Vertical Migration Externalities*

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Abstract

State income taxes affect federal income tax revenue by shifting the spatial distribution of households between high- and low-productivity states, thereby changing household incomes and tax payments. We derive an expression for these fiscal externalities of state taxes in terms of estimable statistics. An empirical quantification using American Community Survey data reveals that the externalities range from large and negative in some states, to large and positive in others. In California, an increase in the state income tax rate and the resulting change in the distribution of households across states lead to a decrease in federal income tax revenue of 39 cents for every dollar of California tax revenue raised. The externality amounts to a 0.27% decrease in total federal income tax revenue for a 1 pp increase in California's state tax rate. Our results raise the possibility that state taxes may be set too high in high-productivity states, and set too low in low-productivity states.

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1 Introduction

State income tax rates differ substantially across the US.[1] These state income tax differentials disincentivize households from living in high-tax states, such as California, and encourage households to live in low-tax states, such as neighboring Nevada.[2]

This tax system and its effect on the spatial distribution of households have implications for federal income tax revenue. In California, for example, residents earn high wages and therefore pay relatively high amounts of federal taxes, in part because California is one of the most productive states in the US. Thus, migration away from California to less productive states may lead to a drop in household income and therefore federal tax revenue. More generally, changes in state taxes may have first-order implications for federal tax revenue by shifting the distribution of households between high- and low-productivity locations. The effect of state taxes on federal tax revenue represents a fiscal externality — the impact on federal tax revenue is not fully internalized by the individual state — and therefore may lead to state taxes that differ from the socially optimal level.[3]

We seek to quantify the effects of state income taxes on federal income tax revenue. We specify a model that relates the spatial distribution of households across states to federal tax revenue. Heterogeneous households choose a state to live in and how many hours they work. Household income, and thus tax payment, depends on the location they choose, reflecting varying productivity levels across states. Changes in state taxes alter the distribution of households across states, thereby affecting federal tax payments. We refer to this effect of state taxes on federal tax revenue as the *vertical migration externality* and derive an expression for it in terms of estimable statistics.[4]

[1]Seven states have no income taxes. California has the highest top marginal tax rate, at 13.3%.

[2]Nevada has no state income tax. Fajgelbaum et al. (2019) quantify how state income tax differentials affect the distribution of households across the US.

[3]See Keen (1998) or Keen and Kotsogiannis (2002) for a discussion of how fiscal externalities between levels of government in a federalist system can lead to state taxes that are not set at the socially optimal level. To the best of our knowledge, ours is the first paper to document and quantify the fiscal externality from state taxes to the federal government that arises through changes in the spatial distribution of households. We discuss the related literature below.

[4]As is standard in the literature, we use the term "vertical" to highlight that the externality is being passed up from states to the federal government. We focus on federal income taxes

Our expression depends on statistics describing the spatial distribution of income and tax burdens, as well as estimates of how the distribution of households would change in response to a change in taxes. We estimate the statistics on the current distribution of households and their tax burden in each state using American Community Survey (ACS) data on household demographics, location choices, and income, combined with the tax simulator, TAXSIM (Feenberg and Coutts, 1993). For statistics describing how the spatial distribution of households responds to changes in state taxes, we utilize migration elasticities from the literature and data on migration flows from the ACS. Together, these statistics allow us to infer how total tax revenue would respond to changes in state income tax rates.

Our results show that the vertical migration externality exhibits significant heterogeneity across states, with some states having a large and positive effect and others a large and negative effect. In California, for every additional dollar of state tax revenue raised, federal income tax revenue drops by 39 cents from households choosing to locate in other states. Other high-productivity states such as New York and Connecticut exhibit similar externalities. California's externality is an economically meaningful effect, as a 1 percentage point increase in California state tax revenue leads to a migration externality which amounts to 0.27% of total federal income tax revenue.

We find that in low-productivity states, increases in state taxes lead households to locate in higher-productivity states, thereby increasing federal tax revenue and creating a positive fiscal externality. For example, an increase in Mississippi taxes results in 31 cents of additional federal tax revenue for each dollar increase in Mississippi state tax revenue. However, these states have a much smaller impact on total federal income tax revenue since they are lower-income and generally smaller in population.

Besides the vertical migration externality, state taxes lead to two other fiscal externalities in our model. First, an increase in state income taxes reduces the marginal benefit of working and therefore leads to a reduction of hours worked

and do not consider the role of other federal tax-transfer programs, such as payroll taxes or food stamps. Incorporating other federal means-tested programs would likely strengthen our results. For example, moving from a high-productivity to a low-productivity state would entail a decrease in payroll taxes in addition to a decrease in federal income taxes.

and federal tax revenue. We refer to this effect as the *vertical hours externality* and find it to be uniformly negative and small in magnitude across all states. Second, migration in response to a change in state taxes increases the population, and therefore state tax revenue, in other states. We refer to this effect as the *horizontal migration externality* and find it to be positive across all states and larger than the vertical hours externality in magnitude. Finally, we find that the sum of these three externalities is negative in high-productivity states such as California but positive in most other states. Taken together, our results suggest that in a federalist system, fiscal externalities may lead to state taxes that are set too high relative to the socially optimal level in high-productivity states, and too low in low-productivity states.

This paper is related to the literature on the distortions caused by taxation in a spatial setting (Albouy, 2009; Suarez Serrato and Zidar, 2016; Fajgelbaum et al., 2019; Fajgelbaum and Gaubert, 2020; Coen-Pirani, 2020; Colas and Hutchinson, 2021).[5] In Albouy (2009), for example, differences in productivity across locations imply that households face a higher income tax burden if they choose to live in high-productivity cities. These differences in tax burdens disincentivize households from living in high-productivity cities and lead to deadweight loss. The focus of this paper is quite different from this literature. We instead document and quantify a novel externality of state taxes that occurs by shifting households between high and low-productivity states.

This paper is also related to a literature which aims to empirically quantify horizontal and vertical externalities (e.g. Besley and Rosen (1998), Goodspeed (2000), Andersson, Aronsson, and Wikström (2004), Brülhart and Jametti (2006), Gordon and Cullen (2012), Giertz and Tosun (2012), or Milligan and Smart (2019)). These papers either do not consider migration or do not allow for productivity differences across states and therefore abstract away from vertical externalities resulting from movement across states. This is the first paper to quantify the vertical fiscal externality arising from changes in the spatial distribution of households. Unlike many of these papers, our approach takes the observed

[5] Fajgelbaum et al. (2019) quantify the spatial misallocation caused by heterogeneity in state tax rates using a quantitative model which includes state taxes, federal taxes, and productivity differences across states. Vertical migration externalities are present in their model but are not quantified.

tax system as given and thus does not involve modeling the non-cooperative game played between state and federal governments. This approach allows us to derive closed-form expressions for fiscal externalities in a setting with heterogeneous households and an arbitrary distribution of productivity levels across locations.

2 Model

2.1 Model Setup

Household types are indexed by b and locations are indexed by j. Household types vary in their productivity, their preferences over labor supply, and the tax schedule they face. Within each household type there exists a continuum of individual households indexed by i. These individual households vary in their preferences over locations but share common productivity levels, tax schedules, and preferences over labor supply within household types.

Let N_b be the measure of type b households across all locations, N_{bj} be the measure of type b households that live in location j, and $P_{bj} = N_{bj}/N_b$ be the proportion of type b households that live in location j. Household pre-tax income is given by $y_{bj} = \ell_{bj} w_j$, where ℓ_{bj} is efficiency labor supplied by a household of type b and w_j is the wage offered in location j.

We will consider states as the locations. Importantly, states vary in their wage levels, which generates variation in pre-tax income for the same household type across states. We think of differences in productivity across states driving the wage differences. These spatial differences in productivity are well supported empirically and are a standard feature of models in urban economics.[6] For now, we fix wages, but in Section 5.1 we analyze the case with endogenous wages. Locations are also associated with a vector of amenities, $\mathbb{X}_j$, and a vector of prices for consumption goods, $\mathbb{R}_j$.[7] We do not specify explicitly how prices or

[6] See e.g. Glaeser and Maré (2001), Roca and Puga (2017), or Baum-Snow, Freedman, and Pavan (Forthcoming) for empirical support of productivity differences across locations and Rosen (1979) and Roback (1982) for urban economics models with productivity differences across locations.

[7] Amenities could include local weather, public goods, or the quality of local restaurants, for example. Prices include both the cost of nontradeable goods (e.g. housing and local services) and tradeable goods.

amenities are determined but allow for them to be endogenous with respect to local taxes and population levels.

States also differ in their state income taxes, with state j's tax collected from household type b given by $(\sigma_{bj}(y_{bj}) + s_j y_{bj})$, where $\sigma_{bj}(\cdot)$ is a non-linear tax function. The second term is a flat tax at a rate of s_j that will allow us to consider uniform marginal increases or decreases in the state tax rate, where we will initially assume $s_j = 0$. Thus, not only does a household type's pre-tax income vary between states, but so could the state tax functions they face.

Households also pay federal income tax, $\tau_b(y_{bj})$. The federal tax function, $\tau_b(\cdot)$, and state tax function, $\sigma_{bj}(\cdot)$, are allowed to vary with the household's type to reflect the different schedules, credits, and exemptions afforded to households (e.g. by marital status or number of children). For now, we assume that federal income taxes are only a function of household type and income, and therefore do not depend directly on state taxes.[8] However, state taxes can affect federal income taxes through their impact on a household's location and labor supply decisions. The after-tax income of a household of type b living in state j is therefore

$$\tilde{y}_{bj} = y_{bj} - \underbrace{(\sigma_{bj}(y_{bj}) + s_j y_{bj})}_{\text{State Tax}} - \underbrace{\tau_b(y_{bj})}_{\text{Federal Tax}}.$$

Total state tax revenue in j is the tax burden for each household type multiplied by the number of those households living in the state, summed across all household types, given by

$$StateRev_j = \sum_b N_{bj} \left(\sigma_{bj}(y_{bj}) + s_j y_{bj}\right). \quad (1)$$

Similarly, total federal tax revenue is the sum of federal income tax payments of households across all states, given by

[8] Households have the option to deduct state and local income taxes from their taxable income, subject to a cap if they itemize their deductions rather than taking the standard deduction. The main model here is equivalent to assuming that all households either take a standard deduction or that their state and local tax liability always exceeds the state and local tax deduction cap. In Section 5.2, we derive the expressions assuming that state taxes may affect federal taxable income, showing that the results are quantitatively similar when we account for this.

$$FedRev = \sum_{j \in J} \sum_{b} N_{bj} \tau_b \left(y_{bj} \right). \tag{2}$$

2.2 Household Decisions

Individual households choose a consumption bundle, the location in which they live, and the amount of labor they supply, accounting for consumption prices, wages, taxes, and amenities. As is common in the spatial equilibrium literature, we assume that we can write the household's utility function associated with living in a given location as the sum of a component that is common to all households of a given type, and an idiosyncratic term that is unique to the individual household. Specifically, consider an individual household i of type b and let ε_{ij} give household i's idiosyncratic preferences for living in location j. We assume the household's utility in location j can be written as

$$U_{bj} \left(c, \ell, \mathbb{X}_j \right) + \varepsilon_{ij},$$

where the function $U_{bj} \left(\cdot \right)$ is common to all households of type b choosing location j, c is a vector of consumption of tradeable and non-tradeable goods, and ℓ is the amount of labor supplied by the household. Households face the budget constraint $\mathbb{R}_j c \leq \tilde{y}_{bj}$.

We can think of a household's optimization as a two-stage problem. In the first stage, the household chooses the optimal labor supply and consumption bundle conditional on each location. Note that all households of a given type will choose the same labor supply conditional on location, which have we denoted by ℓ_{bj}. In the second stage, the household chooses a location by comparing the indirect utility of living in each location, taking labor supply and consumption as given. We can write the household's indirect utility associated with living in location j as

$$V_{bj} \left(w_j, s_j, \mathbb{R}_j, \mathbb{X}_j \right) + \varepsilon_{ij},$$

where $V_{bj} \left(\cdot \right) = \max_{c,\ell} \left[U_{bj} \left(c, \ell, \mathbb{X}_j \right) | \mathbb{R}_j c \leq \tilde{y}_{bj} \right]$.[9] Note that the indirect utility

[9] The indirect utility function also depends implicitly on the tax functions $\sigma_{bj} \left(\cdot \right)$ and $\tau_{bj} \left(\cdot \right)$. These are omitted as arguments as we assume they are fixed throughout our analysis.

function here nests those derived in Kline and Moretti (2014), Diamond (2016), Suarez Serrato and Zidar (2016), Piyapromdee (2021), and Colas and Hutchinson (2021), for example.

