 4.3.1, we use a GMM estimator to consistently estimate the parameters $\varepsilon_W$, $\alpha_0$ and $\alpha_1$. Table A.7 shows the results. Under the external-IV’s and $\chi_W = 1$ specification we find $\hat{\alpha}_0 = .17 \ (0.07)$ and $\hat{\alpha}_1 = -.003 \ (0.025)$.

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

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<th>B. External IVs</th>
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<tr>
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<td>$\alpha_{W0}$</td>
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<td>$\chi_W = 0.5$</td>
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<td>$\alpha_{W0}$</td>
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<td>.17**</td>
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<td>(.031)</td>
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<td>$\chi_W = 1$</td>
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<tr>
<td>$\alpha_{W0}$</td>
<td>.27***</td>
<td>.17**</td>
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<td>$\alpha_{W1}$</td>
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<td>-.003</td>
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<td>(.012)</td>
<td>(.025)</td>
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</table>

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

57
E Appendix to Section 6 (Other Policies)

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

(a) Holding Government Spending Constant

(b) Total Effect
Figure A.5: Lowering Income Tax in California by 1 Percent Point

(a) Employment Changes and Spending Shares

(b) Employment Changes and Sales Shares

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

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

(a) Employment Changes and Spending Shares

(b) Employment Changes and Sales Shares

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

In this subsection we discuss the data used in sections 2.1, 4, and 5.

F.1 Government Finances

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

- State individual income tax rate $t_{yn}^n$: Source: NBER TAXSIM; Dataset: Marginal and Average Tax Rates and Elasticities for the US, using a fixed 1984 (but in/deflated) sample of taxpayers; Variable: Average effective state tax rate on income, “st_avg”, by state and year.

- State sales tax rate $t_{cn}^n$: 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 $t_{x}^n$ and $t_{l}^n$; Source: Suárez Serrato and Zidar (2014)

- Effective Federal Corporate Tax Rate $t_{corp}^{fed}$: 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 $t_{y}^{fed}$: 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 $t_{w}^{fed}$: Source: Congressional Budget Office; Dataset: Average Federal Tax Rates in 2007; Variable: Average Payroll Tax Rates

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

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

- State and Local corporate tax rate: $t_{n}^{corp,s+l} = t_{n}^{corp} \times \frac{R_{StandLocal,corp}^n}{R_{State,corp}^n}$.

- State and Local sales tax rate $t_{n}^{c,s+l} = t_{n}^{c} \times \frac{R_{StandLocal,c}^n}{R_{State,c}^n}$, where the sales revenue used is general sales tax revenue.

- State and Local income tax rate $t_{n}^{y,s+l} = t_{n}^{y} \times \frac{R_{StandLocal,y}^n}{R_{State,y}^n}$.

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

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

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

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

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

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

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

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

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

F.3 Estimation (Section 4.3)

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

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

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

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

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

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