The proportion of households of type b that choose location j is equal to the cumulative density of households for whom indirect utility in j is higher than indirect utility in all other locations. We can write this proportion as the multi-dimensional integral

$$P_{bj} = \int \mathbb{1}\left(V_{bj}\left(\cdot\right) + \varepsilon_j \geq V_{bk}\left(\cdot\right) + \varepsilon_k, \forall k \neq j\right) f_b\left(\varepsilon\right) d\varepsilon, \tag{3}$$

where $\mathbb{1}$ denotes an indicator function and $f_b\left(\varepsilon\right)$ denotes the continuous density of a vector of preferences ε conditional on household type b.

Our analysis will focus on how federal and state tax revenue are affected by uniform changes in state j's tax rate. Our results thus hinge on how the equilibrium distribution of households across locations changes in response to s_j. These effects can be summarized by the total derivatives of choice probabilities with respect to s_j as

$$\frac{dP_{bk}}{ds_j} = \sum_{k' \neq k} \left(\frac{dV_{bk}}{ds_j} - \frac{dV_{bk'}}{ds_j} \right) \int \mathbb{1}_{k' \rightarrow k}\left(\varepsilon\right) f_b\left(\varepsilon\right) d\varepsilon, \tag{4}$$

where $\frac{dV_{bk}}{ds_j}$ and $\frac{dV_{bk'}}{ds_j}$ give total derivatives of s_j on indirect utility, and the indicator function $\mathbb{1}_{k' \rightarrow k}\left(\varepsilon\right)$ takes the value of one if a household is on margin between choosing locations k' and k given a vector of idiosyncratic preferences ε.[10] Note that the equilibrium effect of state taxes on the population of state j (the state which increases its taxes), may work both directly through taxes, but also indirectly through changes in prices and amenities. State taxes can also affect indirect utility in other states through general equilibrium changes in prices and amenities.[11]

[10]Formally, this is given by

$$\mathbb{1}_{k' \rightarrow k}\left(V_{bk'}\left(\cdot\right) + \varepsilon_{k'} \geq V_{bk''}\left(\cdot\right) + \varepsilon_{k''}, \forall k'' \neq k'\right) \times \mathbb{1}\left(V_{bk'}\left(\cdot\right) + \varepsilon_{k'} = V_{bk}\left(\cdot\right) + \varepsilon_k\right).$$

[11]We provide a derivation for equation (4) in Appendix B.1. We are implicitly assuming that indirect utility and the functions determining prices and amenities are differentiable. We assume that the tax systems of other states and the federal are fixed, abstracting away from the

The effect of s_j on the probability of living in state j is simply the negative sum of migration to other states,

$$\frac{dP_{bj}}{ds_j} = -\sum_{k' \neq j} \frac{dP_{bk'}}{ds_j}.$$

2.3 Effect of Changes in State Tax Rates

Our main goal is to understand how increases in state taxes affect tax revenue for the federal government and other states. However, it is useful to show how changes in tax rates affect own state tax revenue first. We then proceed to the main results on federal tax revenue and tax revenue in other states.

State Income Tax First, we investigate the effect of a small increase in s_j on state j's own tax revenue. Increases in state tax rates will have the mechanical effect of collecting more taxes from each household. Additionally, two behavioral effects come either from household migration or from changes in the number of hours worked in response to the tax change.[12] Taking the derivative of equation (1) with respect to s_j and then setting $s_j = 0$, we have

$$\frac{dStateRev_j}{ds_j} = \sum_b N_b \left(P_{bj} y_{bj} + \frac{dP_{bj}}{ds_j} \sigma_{bj} \left(y_{bj} \right) + P_{bj} \frac{d\ell_{bj}}{ds_j} w_j \sigma'_{bj} (y_{bj}) \right),$$

where $\sigma'_{bj}(\cdot)$ is the marginal state income tax rate. Increases in s_j changes the returns to locating and supplying labor in-state j. $\frac{dP_{bj}}{ds_j}$ captures the change in the proportion of households who live in location j as a result of a change in state taxes. $\frac{d\ell_{bj}}{ds_j}$ captures the change in labor supply resulting from changes in state taxes.[13]

Note here that $\frac{dP_{bj}}{ds_j}$ represents the total effect of state taxes on population, taking into account not only the direct effect of a change in the tax rate, but also

possibility that changes in s_j may cause other states or the federal government to change their tax policy.

[12] We use the term "migration" throughout to refer to changes in household location choices.

[13] We focus on migration and labor supply responses to tax changes, abstracting away from other forms of tax avoidance.

the effects of any equilibrium changes in local prices, amenities, or public goods. Therefore, $\frac{dP_{bj}}{ds_j}$ could hypothetically be positive for certain types, if, for example, increases in state taxes lead to sufficiently large increases in the quality of local public goods.

Let $\eta^M_{bj} = \frac{dP_{bj}}{ds_j}\frac{1}{P_{bj}}$ be the reduced-form semi elasticity of location choice with respect to state tax rates. This has been estimated extensively, see Bartik (1991) for an early review.[14] Additionally, let $\eta^\ell_{bj} = \frac{d\ell_{bj}}{ds_j}\frac{1}{\ell_{bj}}$ be the semi elasticity of labor supply with respect to state tax rates. Substituting both of these semi elasticities into the above derivative yields

$$\frac{dStateRev_j}{ds_j} = \sum_b N_{bj}\left(\underbrace{y_{bj}}_{\text{Mechanical}} + \underbrace{\eta^M_{bj}\sigma_{bj}\left(y_{bj}\right)}_{\text{Migration}} + \underbrace{\eta^\ell_{bj} y_{bj}\sigma'_{bj}(y_{bj})}_{\text{Hours Worked}}\right). \tag{5}$$

The first term ("Mechanical" in the equation above) gives the mechanical effect of the state collecting more taxes by increasing the tax rate, representing the additional tax revenue collected from each resident of j. The second term ("Migration") reflects the loss in tax revenue from the households who migrate due to the change in taxes: η^M_{bj} gives the percent change in the proportion of type b households living in state j due to a change in s_j, which we multiply by the state taxes they pay. The final term ("Hours Worked") captures the effect of the change in tax rates on the household's labor supply decision: η^ℓ_{bj} is the percent change in hours supplied, multiplying by y_{bj} transforms this into the change in income. Then we multiply by the marginal tax rate, $\sigma'_{bj}(y_{bj})$, to convert the change in income to the change in taxes paid.

A change in state taxes in location j not only affects the state's own tax revenue but also affects tax revenue collected by the federal government and other states due to migration and changes in labor supply, as we explore below.

Federal Income Tax Now consider the effect of a small increase in s_j on total federal tax revenue. First, taking the derivative of equation (2) with respect to

[14] Examples of more recent papers estimating the effects of local taxes on migration include Kleven et al. (2014), Moretti and Wilson (2017), Agrawal and Foremny (2019), and Rauh and Shyu (2019).

s_j, we have

$$\frac{dFedRev}{ds_j} = \sum_b N_b \left[\underbrace{\frac{dP_{bj}}{ds_j}\tau_b\left(y_{bj}\right)}_{\text{Migration from } j} + \sum_{k\neq j} \underbrace{\left(\frac{dP_{bk}}{ds_j}\tau_b\left(y_{bk}\right)\right)}_{\text{Migration to } k} + \underbrace{P_{bj}w_j\tau_b'(y_{bj})\frac{d\ell_{bj}}{ds_j}}_{\text{Hours worked}} \right]. \tag{6}$$

Here, the first term ("Migration from j") captures the decrease in tax revenue resulting from the decrease in j's population, and the second term ("Migration to k") captures the increase in tax revenue resulting from increases in population in other states. The final term ("Hours Worked") captures the lost tax revenue from decreases in labor supply.

Let $\omega_{bjk} \equiv \left(\frac{dP_{bk}}{ds_j}\right) / \left(\sum_{k'\neq j}\frac{dP_{bk'}}{ds_j}\right)$ be the *migration weight*. Loosely speaking, we can think of this as the probability a household of type b will migrate to location k conditional on leaving j in response to a tax change. Using the fact that $\sum_{k'\neq j}\frac{dP_{bk'}}{ds_j} = -\frac{dP_{bj}}{ds_j}$, we can write $\frac{dP_{bk}}{ds_j} = -\omega_{bjk}\frac{dP_{bj}}{ds_j}$. Now, define $\tau_{bj}^o \equiv \sum_{k\neq j}\omega_{bjk}\tau_b\left(y_{bk}\right)$ as the weighted outside option tax income, given by the federal tax burden a household would face if they moved, multiplied by each state's migration weight, summed across all states. This roughly tells us the expected federal tax payment if a type b household leaves j. Substituting these two definitions into equation (6), we have the effect on federal tax revenue in terms of elasticities as

$$\frac{dFedRev}{ds_j} = \sum_b N_{bj}\left[\eta_{bj}^M\tau_b\left(y_{bj}\right) - \eta_{bj}^M\tau_{bj}^o + \eta_{bj}^\ell y_{bj}\tau_b'(y_{bj})\right]. \tag{7}$$

We can then rewrite equation (7) in terms of the effect on federal tax revenue that operates through household location choices and the effect that operates through labor supply as

$$\frac{dFedRev}{ds_j} = VME_j + VHE_j, \tag{8}$$

where VME_j is what we call the vertical migration externality and VHE_j is the vertical hours externality, both formally defined below. We use the term vertical to emphasize that the externality is being passed up from states to the federal government.[15]

The vertical migration externality is the change in federal tax revenue that results from households relocating in response to a change in state taxes, thus earning different pre-tax incomes since states vary in their productivity levels. The two left-hand terms in equation (7) give the expression for this externality as

$$VME_j = \sum_b N_{bj} \eta_{bj}^M \left(\tau_b \left(y_{bj} \right) - \tau_{bj}^o \right). \tag{9}$$

Some households will choose to relocate if state j increases its taxes, due to both the decrease in after-tax income they could earn in-state j and also due to equilibrium changes in prices and amenities. The semi-elasticity of location choice with respect to state taxes, η_{bj}^M, captures the magnitude of this migration, which we then multiply by the difference in federal tax revenue collected for the households that move, $\left(\tau_b \left(y_{bj} \right) - \tau_{bj}^o \right)$, to obtain the migration effect. The distribution of other states that households migrate to, and thus incomes that they earn, is reflected in τ_{bj}^o. The difference between $\tau_b \left(y_{bj} \right)$ and τ_{bj}^o determines the sign of the externality. If j is a high-productivity, high-wage state, then an increase in taxes could decrease federal tax revenue. This is because the tax change could induce households to move from state j to relatively lower-productivity, lower-wage states. Meanwhile, if j has low wages, then an increase in their tax rate could increase federal tax revenue by incentivizing households to move away from j to higher-productivity states.

Additionally, households alter their labor supply decision in response to a change in taxes since taxes decrease the marginal benefit of working. The right-hand term in equation (7) gives the vertical hours externality,

$$VHE_j = \sum_b N_{bj} \eta_{bj}^\ell y_{bj} \tau_b'(y_{bj}). \tag{10}$$

Increases in state taxes reduce the returns to supplying labor in location j.

[15] This effect on federal revenue will overstate the fiscal externality slightly if a substantial portion of the additional federal revenue goes to fund public goods in state j. For example, if X percent of the additional federal revenue funds public goods in j, then the fiscal externality is given by $\frac{1-X}{100} \frac{\partial FedRev}{\partial s_j}$.

Thus, increases in state taxes will reduce income in j, which subsequently reduces the amount of federal tax collected. Again, η^{ℓ}_{bj} gives the percent change in hours worked in response to the increase in taxes. We multiply this by income, y_{bj}, to give the change in income, and then multiply by the marginal federal tax rate, $\tau_b'(y_{bj})$, to give the resulting change in federal taxes paid by each household. Finally, we multiply by N_{bj} and sum across all household types to calculate the effect on federal tax revenue.

Together, the vertical migration externality and the vertical hours externality describe the effects of state taxes on federal tax revenue. Note that equations (9) and (10), the formulas for these externalities, are expressed solely in terms of elasticities, populations, income levels, and tax rates. Given estimates of these objects, we can quantify the externalities without the need to utilize simulation methods and without the need to specify and estimate the underlying structural objects. We quantify these vertical externalities in Section 3. However, we first provide an expression for horizontal migration externalities, the effect of state taxes on tax revenue in other states.

Other State Income Taxes The changes in the distribution of households across locations will also impact the tax revenue collected by other states, who could gain households in their taxable population if state j increases their tax rate.[16] We refer to this as the horizontal migration externality. The effect of j's state taxes on state k's tax revenue can be written in terms of elasticities as

$$\frac{dStateRev_k}{ds_j} = -\sum_b N_{bj}\eta^M_{bj}\omega_{bjk}\sigma_{bk}\left(y_{bk}\right),$$

where η^M_{bj} reflects the percent change in the proportion of type b households living in j, which then is multiplied by N_{bj} and the migration weight, ω_{bjk}, to determine the number of additional households who choose to locate in state k.[17] Finally, multiplying by $\sigma_{bk}(y_{bk})$ gives the state tax revenue collected from those migrants in state k.

[16] We focus on state tax revenue from state income taxes. Increasing the population of a given state would likely also lead to increases in sales tax revenue and local property tax revenue, which would imply larger horizontal externalities.

[17] For this equation, we use the fact that $\frac{dP_{bk}}{ds_j} = -\omega_{bjk}\frac{dP_{bj}}{ds_j} = -\omega_{bjk}\eta^M_{bj}P_{bj}$.

Similarly to federal taxes, we define $\sigma^o_{bj} \equiv \sum_{k \neq j} \omega_{bjk} \sigma_{bk}(y_{bk})$ as the weighted average of taxes collected in other states. Summing across all states $k \neq j$, we have the effect on other state taxes, which we define as the horizontal migration externality

$$HME_j \equiv \sum_{k \neq j} \frac{dStateRev_k}{ds_j} = -\sum_b N_{bj} \eta^M_{bj} \sigma^o_{bj}. \tag{11}$$

Here σ^o_{bj} gives the weighted average state tax burden, which gives the expected state taxes paid by a household who leaves location j. We multiply this by the number of households who relocate, $N_b \eta^M_{bj}$. This externality will be positive if increases in j's state taxes lead to increases in the tax base in other states.[18]

Because of these three fiscal externalities, state tax rate decisions can spill over to the federal government and other states. If these externalities are not internalized by the individual states, then states may not set their income taxes to socially optimal levels. The negative vertical hours externality will lead to state taxes being set too high, while the horizontal migration externality, which we expect to be positive, will lead states to set taxes too low relative to the optimum.[19] However, we expect the magnitude and sign of the vertical migration externality to vary across states. This implies that the comparison of existing to socially optimal state income tax rates may differ substantially across states.

3 Quantification

3.1 Data Inference

To quantify the expressions in our model, we make use of the 2019 5-year aggregated ACS, which contains data on location, demographics, income, birthplace,

[18] Note that we only account for externalities that work through state income tax revenue. There could be other horizontal externalities as well. For example, if individual states value the welfare of their residents, then an influx of households from another state may lead to general equilibrium price changes with will affect local resident utility. We are agnostic about a state's welfare function and therefore choose to focus only on the externalities that operate through tax revenue.

[19] This logic follows Keen and Kotsogiannis (2002).

and location in the previous year for a sample of over 6 million households.[20] We limit our sample to households where the household head is between 18 and 65 years old, and we drop households who live in group quarters or who are missing education information. We combine these ACS data with the tax simulator TAXSIM, which we utilize to calculate each household's state and federal income taxes. Below we describe how we use these data to calculate the statistics in equations (9) through (11).

Household Types We consider several definitions of household types. Ultimately, we find similar results with all of the definitions. In our baseline specification, we define types based on the education and potential experience of the household head. We first divide households into four groups based on the education of the household head: high school dropouts, high school graduates, some college, and college or more. Next, as in Borjas (2003), we divide the potential experience of the household head into 8 categories, starting with 0-5 years of experience and ending with 36 years or greater experience. We interact the household head's education with their experience group to create 32 types. We then calculate N_b as the number of households of each type and P_{bj} as the fraction of those households living in each state.

In Appendix A.6, we consider an additional specification in which we define a household's type by their education, experience, and race and a specification in which we define the type by the education only. The results are similar in both specifications.[21]

Federal and State Taxes We utilize the ACS data and NBER's TAXSIM (Feenberg and Coutts, 1993) to calculate the federal and state tax burdens, $\tau_b(y_{bj})$ and $\sigma_{bj}(y_{bj})$, and the federal and state marginal tax rates, $\tau_b'(y_{bj})$ and $\sigma_{bj}'(y_{bj})$. TAXSIM is a tax calculator that replicates the state, federal and payroll tax codes in a given year, given data on various sources of income, sources of deductions, household location, and demographics (e.g. marital status, age, and number of

[20]We download these data from IPUMS (Ruggles et al., 2021).

[21]We've also considered a specification in which we define all households as the same type. The results are quite different in this case. This makes sense, given that there is considerable selection on education across locations.

children). We use tax schedules from the year 2019.

We first use TAXSIM to calculate the tax levels and rates for each household in the data, using each household's state of residence, marital status, wage and business income of household head and spouse, the number of children, and age of the household head and spouse. Then, we calculate each of the four sets of statistics as the average tax amounts and marginal tax rates in each state for each type.

A key underlying assumption we make here is that conditional on household type, there is no selection on unobservables that affect income across locations. This allows us to estimate the counterfactual tax burden if a household were to locate in another state as the mean tax burden faced by the same household type in that other state.

While there is strong selection on education levels across cities, much of the literature finds that selection on unobservables across locations is limited, conditional on education.[22]

Migration Weights Next, we turn to the migration weights, ω_{bjk}, which dictate the distribution of where households choose to relocate to in response to a change in state taxes. It would be difficult to estimate pairwise location-choice elasticities with respect to state taxes for all states.

Intuitively, we expect the migration weight to be larger for a destination k in which many households are close to indifferent between choosing state j and choosing state k. One might think that households who recently moved between states j and k are close to marginal between choosing the two states. In light of this, we approximate migration weights from state j by using the distribution of households who recently emigrated from state j in the data. Specifically, we use the ACS's migration history question, which asks where households lived in the previous year. This allows us to focus on households who lived in state j in the previous year but currently live elsewhere. We use these data to calculate the fraction of these households who lived in j in the previous year but now live in state k.

[22] See e.g. Diamond (2016) for selection on education across cities. See Baum-Snow and Pavan (2012) and Roca and Puga (2017) for examples of limited selection on unobservables after controlling for education.

Formally, let $N^b_{j\to k}$ be the total number of households who lived in state j in the previous year and currently live in state k. We set the migration weights as

$$\omega_{bjk} = \frac{N^b_{j\to k}}{\sum_{k'\neq j} N^b_{j\to k'}}.$$

We consider several other specifications in Appendix A.4. The results are similar across all specifications.

Elasticities A key parameter is η^M_{bj}, the location-choice elasticity with respect to taxes. For this, we rely on estimates from the literature. In our main specification, we utilize estimates from Colas and Hutchinson (2021), who simulate general equilibrium elasticities of location-choice with respect to after-tax income, holding hours constant, using their estimated quantitative spatial equilibrium model. To utilize these elasticities in our formulas, we must first translate them to elasticities with respect to taxes. Letting ε^M_b be a given type's elasticity of location-choice with respect with respect to after-tax income, holding hours constant, we can calculate the elasticity with respect to taxes as $\eta^M_{bj} = -\varepsilon^M_b \frac{y_{bj}}{\tilde{y}_{bj}}$, where, as before, y_{bj} is pre-tax income and $\tilde{y}_{bj}$ is after-tax income. Following their estimates, we use a value of $\varepsilon^M_b = 2.5$ for households with less than a college education and $\varepsilon^M_b = 5.7$ for households with some college or greater.

In calibrating the model, we make a strong restriction that these location-choice elasticities are constant across states and demographic groups. In reality, location-choice elasticities would likely vary across states and demographic groups within broad education categories. For example, we might expect younger workers to be more responsive to income changes in their location choices than older workers. We examine the sensitivity of our results with respect to these parameters in Section 5.3. In Appendix A.5, we recalculate our results using the elasticities from Albouy (2009) and from Gordon and Cullen (2012).

We utilize estimates of intensive margin elasticities with respect to wages to calculate η^ℓ_{bj}, the semi elasticity of labor supply with respect to state taxes. Let $\varepsilon^\ell_b = \frac{\partial \ell_{bj}}{\partial \tilde{w}_{bj}} \frac{\tilde{w}_{bj}}{\ell_{bj}}$ be the elasticity of labor supply with respect to after-tax wages. As we show in Appendix B.2, we can write η^ℓ_{bj} in terms of the labor supply elasticity

ε_b^ℓ as

$$\eta_{bj}^{\ell} = \frac{\varepsilon_b^\ell y_{bj}/\tilde{y}_{bj}}{1-\varepsilon_b^\ell \theta_{bj} y_{bj}/\tilde{y}_{bj}}, \tag{12}$$

where $\theta_{bj} = \sigma'_{bj}(y_{bj}) + \tau'_j(y_{bj}) - \frac{\sigma_{bj}(y_{bj})+\tau_b(y_j)}{y_{bj}}$ is the difference between the combined marginal tax rate and the combined average tax rate. We set $\varepsilon_b^\ell = .25$ for all demographic groups based on the estimates from Chetty (2012).[23]

3.2 The Vertical Migration Externality of One Household

To better understand the mechanics of our quantification, Table 1 illustrates the change in federal revenue associated with one household moving from California to another state, where we focus on a single household type, college-educated households with 0 to 5 years of potential experience. The first row shows the average federal tax payment, ($\tau\left(y_{bj}\right)$ in equation 9) and the average state tax of a household of this type living in California, all measured in thousands of dollars. California has high productivity and high state income taxes, so federal and state taxes paid by the average member of this household type are high. Note that we display the average taxes for households living in California, not the tax burden associated with a household earning the average income in California. We display the average incomes for these household types in Appendix A.1.

The next five rows show the five states with the highest migration weights (ω_{bjk}) for California for this household type. These represent the proportion of households who leave California that will locate in each state. The states with the highest migration weights for California are Texas and New York, two large states, and Washington, Arizona, and Oregon, three states geographically close to California. Of these, Washington and New York are relatively high-income states and are therefore associated with high federal tax payments, while Arizona and Oregon are lower-income states with lower associated federal tax payments. The final row ("Weighted Average") gives the average federal tax payment and state taxes across all states weighted by their migration weights.

[23] Chetty (2012) reports compensated labor supply elasticities. The elasticities in our formulas, on the other hand, refer to uncompensated elasticities. The uncompensated elasticities are likely only slightly lower than compensated elasticities (Chetty et al., 2013). Accounting for this would reduce the size of the vertical hours externality slightly.

		Weight	Federal Tax	State Tax
California			8.0	2.9
Migration Sources		Weight		
1	Texas	10.1	5.9	0.0
2	Washington	10.0	7.8	0.0
3	New York	8.7	7.8	3.1
4	Arizona	5.9	4.6	1.3
5	Oregon	5.8	4.3	3.3
	Weighted Average		5.5	1.6

Table 1: Average federal tax payment, and state taxes for college-educated households with 0-5 potential experience in California and its largest migration partners. The column "Weight" presents 100% $\times\ \omega_{bjk}$. We display household income, federal tax payments, and state taxes in thousands of dollars. "Weighted Average" gives the average household income, federal tax payment, and state taxes across all states weighted by their migration weights.

We can use these statistics to calculate the change in federal revenue associated with a household leaving California, given by $-\left(\tau_b\left(y_{bj}\right) - \tau^o_{bj}\right)$ in equation (9). We find that one household of this type leaving California decreases federal tax revenue by $8.0 - 5.5 = 2.5$ thousand dollars. The product of this amount and the number of households who leave the state in response to a state tax increase, given by $N_{bj}\eta^M_{bj}$, summed across all household types gives the full vertical migration externality for California. Similarly, the change in tax revenue of other states associated with one household of this type leaving California is equal to $\sigma^o_{bj} = 1.6$ thousand dollars. This number, multiplied by the number of households who exit the state, summed across household types gives the horizontal migration externality.

Table 2 repeats this exercise for the state of Mississippi. From the first row, we can see that Mississippi has low federal tax payments, reflecting Mississippi's low-income levels. A household of this type leaving Mississippi leads to an *increase* in federal tax revenue of $5.0 - 2.9 = 2.1$ thousand dollars and an increase in state tax revenue in other states of 1.2 thousand dollars.

		Weight	Federal Tax	State Tax
Mississippi			2.9	1.5
Migration Sources		Weight		
1	Texas	15.8	5.9	0.0
2	Tennessee	12.4	4.2	0.0
3	Louisiana	7.8	5.3	1.7
4	Alabama	7.3	3.7	1.8
5	Florida	6.1	4.5	0.0
	Weighted Average		5.0	1.2

Table 2: Average federal tax payment, and state taxes for college-educated households with 0-5 potential experience in Mississippi and its largest migration partners. The column "Weight" presents 100% $\times$ ω_{bjk}. We display household income, federal tax payments, and state taxes in thousands of dollars. "Weighted Average" gives the average household income, federal tax payment, and state taxes across all states weighted by their migration weights.

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.39	-0.08	0.25	-0.21
Large States				
Texas	-0.06	-0.04	0.19	0.09
Florida	0.12	-0.03	0.23	0.32
New York	-0.29	-0.07	0.34	-0.02
Low Income States				
Arkansas	0.26	-0.04	0.24	0.45
Mississippi	0.31	-0.03	0.22	0.50
West Virginia	0.31	-0.04	0.30	0.57

Table 3: Fiscal externalities as a fraction of increase in state tax revenue for selected states. The first column gives the vertical migration externality, formally given by $VME/\left(\frac{dStateRev}{ds_j}\right)$. The next column gives the vertical hours externality given by $VHE/\left(\frac{dStateRev}{ds_j}\right)$. The third column of each table displays the horizontal externality given by $HME/\left(\frac{dStateRev}{ds_j}\right)$. The results for all states are displayed in Section A.2.

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.27%	-0.05%	0.17%	-0.15%
Large States				
Texas	-0.04%	-0.03%	0.13%	0.06%
Florida	0.05%	-0.01%	0.10%	0.14%
New York	-0.11%	-0.03%	0.13%	-0.01%
Low Income States				
Arkansas	0.01%	0.00%	0.01%	0.02%
Mississippi	0.01%	0.00%	0.01%	0.02%
West Virginia	0.01%	0.00%	0.01%	0.01%

Table 4: Fiscal externalities as a percentage of total income tax revenue for selected states. The first column gives the vertical migration externality, formally given by $100\% \times .01 \times VME/FedRev$. The next column gives the vertical hours externality given by $100\% \times .01 \times VHE/FedRev$. The third column of each table displays the horizontal externality given by $100\% \times .01 \times HME/FedRev$.

4 Results and Discussion

Consider a small increase in California state taxes ds_j that leads to one additional dollar of state tax revenue such that $ds_j \left(\frac{dStateRev}{ds_j}\right) = 1$.[24] Table 3 reports the fiscal externalities associated with this small increase in state taxes. In order to understand the magnitude of these effects, Table 4 also reports the fiscal externalities associated with a 1 percentage point increase in state taxes as a percentage of total federal income tax revenue.

The first row of each table shows the vertical and horizontal fiscal externalities for the state of California. The first column shows a vertical migration externality of -0.39 for California.[25] This implies that every dollar of California tax revenue raised by an increase in state taxes is associated with 39 cents of lost federal tax revenue through changes in the spatial distribution of households. California is a relatively high income state, and therefore California residents pay high income

[24] The change in state revenue $\left(\frac{dStateRev}{ds_j}\right)$ is positive in all our calculations—increasing a states tax rate from the current level always leads to an increase in state taxes.

[25] The vertical migration externality in Table 3 is formally given by $VME/\left(\frac{dStateRev}{ds_j}\right)$. The vertical migration externality in Table 4 is formally given by $100\% \times .01 \times VME/FedRev$.

taxes. When households leave California in response to an increase in state taxes, they, on average, move to states where they earn lower incomes and therefore face lower federal income tax burdens. Since California is a large state, the magnitude of this effect is substantial: the vertical migration externality of a 1 pp increase in California state taxes is equal to -0.27% of total federal government income tax revenue.

The next column gives the vertical hours externality: the reduction in federal tax revenue resulting from a reduction in hours worked. The vertical hours externality, at -0.08 for California, is less than 25% as large as the state's vertical migration externality in magnitude. Together this implies a total vertical externality of -0.47 — the federal government loses nearly 50 cents for each additional dollar of California state tax revenue. The third column of each table displays the horizontal migration externality: the increase in tax revenue of other states resulting from households leaving California and paying taxes elsewhere. This horizontal externality is 0.25, slightly smaller in magnitude than the vertical migration externality. All together, this implies a total externality of -0.21 for each dollar of California state tax revenue. A small increase in California state taxes leading to $1 in additional California revenue would lead to 21 cents in lost revenue for the federal government and other states.

The next rows show the results for several additional states. First, we show the results for the next three largest states by population. The vertical migration externality is negative for both New York and Texas, two relatively high income states, but positive for Florida, a lower income state. Next we show the results for the three poorest states by income per capita: Arkansas, Mississippi, and West Viriginia. For these three states, out-migration leads to an *increase* in government revenue of 26 to 31 cents for each dollar of additional state tax revenue. These results highlight the heterogeneity of the vertical migration externalities, which range from large and positive for lower income states states to large and negative for higher income states. This contrasts with the vertical hours externality, which is negative and relatively small for all states, and the horizontal migration externality, which is positive and relatively close in magnitude for all states.

The results for all states are presented in Figure 1, which are shown in table format in Appendix A.2. Figure 1 presents the vertical migration externality as a

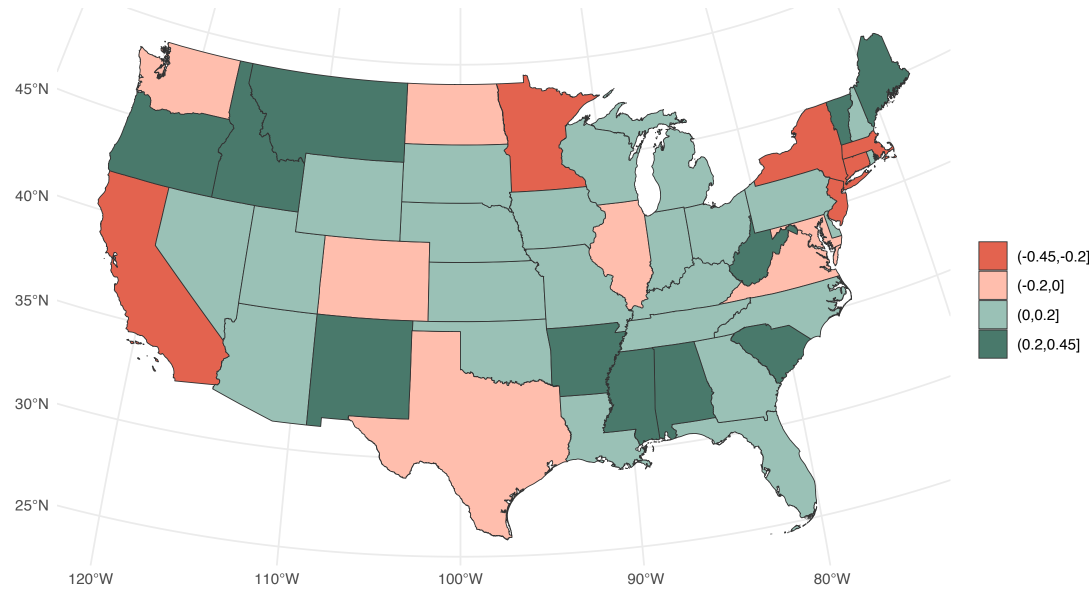

Figure 1: Vertical migration externalities as a fraction of increase in state tax revenue for all states. States in purple have negative vertical migration externalities while states in green have positive vertical migration externalities.

fraction of increased state revenue for the continental US. The externality ranges from -0.43 in Connecticut to 0.38 in New Mexico and is positive for 36 out of 50 states. The total vertical externality, given by the sum of the vertical migration and hours externalities is positive for 32 states. For the majority of states, a small increase in state taxes leads to an *increase* in federal tax revenue.

5 Extensions and Robustness

5.1 Endogenous Wages

In the main specification of the model, we assumed that wages were exogenously given and did not change when calculating the effects of a marginal increase in state taxes. Here, we allow for wages to be endogenous and to respond to changes in population induced by changes in state tax rates. In particular, a large literature has emphasized the importance of agglomeration effects—that productivity and potentially wages may increase in response to larger population as a result of knowledge spillovers, better firm-worker matching, or increasing returns to scale.[26] If wages are endogenous to labor supply, this would to lead additional fiscal effects. For example, with agglomeration affects, a decrease in California's population will lower wages, and therefore tax payments in California, but raise wages and tax payments elsewhere.

We consider a simple setup where labor supplied by all households is perfectly substitutable. Let $L_j = \sum_b N_b P_{bj} \ell_{bj}$ be the aggregate labor supply in state j, and $\varepsilon^w = \frac{dw_j}{dL_j} \frac{L_j}{w_j}$ be the elasticity of wages with respect to aggregate labor supply, which we assume to be constant across all states. A positive value of ε^w implies agglomeration effects—that wage levels increase in aggregate labor supply.[27] In this section, we abstract away from the impact of endogenous wages on hours of labor supplied for simplicity and therefore set $\eta^{\ell}_{bj} = 0$.[28] We show the results here, with detailed derivations of the expressions covered in Section B.3.

State Income Tax The effect of an increase in state j's taxes on its own tax revenue is given by

$$\frac{dStateRev_j}{ds_j} = \sum_b N_{bj} \left(\underbrace{y_{bj}}_{\text{Mechanical}} + \underbrace{\eta^M_{bj} \sigma_{bj} \left(y_{bj}\right)}_{\text{Migration}} + \underbrace{\eta^M_{bj} \varepsilon^w y_{bj} \bar{\sigma}'_j (y_{bj})}_{\text{Endogenous Wages}} \right), \tag{13}$$

where $\bar{\sigma}'_j(y_{bj}) = \frac{\sum_b N_{bj} \eta^M_{bj} y_{bj} \sigma'_{bj}(y_{bj})}{\sum_b N_{bj} y_{bj}}$ is the income-weighted average marginal state tax rate. As before, the first two terms represent the mechanical effect and the effects of out-migration on state tax revenue. The third term ("Endogenous Wages") is new and represents the change in state tax revenue resulting from

[26] See, e.g. Rosenthal and Strange (2001) or Duranton and Puga (2004).

[27] It's worth noting that ε^w is not a labor demand elasticity, in that the responses we are concerned with do not assume that capital and other inputs of production, are held constant. Further, ε^w is defined at the state level, and not the firm level, and includes the effects of population on overall productivity.

[28] Our calibrations of η^{ℓ}_{bj} in the main section are calculated using estimates of labor supply elasticities. Therefore, solving for an equilibrium with endogenous hours and wages involves solving for a fixed point in wages and hours worked in each state. This could incorporated by utilizing the integral equation approach developed by Sachs, Tsyvinski, and Werquin (2020) and later employed by Colas and Sachs (2021). In contrast, we treat the location-choice elasticities η^M_{bj} as the reduced form effect of state taxes on population. These elasticities would hypothetically include changes in population as result of endogenous wage and price changes, in addition to the direct effect of taxes.

changes in local wages. If ε^w is positive due to agglomeration effects, then wages in state j will decrease in response to the increase in taxes, since there are fewer people to produce the productivity spillovers driving agglomeration effects.

Federal Income Tax The change in federal tax revenue resulting from a small increase in state j's tax rate is largely the same as the main specification, but now wages in every state can change, producing an additional externality. The derivative of federal tax revenue with respect to s_j is

$$\frac{dFedRev}{ds_j} = VME_j + VWE_j. \tag{14}$$

This effect now contains the vertical migration externality, as before, and a wage response, reflecting the fiscal effects arising from endogenous wages. We call the new effect on federal tax revenue from endogenous wages the *vertical wage externality*, which is given by

$$VWE_j = \varepsilon^w \sum_b N_{bj}\eta_{bj}^M \left(y_{bj}\bar{\tau}_j' - (y\bar{\tau}')^o\right). \tag{15}$$

Here, $\bar{\tau}_j' = \frac{\sum_b N_{bj} y_{bj} \tau_b'(y_{bj})}{\sum_b N_{bj} y_{bj}}$ is the income-weighted marginal federal tax rate and $(y\bar{\tau}')^o = \sum_{k\neq j} \omega_{bjk} y_{bk} \bar{\tau}_k'$ is the migration weighted average of these income weighted marginal tax rates across all other states. With agglomeration effects, increases in California's taxes decrease California's population and therefore wage and tax payments, but increase population and tax payments elsewhere. How these changes in wages translate into government revenue is determined by the difference in the income-weighted average federal tax rates in California compared to other states.

Other State Income Taxes Similarly, endogenous wage changes will also have implications for state tax revenue in other states. The derivative of state k's tax revenue with respect to s_j is now given by

$$\frac{dStateRev_k}{ds_j} = HME_j + HWE_j. \tag{16}$$

As before, a change in state taxes in state j increases the tax base in other states via migration, an effect we referred to as the horizontal migration externality in equation (11). In addition, these population shifts change wages in other states, which leads to additional fiscal effects. We refer to this additional effect as the *horizontal wage externality*, which is given by

$$HWE_j = -\varepsilon^w \sum_b N_{bj}\eta_{bj}^M (y\bar{\sigma}')^o, \tag{17}$$

where $(y\bar{\sigma}')^o$ is the income-weighted average marginal state tax rate, averaged across all states, and is formally given by $(y\bar{\sigma}')^o = \sum_{k\neq j} \omega_{bjk} y_{bk} \frac{\sum_b N_{bk} y_{bk} \sigma'_{bk}(y_{bk})}{\sum_b N_{bk} y_{bk}}$. Influxes in population to other states will lead to increase in wages when $\varepsilon^w > 0$. The migration weighted average of state marginal tax rates multiplied by income determines how these increases in wages translate into state tax revenue.

Results For our quantification, we use a value of $\varepsilon^w = .02$ for all states based on the results from Combes et al. (2010), who estimate the elasticity of wages with respect to population density using historical and geographical instruments to deal with the endogeneity of labor quantity and labor quality.[29] The results are displayed in Table 5.[30] As in Table 3, we display the externalities as the ratio of the externality over the change in state tax.[31]

Columns 2 and 4 present the two new externalities which arise as a result of endogenous wages. The second column displays the vertical wage externality. As expected, the vertical wage externality for California is negative. Intuitively, if increases in population lead to increases in wages ($\varepsilon^w > 0$), out-migration from California leads to a wage decrease in California and a wage increase in other states. The wage decrease in California has larger tax consequences than wage

[29] This is a fairly conservative estimate relative to the rest of the literature. In their meta-analysis of agglomeration effects, Melo, Graham, and Noland (2009) report an average agglomeration elasticity of 0.043 across studies, with a maximum elasticity of 0.194 and a minimum elasticity of −0.088.

[30] For these calculations, we use the same estimates of location-choice elasticities from Colas and Hutchinson (2021) as in our baseline specification. One slightly inconsistency is that the elasticities from Colas and Hutchinson (2021) are calculated using a model that does not allow for agglomeration effects. We have recalculated these vertical wage externalities using a location-choice elasticity of $\varepsilon_b = 6$ as in Albouy (2009), who chooses this elasticity based on reduced form estimates of population with respect to state taxes summarized in Bartik (1991), and found similar results.

[31] The VME and VHE are slightly larger than those displayed in Table 3 because the change in state tax (the denominator) is slightly smaller than that in Table 3.

	Individual Externalities				
	VME	VWE	HME	HWE	Total
California	-0.39	-0.01	0.25	0.01	-0.14
Large States					
Texas	-0.06	0.00	0.19	0.00	0.13
Florida	0.12	0.00	0.23	0.00	0.36
New York	-0.29	0.00	0.35	0.01	0.05
Low Income States					
Arkansas	0.26	0.01	0.24	0.00	0.51
Mississippi	0.32	0.01	0.22	0.00	0.55
West Virginia	0.31	0.01	0.30	0.01	0.63

Table 5: Fiscal externalities as a fraction of increase in state tax revenue for selected states with endogenous wages. The first column gives the vertical migration externality, formally given by $VME/\left(\frac{dStateRev}{ds_j}\right)$. The next column gives the vertical wage externality given by $VWE/\left(\frac{dStateRev}{ds_j}\right)$. The third column of the table displays the horizontal migration externality given by $HME/\left(\frac{dStateRev}{ds_j}\right)$. The fourth column of the table displays the horizontal wage externality given by $HWE/\left(\frac{dStateRev}{ds_j}\right)$.

increases elsewhere because households in California face higher marginal tax rates than households in other states. In general, the vertical wage externalities are of the same sign as vertical migration externalities, but are much smaller in magnitude. The fourth column displays the horizontal wage externalities. These are all positive, but also small in magnitude. As households move into other states, this leads to an increase in wages which leads to additional state tax revenue. Taken together, incorporating endogenous wages does not change our main conclusions.

5.2 State and Local Income Tax Deductions

When paying federal taxes, households can reduce their taxable income by deducting taxes paid to other entities. This is called the State and Local Tax deduction (SALT), which was capped at $\$10,000$ by the Tax Cuts and Jobs Act of 2017. Our main specification is consistent with either all households taking the standard deduction or state and local taxes exceeding the SALT cap. If we allow for state taxes to directly affect taxable income through a SALT deduction, changes in state taxes will also affect federal tax revenue by changing households' deductions and therefore taxable income. Appendix A.3 solves the model when we allow for this possibility, finding that this does not significantly change our main results. The lack of impact is driven by the fact that relatively few households itemize their deductions, or if they do itemize, their state and local tax payment exceeds the SALT cap.

5.3 Robustness

In our baseline specification, we calibrated η^M_{bj}, the elasticity of location-choice with respect to state taxes, using the estimates from Colas and Hutchinson (2021). In this section, we examine the robustness of our quantifications of the vertical migration externality with respect to the location-choice elasticity.[32] Recall that in our baseline specification we found a vertical migration externality of -0.39 for California.

In Figure 2, we evaluate equation (9) for the state of California using a range of values of η^M_{bj} for households without college experience and for households with college experience. For this exercise, we set η^M_{bj} constant as a constant value across locations. the Y-axis varies $\eta^M_{College}$ for households who's head has college experience from $|\eta^M| = 1$ to $|\eta^M| = 10$ and the X-axis varies $\eta^M_{NoCollege}$ for households who's head has no college experience.

Darker shades represent larger externalities. In the extreme case when $|\eta^M| = 10$ for all workers, we find a vertical migration externality of -0.73, roughly 50% larger than our baseline estimates. When we set $|\eta^M| = 6$ for all workers, consistent with Albouy (2009), we find a vertical migration externality of -0.29, close to our baseline estimate of -0.39. Overall, the location-choice elasticity of skilled households plays a much larger role in determining the externality, as skilled households have larger income differences across states and face higher marginal tax rates. Therefore, the differences in federal tax burden for skilled households across states is much larger than for unskilled households.

[32] We further explore robustness with respect to the location-choice elasticities in Appendix A.5. In that Section, we reproduce our main results using estimates of the location-choice elasticity from Gordon and Cullen (2012) and based on estimates from Bartik (1991).

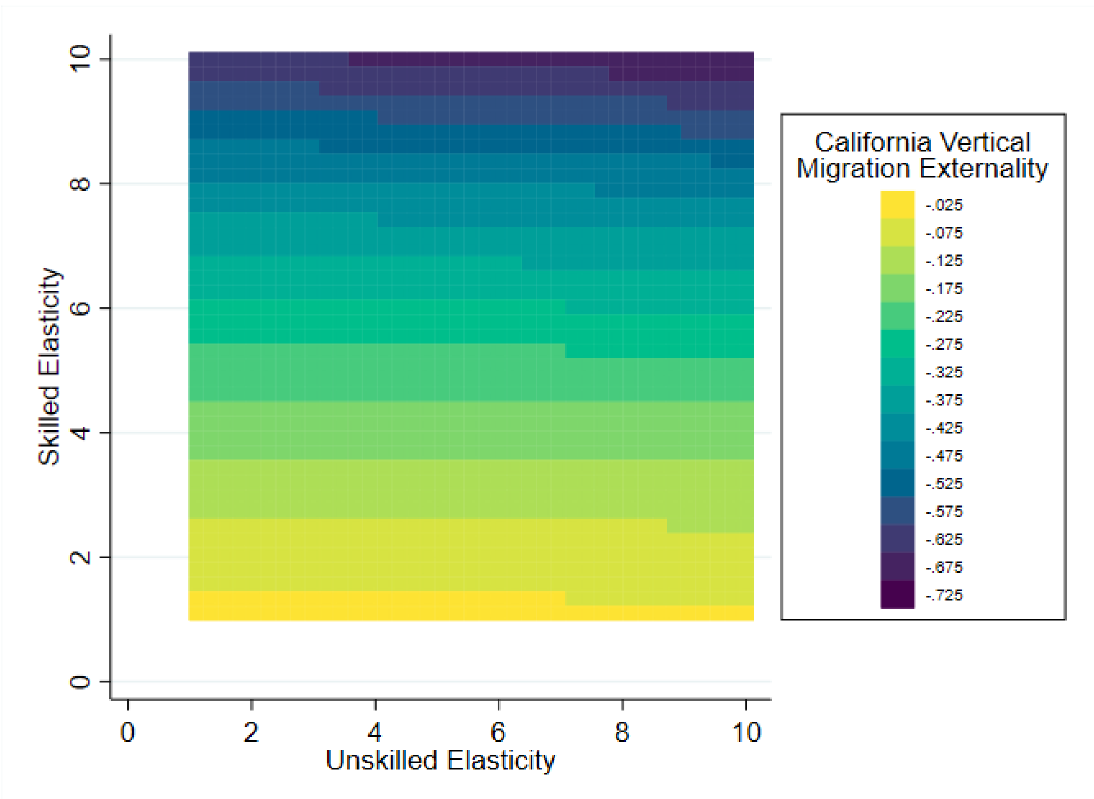

Figure 2: Vertical migration externalities for California for a range of values for $|\eta^M_{bj}|$ for skilled and unskilled households. The Y-axis varies $|\eta^M_{College}|$ for households who's head has college experience and the X-axis varies $|\eta^M_{NoCollege}|$ for households who's head has no college experience.

5.4 Distributional Effects

This paper aims to quantify fiscal externalities, but the resulting policy implications also have important welfare and distributional consequences. The distributional effects may be particularly important not only because a policy designed to internalize vertical migration externalities could lead to reducing taxes in high-income states and increasing taxes in low-income states but also because, within each state, high-income households may be more likely to be able to migrate in response to a change in state taxes.[33] Analyzing the welfare or distributional effects would be possible using a structural model that explicitly specifies household utility functions and the processes determining local prices and amenities, an approach different than the one we take here. One could use such a framework to measure the impact of changing state taxes throughout the income distribution, which informs *who* benefits from or bears the burden of tax changes. Additionally, one could measure the effect of changing the progressivity of state income taxes rather than the uniform increase in tax rates that we consider.

6 Conclusion

We have shown that state taxes lead to significant fiscal externalities by shifting the distribution of households between high-income and low-income states. We specified a model with heterogeneous households that vary in the state which they live and the hours of labor they supply. We then derived expressions for the effect of a small increase in state taxes on federal tax revenue, as well as tax revenue in other states.

The vertical migration externalities we find are large in magnitude and robust across a variety of specifications. We find that a one dollar increase in California income tax revenue would decrease federal tax revenue by 39 cents from migration alone. This effect is significant in magnitude, as a 1 percentage point increase in California state tax revenue leads to a migration externality that amounts to 0.27% of total federal income tax revenue. Additionally, there is wide heterogeneity among states, with 36 out of 50 states having a positive vertical migra-

[33] Bound and Holzer (2000) find that high-skilled workers are more likely to migrate in response to shifts in labor demand.

tion externality. We believe the vertical migration externality that we highlight adds a new dimension to the fiscal federalism discussion: in a federalist system, state taxes may be set too high in high-productivity states and too low in low-productivity states because of the vertical migration externality. We are the first to document and quantify this effect.

Future work could explore the efficiency costs associated with these externalities. It would then be natural to analyze how these inefficiencies could be corrected by Pigouvian subsidies, similar to the subsidies suggested by Wildasin (1989) to correct for horizontal externalities. As discussed earlier, it is important to address the distributional impacts of such policy recommendations, as they could be regressive. It would also be interesting to analyze these effects in a dynamic setting, where the short-run effects may differ from the long-run effects studied here. We leave these questions for future research.

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A Results and Extensions Appendix

A.1 Average Household Income for Selected States

Table 6 shows the average household income for college-educated households with 0 to 5 years of potential experience for households in California and California's largest migration partners. Table 7 repeats the exercise for the state of Mississippi. These average incomes are not used directly in our quantification. We calculate tax burdens and tax rates as average taxes and tax rates over the households in question, not the tax burden or tax rate associated with the average household income.

			Average HH Income
California			63.9
Migration Sources		Weight	
1	Texas	10.1	58.3
2	Washington	10.0	66.1
3	New York	8.7	62.5
4	Arizona	5.9	50.2
5	Oregon	5.8	48.9

Table 6: Average household income for college-educated households with 0-5 potential experience in California and its largest migration partners. The column "Weight" presents 100% $\times\ \omega_{bjk}$.

A.2 All States

Table 8 displays the results from Section 4 for all states. The table displays the vertical migration externality (VME), vertical hours externality (VHE), and horizontal migration externality as a fraction of the increase in state tax revenue for all states. See Section 4 for details.

		Average HH Income
Mississippi		45.2
Migration Sources	Weight	
1 Texas	15.8	58.3
2 Tennessee	12.4	49.1
3 Louisiana	7.8	55.2
4 Alabama	7.3	47.3
5 Florida	6.1	49.1

Table 7: Average household income for college-educated households with 0-5 potential experience in Mississippi and its largest migration partners. The column "Weight" presents $100\% \times \omega_{bjk}$.

	Individual Externalities					Individual Externalities			
State	VME	VHE	HME	Total	State	VME	VHE	HME	Total
Alabama	0.20	-0.04	0.24	0.40	Montana	0.32	-0.05	0.30	0.58
Alaska	-0.04	-0.04	0.16	0.08	Nebraska	0.16	-0.05	0.28	0.39
Arizona	0.15	-0.04	0.25	0.36	Nevada	0.08	-0.03	0.21	0.26
Arkansas	0.26	-0.04	0.24	0.45	NewHampshire	0.04	-0.04	0.20	0.20
California	-0.39	-0.08	0.25	-0.21	NewJersey	-0.32	-0.07	0.25	-0.14
Colorado	-0.02	-0.06	0.25	0.18	NewMexico	0.38	-0.03	0.21	0.56
Connecticut	-0.43	-0.08	0.29	-0.22	NewYork	-0.29	-0.07	0.34	-0.02
Delaware	0.07	-0.06	0.30	0.31	NorthCarolina	0.18	-0.05	0.31	0.44
Florida	0.12	-0.03	0.23	0.32	NorthDakota	-0.01	-0.04	0.20	0.15
Georgia	0.04	-0.06	0.26	0.24	Ohio	0.08	-0.04	0.23	0.26
Hawaii	0.17	-0.07	0.40	0.50	Oklahoma	0.17	-0.04	0.18	0.31
Idaho	0.27	-0.04	0.28	0.50	Oregon	0.30	-0.08	0.34	0.57
Illinois	-0.14	-0.06	0.28	0.08	Pennsylvania	0.06	-0.05	0.26	0.27
Indiana	0.11	-0.04	0.22	0.28	RhodeIsland	0.16	-0.05	0.31	0.41
Iowa	0.14	-0.06	0.31	0.39	SouthCarolina	0.22	-0.05	0.30	0.47
Kansas	0.16	-0.05	0.26	0.37	SouthDakota	0.19	-0.03	0.20	0.36
Kentucky	0.04	-0.05	0.23	0.23	Tennessee	0.07	-0.03	0.20	0.23
Louisiana	0.13	-0.04	0.19	0.27	Texas	-0.06	-0.04	0.19	0.09
Maine	0.34	-0.05	0.28	0.57	Utah	0.11	-0.05	0.23	0.28
Maryland	-0.10	-0.07	0.31	0.14	Vermont	0.36	-0.05	0.32	0.63
Massachusetts	-0.27	-0.07	0.27	-0.08	Virginia	-0.11	-0.07	0.30	0.13
Michigan	0.11	-0.05	0.24	0.30	Washington	-0.08	-0.04	0.22	0.09
Minnesota	-0.25	-0.08	0.29	-0.03	WestVirginia	0.31	-0.04	0.30	0.57
Mississippi	0.31	-0.03	0.22	0.50	Wisconsin	0.14	-0.06	0.31	0.39
Missouri	0.01	-0.05	0.26	0.22	Wyoming	0.05	-0.04	0.17	0.18

Table 8: Fiscal externalities as a fraction of increase in state tax revenue for all states. The first column gives the vertical migration externality, formally given by $VME/\left(\frac{dStateRev}{ds_j}\right)$. The next column gives the vertical hours externality given by $VHE/\left(\frac{dStateRev}{ds_j}\right)$. The third column of the table displays the horizontal externality given by $JME/\left(\frac{dStateRev}{ds_j}\right)$.

A.3 Appendix: State and Local Income Tax Deductions

The following section solves the model when we allow for this possibility, finding that this does not significantly change our main results. The lack of impact is driven by the fact that relatively few households itemize their deductions, or if they do itemize, their state and local tax payment exceeds the SALT cap.

Let $t_b(y_{bj} - d_{bj})$ be the federal tax function allowing for deductions, d_{bj}. We use $t_b(\cdot)$, rather than $\tau_b(\cdot)$ here because the tax function here takes income minus deductions as an argument, where $\tau_b(\cdot)$ only takes income as an argument. Households either take a variable deduction, representing an itemized deduction for households who are not subject to the SALT cap, or take a fixed deduction, representing a standard deduction or an itemized deduction for households above the SALT cap. Let the variable deduction for households of type b in state j be $d_{bj}^V = (\sigma_{bj}(y_{bj}) + s_j y_{bj}) + o_b$, where o_b is deductions other than the state income tax deduction. Let d_{bj}^F be the fixed deduction for households of type b. Thus, after-tax income is now given by

$$\tilde{y}_{bj} = y_{bj} - (\sigma_{bj}(y_{bj}) + s_j y_{bj}) - t_b(y_{bj} - d_{bj}).$$

Let λ_{bj} be the proportion of type b households in state j who take the variable deduction, and let $(1 - \lambda_{bj})$ be the proportion of households who take the fixed deduction. We assume the λ's are given exogenously.

Federal Income Tax As shown in Appendix B.4, the effect of an increase in state j's tax rate on federal tax revenue is

$$\frac{dFedRev}{ds_j} = VME_j^{SALT} + VHE_j^{SALT} + \underbrace{\sum_b N_{bj}\lambda_{bj} y_{bj} t_b'(y_{bj} - d_{bj}^V)}_{\text{Deduction effect}} \tag{18}$$

where VME_j^{SALT} and VHE_j^{SALT} are modified slightly from the main specification, as described below.

The addition of state tax deductions has three effects on federal tax revenue for variable deduction households. First, increasing state taxes reduces the taxable income left for federal taxes since the state tax payment can be deducted when calculating federal taxes. This directly decreases the amount of federal taxes paid, which is captured by the third term in equation (18), $y_{bj} t_b'(y_{bj} - d_{bj}^V)$. Second, migration away from state j induced by an increase in taxes there is mitigated, since the increase in the state tax burden faced by households is partially offset by a decrease in federal taxes paid. The vertical migration externality is now the weighted average of the externality for variable deduction households and fixed deduction households.

$$
\begin{aligned}
VME_j^{SALT} = \sum_b N_{bj} \Big[& \lambda_{bj} \eta_{bj}^{M,V} \left(t_b \left(y_{bj} - d_{bj}^V \right) - t_{bj}^{o,V} \right) \\
& + (1 - \lambda_{bj}) \eta_{bj}^{M,F} \left(t_b \left(y_{bj} - d_{bj}^F \right) - t_{bj}^{o,F} \right) \Big] ,
\end{aligned}
\tag{19}
$$

where $t_{bj}^{o,V} = \sum_{k \neq j} \omega_{bjk} t_b(y_{bk} - d_{bj}^V)$ and $t_{bj}^{o,F} = \sum_{k \neq j} \omega_{bjk} t_b(y_{bk} - d_b^F)$ are the weighted average federal tax revenue from other states, weighted by the proportion of type b households in state j that move to another state k. Additionally, $\eta_{bj}^{M,V} = -\varepsilon_b^M \left(1 - t_b'(y_{bj} - d_{bj}^V)\right) \frac{y_{bj}}{\tilde{y_{bj}}}$ and $\eta_{bj}^{M,F} = -\varepsilon_b^M \frac{y_{bj}}{\tilde{y_{bj}}}$ are the semi elasticities of migration with respect to state taxes for variable and fixed deductions. The effect of the SALT deduction on migration is seen in the difference between $\eta_{bj}^{M,V}$ and $\eta_{bj}^{M,F}$, where $\eta_{bj}^{M,F}$ is the same as the main specification, and $\eta_{bj}^{M,V}$ is scaled down by one minus the marginal federal tax rate.

Finally, households respond to the change in after-tax wages by altering the hours that they work. The vertical hours externality is now

$$
\begin{aligned}
VHE_j^{SALT} = \sum_b N_{bj} \big[& \lambda_{bj} (1 - \sigma_{bj}') \eta_{bj}^{\ell} y_{bj} t_b'(y_{bj} - d_{bj}^V) \\
& + (1 - \lambda_{bj}) \eta_{bj}^{\ell} y_{bj} t_b'(y_{bj} - d_b^F) \big] ,
\end{aligned}
\tag{20}
$$

where the externality is scaled down by one minus the marginal state tax rate for variable deduction households since state taxes now affect federal taxes through the SALT deduction.

Other State Income Taxes The addition of SALT deductions to the model also changes the effect of an increase in state j's tax rate on tax revenue in other states. This is due to the dampening of the migration response created by the SALT deduction, which is captured by taking the weighted average of $\eta_{bj}^{M,V}$ and $\eta_{bj}^{M,F}$,

$$HME_j^{SALT} = -\sum_b N_{bj} \left(\lambda_{bj} \eta_{bj}^{M,V} + (1 - \lambda_{bj}) \eta_{bj}^{M,F} \right) \sigma_{bj}^o. \tag{21}$$

Results To quantify equation (18), we additionally need estimates of λ_{bj}, the fraction of households for whom state taxes affect their federal tax burden. For this, we use estimates of the fraction of households who itemize their deductions by income percentile produced by the Tax Foundation.[34] Specifically, for each household type and location, we calculate the portion of households in each income percentile. We then calculate λ_{bj} as the weighted average of the fraction of households who itemize across income percentiles within each demographic-location group. Recall that λ represents the fraction of households who both itemize their deductions and for whom state tax deductions do not exceed the SALT deduction cap. Therefore, our estimates of λ_{bj} will overstate the amount of households who take a variable deduction since the estimates also include households who exceed the state and local tax deduction cap. We again use TAXSIM to calculate tax rates. One complication is that we do not observe which households in our data take an itemized deduction and who take the standard deduction. We therefore calibrate both $t_b'(y_{bj} - d_b^F)$ and $t_b'(y_{bj} - d_b^V)$ as the average marginal tax rates conditional on type and location and both $t_b(y_{bj} - d_b^F)$ and $t_b(y_{bj} - d_b^V)$ as the average tax levels conditional on type and location.

The main results are displayed in Table 9. Across the board, the results are very similar to the results in Section 4.

A.4 Alternative Estimates of Migration Weights

Recall that in our main specification, we calculated the migration weights fraction of migrants from location j who choose to locate in state k: $\omega_{bjk} = \frac{N_{j\to k}^b}{\sum_{k' \neq j} N_{j \to k'}^b}$. In this section, we re-calculate our main results under several alternative estimation methods.

[34] https://taxfoundation.org/standard-deduction-itemized-deductions-current-law-2019/

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.42	-0.07	0.23	-0.26
Large States				
Texas	-0.09	-0.04	0.18	0.05
Florida	0.10	-0.03	0.22	0.29
New York	-0.33	-0.07	0.32	-0.08
Low Income States				
Arkansas	0.23	-0.04	0.23	0.42
Mississippi	0.29	-0.03	0.22	0.47
West Virginia	0.28	-0.04	0.29	0.53

Table 9: Fiscal externalities as a fraction of increase in state tax revenue for selected states with state tax deductions.

First, we again use the ACS' migration history questions and calculate the migration weight as the fraction of households who migrated to state j who originated from state k. Again, letting $N^b_{j\to k}$ represent the number of households who migrate from state j to state k, we can write this alternative weight as

$$\tilde{\omega}_{bjk} = \frac{N^b_{k\to j}}{\sum_{k'\neq j} N^b_{k'\to j}}.$$

The results using this alternative set of migration weights are shown in Table 10. The results are very similar to the baseline specification.

Next, we make use of the information on the household's state of birth and calculate the migrate weights as the fraction of households who's head was born in state j who currently live in state k. Let $N^b_{bpl=j,k}$ represent the number of households who were born in state j. We define our next set of migration weights as

$$\hat{\omega}_{bjk} = \frac{N^b_{bpl=j,k}}{\sum_{k'\neq j} N^b_{bpl=j,k'}}.$$

The results are shown in Table 11 and again are similar to the baseline results.

Finally, we calculate the migration weights as the fraction of total households of a given demographic group who live in a given state k. Formally, this is given

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.40	-0.07	0.31	-0.17
Large States				
Texas	-0.10	-0.04	0.18	0.04
Florida	0.09	-0.03	0.24	0.29
New York	-0.32	-0.07	0.37	-0.02
Low Income States				
Arkansas	0.16	-0.04	0.27	0.39
Mississippi	0.26	-0.03	0.26	0.49
West Virginia	0.41	-0.04	0.39	0.76

Table 10: Fiscal externalities as a fraction of increase in state tax revenue for selected states. Migration weights are calculated as the fraction of households who migrated to state j who originated from state k.

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.40	-0.07	0.26	-0.21
Large States				
Texas	-0.05	-0.04	0.20	0.12
Florida	0.12	-0.03	0.24	0.32
New York	-0.33	-0.07	0.33	-0.07
Low Income States				
Arkansas	0.25	-0.04	0.23	0.44
Mississippi	0.34	-0.03	0.24	0.55
West Virginia	0.33	-0.04	0.30	0.59

Table 11: Fiscal externalities as a fraction of increase in state tax revenue for selected states. Migration weights are calculated as the fraction of households who's head was born in state j who currently live in state k.

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.36	-0.07	0.29	-0.14
Large States				
Texas	-0.01	-0.04	0.21	0.17
Florida	0.17	-0.03	0.25	0.38
New York	-0.38	-0.07	0.32	-0.13
Low Income States				
Arkansas	0.33	-0.04	0.32	0.60
Mississippi	0.45	-0.03	0.32	0.73
West Virginia	0.41	-0.04	0.33	0.71

Table 12: Fiscal externalities as a fraction of increase in state tax revenue for selected states. Migration weights are calculated as the fraction of total households of a given demographic group who live in a given state k.

by

$$\omega_{bjk} = \frac{N_k^b}{\sum_{k' \neq j} N_{k'}^b}.$$

The results are shown in Table 12. The results are very similar to the baseline results.

A.5 Alternative Measures of Location-Choice Elasticity

In Table 13, we replicate the main results, but instead set $\eta_{bj}^M = -6$ for all types and locations, based on Albouy (2009) and Bartik (1991). The results are very similar to the baseline results.

Next, we use the estimates of location-choice elasticities from Gordon and Cullen (2012), who estimate location-choice elasticities by income quintile using an equilibrium model of federal and state spending with migration across states. As there baseline estimates include negative elasticities for some groups, we utilize their estimates where they set an elasticity of 0.5 for the bottom three income quintiles, based on the estimates of Kennan and Walker (2011), and estimate the location-choice elastictities for the top two quintiles.

Since they provide elasticities by income quintiles, we define types as income

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.29	-0.07	0.21	-0.15
Large States				
Texas	-0.05	-0.04	0.19	0.10
Florida	0.12	-0.03	0.24	0.32
New York	-0.22	-0.07	0.29	0.00
Low Income States				
Arkansas	0.27	-0.04	0.25	0.48
Mississippi	0.32	-0.03	0.24	0.52
West Virginia	0.33	-0.04	0.33	0.61

Table 13: Fiscal externalities as a fraction of increase in state tax revenue for selected states. We set $\eta_{bj}^{M} = -6$ for all types and locations, based on Albouy (2009) and Bartik (1991).

quintile interacted with household head's education and potential experience. We set $\varepsilon_b^M = 0.5$ for the bottom three income quintiles, set $\varepsilon_b^M = 15.7$ for the fourth quintile, and set $\varepsilon_b^M = 7.4$ for the top income quintile. The results are included in Table 14.

A.6 Alternative Type Definitions

In the baseline case, we defined types by education and potential experience of the household head. In Table 15, we divide households into four groups based on the education of the household head: high school dropouts, high school graduates, some college, and college or more. The results are similar to the baseline specification.

In Table 16, we consider a third specification in which we interact the education and experience types with the race of the household head, defined as whether or not the household head identifies as "white". This gives us a total of 64 types. The results are again similar to the baseline specification.

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.39	-0.15	0.64	0.10
Large States				
Texas	-0.03	-0.06	0.31	0.23
Florida	-0.05	-0.06	0.32	0.21
New York	-0.55	-0.16	0.82	0.11
Low Income States				
Arkansas	0.04	-0.10	0.39	0.33
Mississippi	0.01	-0.08	0.36	0.29
West Virginia	0.08	-0.10	0.55	0.54

Table 14: Fiscal externalities as a fraction of increase in state tax revenue for selected states. We use estimates of location-choice elasticities from Gordon and Cullen (2012).

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.39	-0.07	0.26	-0.21
Large States				
Texas	-0.04	-0.04	0.19	0.11
Florida	0.10	-0.03	0.23	0.30
New York	-0.26	-0.07	0.36	0.03
Low Income States				
Arkansas	0.28	-0.04	0.23	0.47
Mississippi	0.31	-0.03	0.22	0.50
West Virginia	0.36	-0.04	0.32	0.64

Table 15: Fiscal externalities as a fraction of increase in state tax revenue for selected states. Household types are defined by the education level of the household head.

	Individual Externalities			
	VME	VHE	HME	Total
California	-0.43	-0.07	0.24	-0.27
Large States				
Texas	-0.07	-0.04	0.19	0.08
Florida	0.13	-0.03	0.23	0.34
New York	-0.32	-0.07	0.34	-0.05
Low Income States				
Arkansas	0.27	-0.04	0.24	0.47
Mississippi	0.27	-0.04	0.21	0.44
West Virginia	0.39	-0.04	0.32	0.67

Table 16: Fiscal externalities as a fraction of increase in state tax revenue for selected states. Household types are defined by the education level, potential experience, and race of the household head.

B Theoretical Appendix

B.1 Derivation of Equation 4

From equation (3), we can write the probability that a household of type b chooses state k as

$$P_{bk} = \int \mathbb{1}\left(V_{bk}\left(\cdot\right) - V_{bk'}\left(\cdot\right) \geq \varepsilon_{k'} - \varepsilon_{k}, \forall k' \neq k\right) f_{b}\left(\varepsilon\right) d\varepsilon.$$

Let $\tilde{\varepsilon}_{k'} = \varepsilon_{k'} - \varepsilon_{k}$ and $g_{b}\left(\tilde{\varepsilon}\right)$ denote the joint distribution of $\tilde{\varepsilon}$ for type b. We can write the choice probability in terms of $\tilde{\varepsilon}$ as

$$P_{bk} = \int \mathbb{1}\left(V_{bk}\left(\cdot\right) - V_{bk'}\left(\cdot\right) \geq \tilde{\varepsilon}_{k'}, \forall k' \neq k\right) g_{b}\left(\tilde{\varepsilon}\right) d\tilde{\varepsilon},$$

This multidimensional integral is equal to the density function $g_{b}\left(\cdot\right)$ integrated over the range for which the indicator function takes a positive value:

$$P_{bk} = \int_{-\infty}^{V_{bk}-V_{b1}} \int_{-\infty}^{V_{bk}-V_{b2}} \ldots \int_{-\infty}^{V_{bk}-V_{bJ}} g_{b}\left(\tilde{\varepsilon}\right) d\tilde{\varepsilon}$$

Taking the total derivative yields

$$\frac{dP_{bk}}{ds_j} = \left(\frac{dV_{bk}}{ds_j} - \frac{dV_{b1}}{ds_j}\right) \int_{-\infty}^{V_{bk}-V_{b2}} \dots \int_{-\infty}^{V_{bk}-V_{bJ}} g_b\left(\tilde{\varepsilon}|\tilde{\varepsilon}_1 = V_{bk} - V_{b1}\right) d\tilde{\varepsilon} +$$
$$\left(\frac{dV_{bk}}{ds_j} - \frac{dV_{b2}}{ds_j}\right) \int_{-\infty}^{V_{bk}-V_{b1}} \dots \int_{-\infty}^{V_{bk}-V_{bJ}} g_b\left(\tilde{\varepsilon}|\tilde{\varepsilon}_2 = V_{bk} - V_{b2}\right) d\tilde{\varepsilon} +$$
$$\dots$$
$$\left(\frac{dV_{bk}}{ds_j} - \frac{dV_{bJ}}{ds_j}\right) \int_{-\infty}^{V_{bk}-V_{b1}} \dots \int_{-\infty}^{V_{bk}-V_{bJ-1}} g_b\left(\tilde{\varepsilon}|\tilde{\varepsilon}_J = V_{bk} - V_{bJ}\right) d\tilde{\varepsilon}.$$

We can rewrite this total derivative using indicator functions as

$$\frac{dP_{bk}}{ds_j} = \sum_{k' \neq k} \left(\frac{dV_{bk}}{ds_j} - \frac{dV_{bk'}}{ds_j}\right) \int \mathbb{1}_{k' \to k}\left(\varepsilon\right) g_b\left(\tilde{\varepsilon}\right) d\varepsilon,$$

where we define the indicator for marginal households as

$$\mathbb{1}_{k' \to k}\left(\varepsilon\right) = \mathbb{1}\left(V_{bk}\left(\cdot\right) - V_{bk''}\left(\cdot\right) \geq \tilde{\varepsilon}_{k''}, \forall k'' \neq k\right) \times \mathbb{1}\left(V_{bk'}\left(\cdot\right) - V_{bk}\left(\cdot\right) = \tilde{\varepsilon}_{k'}\right).$$

Plugging in the definition of $\tilde{\varepsilon}$ yields equation (4).

B.2 Derivation of Equation 12

Before, solving for η^{ℓ}_{bj}, it will be useful to first solve for $\frac{d\tilde{w}_{bj}}{ds_j}$, the derivative of after-tax wages with respect to state taxes. Note that after-tax wages are given by after-tax income divided by hours worked:

$$\tilde{w}_{bj} = w_j - \frac{\sigma_{bj}(y_{bj}) + s_j y_{bj} + \tau_b\left(y_{bj}\right)}{\ell_{bj}}.$$

Taking the derivative of $\tilde{w}_{bj}$ with respect to s_j and rearranging yields

$$\frac{d\tilde{w}_{bj}}{ds_j} = \frac{\sigma_{bj}(y_{bj}) + \tau_b(y_{bj})}{\ell_{bj}^2}\frac{d\ell_{bj}}{ds_j} - \frac{\sigma'_{bj}(y_{bj}) + \tau'_b(y_{bj})}{\ell_{bj}}\frac{dy_{bj}}{ds_j} - w_b$$
$$\frac{d\tilde{w}_{bj}}{ds_j} = -w_b\left(\left(\sigma'_{bj}(y_{bj}) + \tau'_j(y_{bj}) - \frac{\sigma_{bj}(y_{bj}) + \tau_b(_{bj})}{y_{bj}}\right)\frac{1}{\ell_{bj}}\frac{d\ell_{bj}}{ds_j} + 1\right).$$

Letting $\theta_{bj} = \sigma'_{bj}(y_{bj}) + \tau'_j(y_{bj}) - \frac{\sigma_{bj}(y_{bj})+\tau_b(_{bj})}{y_{bj}}$ denote the difference between the marginal tax rate and the average tax rate, we can rewrite the above derivative as

$$\frac{d\tilde{w}_b}{ds_j} = -w_{bj}\left(\frac{\theta_{bj}}{\ell_{bj}}\frac{d\ell_{bj}}{ds_j} + 1\right).$$

We will now use this to solve for η^{ℓ}_{bj}. Plugging $\frac{d\tilde{w}_b}{ds_j}$ into the definition of η^{ℓ}_{bj} yields

$$\eta^{\ell}_{bj} = \varepsilon^{\ell}_b\frac{\ell_{bj}}{\tilde{w}_j}\left(-w_j\left(\frac{\theta_{bj}}{\ell_{bj}}\frac{d\ell_{bj}}{ds_j} + 1\right)\right)\frac{1}{\ell_{bj}}.$$

Finally, using the fact that $w_j/\tilde{w}_{bj} = y_{bj}/\tilde{y}_{bj}$, we can rewrite the above expression as

$$\eta^{\ell}_{bj} = \frac{\varepsilon^{\ell}_b y_{bj}/\tilde{y}_{bj}}{1 - \varepsilon^{\ell}_b\theta_{bj}y_{bj}/\tilde{y}_{bj}}.$$

B.3 Derivations for Endogenous Wage Specification

Here we derive the expressions for the effect of an increase in s_j on federal and state tax revenue. $L_j = \sum_b N_b P_{bj}\ell_{bj}$ is the aggregate labor supply in state j, and $\varepsilon^w = \frac{dw_j}{dL_j}\frac{L_j}{w_j}$ is the elasticity of wages with respect to aggregate labor supply, which we assume to be constant across all states. Additionally, $\eta^w_{jk} = \frac{dw_k}{ds_j}\frac{1}{w_k}$ is the semi elasticity of wages in state k with respect to state taxes in state j. Now, the effect of a change in state tax rates on household income is $dy_{bj}/ds_j = y_{bj}(\eta^{\ell}_{bj} + \eta^w_j)$. For states $k \neq j$, the effect of a change in state j's on household income in state k is $dy_{bk}/ds_j = y_{bk}\eta^w_{jk}$.

State Income Tax Similarly to the main model, we start by taking the partial derivative of equation (1) with respect to s_j at $s_j = 0$ and substituting in the above expression for dy_{bj}/ds_j. This results in

$$\frac{dStateRev_j}{ds_j} = \sum_b N_{bj} \left(y_{bj} + \eta_b^m \sigma_{bj} \left(y_{bj} \right) + y_{bj} (\eta_{bj}^{\ell} + \eta_j^w) \sigma'_{bj}(y_{bj}) \right).$$

This is the same as the main model, except for an extra term to capture the change in wages. In order to write η_j^w in terms of ε^w, we must calculate the effect of state j's taxes on aggregate labor supply in state j, as $\eta_j^w = \frac{dw_j}{dL_j} \frac{dL_j}{ds_j} \frac{1}{w_j}$. Using our migration semi elasticities from before, we have $dL_j/ds_j = \sum_b N_{bj} \eta_{bj}^m \ell_{bj}$. Additionally, let $\bar{\sigma}'_j(y_{bj}) = \frac{\sum_b N_{bj} \eta_{bj}^m y_{bj} \sigma'_{bj}(y_{bj})}{\sum_b N_{bj} y_{bj}}$ be the income weighted average of the marginal state tax rate. Substituting these into the expression for η_{jk}^w, we have $\eta_j^w = \varepsilon^w \bar{\sigma}'(y_{bj})$. Thus, the percent change in state j's wages due to a small increase in s_j is the elasticity of wages with respect to labor supply multiplied by the labor weighted average of η_{bj}^M, which is the percentage decrease in the proportion of households living in state j from a marginal increase in s_j. We now arrive at equation (13),

$$\frac{dStateRev_j}{ds_j} = \sum_b N_{bj} \left(y_{bj} + \eta_b^m \sigma_{bj} \left(y_{bj} \right) + \eta_b^m \varepsilon^w y_{bj} \bar{\sigma}'_j(y_{bj}) \right).$$

Federal Income Tax As with state taxes, the change in federal tax revenue resulting from a small increase in s_j is largely the same as the main specification, but now wages in every state can change, producing an additional externality. Since wages in every state can change, the change in income in state k due to a small increase in s_j is $dy_{bk}/ds_j = y_{bk} \eta_{jk}^w$. Taking the derivative of equation(2) with respect to s_j and substituting in $\tau_{bj}^o \equiv \sum_{k \neq j} \omega_{bjk} \tau_b \left(y_{bk} \right)$ as we did in the main results, we have equation (14),

$$\frac{dFedRev}{ds_j} = \sum_b N_{bj} \left[\eta_b^m \left(\tau_b \left(y_{bj} \right) - \tau_{bj}^o \right) \right] + \sum_k N_{bk} y_{bk} \eta_{jk}^w \tau'_b(y_{bk}).$$

This effect now contains a migration response and a wage response. We can use the migration weights, ω_{bjk}, to determine the change in aggregate labor supply in state k from a small increase in s_j, as follows $dL_k/ds_j = -\sum_b N_{bj} \omega_{bjk} \eta_{bj}^m \ell_{bk}$. Thus, for states $k \neq j$, we have

$$\eta_{jk}^w = -\varepsilon^w \frac{\sum_b N_{bj} \omega_{bjk} \eta_{bj}^m \ell_{bk}}{\sum_b N_{bk} \ell_{bk}}. \tag{22}$$

We call the new effect on federal tax revenue from endogenous wages the vertical wage externality (VWE). Taking the wage effect term from the above change in federal tax revenue and substituting in η_j^w from the state revenue section above and equation (22) for the wage semi elasticities, we get equation (15),

$$VWE_j = \varepsilon^w \sum_b N_{bj}\eta_{bj}^m \left(y_{bj}\bar{\tau}_j' - (y\bar{\tau}')^o\right),$$

where $\bar{\tau}_j' = \frac{\sum_b N_{bj}y_{bj}\tau_b'(y_{bj})}{\sum_b N_{bj}y_{bj}}$ is the income weighted marginal federal tax rate and $(y\bar{\tau}')^o = \sum_{k\neq j}\omega_{bjk}y_{bk}\bar{\tau}_k'$ is the migration weighted average of these income weighted marginal tax rates across all other states.

Other State Income Taxes As seen in the federal tax case, wages in other states respond endogenously to the migration induced by a small increase in s_j. Taking the derivative of some state k's tax revenue with respect to s_j gives

$$\frac{dStateRev_k}{ds_j} = \sum_b N_b \left(\frac{dP_{bk}}{ds_j}\sigma_{bk}\left(y_{bk}\right) + P_{bk}\sigma_{bk}'(y_{bk})\frac{dy_{bk}}{ds_j}\right).$$

The first term can be simplified as it was in the main model, and we can substitute the expression for dy_{bk}/ds_j from the federal tax section to give

$$\frac{dStateRev_k}{ds_j} = -\sum_b N_{bj}\left(\eta_b^m\omega_{bjk}\sigma_{bk}\left(y_{bk}\right) + y_{bk}\eta_{jk}^w\sigma_{bk}'(y_{bk})\right).$$

Summing across all states $k \neq j$, we arrive at the horizontal wage externality in equation (17),

$$HME_j = -\varepsilon^w \sum_b N_{bj}\eta_b^m (y\bar{\sigma}')^o,$$

where $(y\bar{\sigma}')^o = \sum_{k\neq j}\omega_{bjk}y_{bk}\frac{\sum_b N_{bk}y_{bk}\sigma_{bk}'(y_{bk})}{\sum_b N_{bk}y_{bk}}$.

B.4 Derivations for State Income Tax Deductions

Recall after-tax income when including deductions, d_{bj}, is

$$\tilde{y}_{bj} = y_{bj} - \left(\sigma_{bj}\left(y_{bj}\right) + s_j y_{bj}\right) - t_b\left(y_{bj} - d_{bj}\right),$$

where the federal tax function, $t_b(\cdot)$, is now a function of income after deductions. The variable deduction for household type b in state j is $d_{bj}^V = (\sigma_{bj}(y_{bj}) + s_j y_{bj}) + o_b$, where o_b is deductions other than the state income tax deduction, and the fixed is denoted as d_b^F. λ_{bj} is the proportion of type b households in state j who have a variable deduction, and $(1-\lambda_{bj})$ is the proportion of households who have a fixed deduction.

State Income Taxes The change in state j's tax revenue due to a small increase in s_j is the same as equation (5) in the main model,

$$\frac{dStateRev_j}{ds_j} = \sum_b N_{bj}\left(y_{bj} + \eta_{bj}^M \sigma_{bj}(y_{bj}) + \eta_{bj}^\ell y_{bj}\sigma'_{bj}(y_{bj})\right),$$

however, estimation of η_{bj}^M is different. Using the location-choice elasticity with respect to after-tax income, we have $\eta_{bj}^M = \varepsilon_b^M \frac{d\tilde{y}_{bj}}{ds_j}\frac{1}{\tilde{y}_{bj}}$. For those who itemize their deductions, $d\tilde{y}_{bj}/ds_j = -y_{bj}\left(1 - t'_b(y_{bj} - d_{bj}^V)\right)$[35]. Thus, we have that

$$\eta_{bj}^{M,V} = -\varepsilon_b^M\left(1 - t'_b(y_{bj} - d_{bj}^V)\right)\frac{y_{bj}}{\tilde{y_{bj}}}.$$

For those to take the standard deduction, the migration semi elasticity is the same as the main model. We have that $d\tilde{y}_{bj}/ds_j = -y_{bj}$, thus

$$\eta_{bj}^{M,F} = -\varepsilon_{bj}^M \frac{y_{bj}}{\tilde{y_{bj}}}.$$

Federal Income Taxes Federal tax revenue is now given by

$$FedRev = \sum_b N_b \sum_{k\in J} P_{bk}\left[\lambda_{bk} t_b(y_{bk} - d_{bk}^V) + (1-\lambda_{bk}) t_b(y_{bk} - d_b^F)\right].$$

To find the effect of state j increasing tax rates, we take the derivative with respect to s_j. Noting that $\frac{d(y_{bj} - d_{bj}^V)}{ds_j} = y_{bj}\eta_{bj}^\ell - y_{bj}(\sigma'_{bj}\eta_{bj}^\ell + 1) = y_{bj}(\eta_{bj}^\ell(1-\sigma'_{bj}) - 1)$, we have

[35] Recall that ε_b^M measures the elasticity of population with respect to after-tax wages, holding hours constant. Thus, in this derivation we set $\eta^\ell = 0$

$$\frac{dFedRev}{ds_j} = \sum_b N_{bj} \Big[\lambda_{bj} \Big(\eta^{M,V}_{bj} \Big(t_b \left(y_{bj} - d^V_{bj} \right) - t^{o,V}_{bj} \Big) + y_{bj} t'_b (y_{bj} - d^V_{bj}) \left(\eta^{\ell}_{bj} (1 - \sigma'_{bj}) - 1 \right) \Big)$$
$$+ (1 - \lambda_{bj}) \Big(\eta^{M,F}_{bj} \Big(t_b \left(y_{bj} - d^F_{bj} \right) - t^{o,F}_{bj} \Big) + \eta^{\ell}_{bj} y_{bj} t'_b (y_{bj} - d^F_{bj}) \Big) \Big].$$

where $t^{o,V}_{bj} = \sum_{k \neq j} \omega_{bjk} t_b (y_{bk} - d^V_{bj})$ and $t^{o,F}_{bj} = \sum_{k \neq j} \omega_{bjk} t_b (y_{bk} - d^F_{bj})$. This result is equation (18) after substituting in equations (19) and (20).