Supplementary Material to:

A New Approach to Evaluating the Welfare Effects of Decentralized Policies

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Abstract

This online appendix derives the mathematical proofs, extends the baseline model, explains our empirical applications in detail and provides additional empirical material. Supplementary Material S.A extends the baseline model to include the taxation of nonresidents, including origin-based commodity taxation and non-resident labor taxation. Supplementary Material S.B establishes the link with Pigouvian tranfers, local MVPF, social MVPF and marginal welfare. Supplementary Material S.C addresses frequently asked questions about the estimation of MVPFs in open-economies. In particular, it discusses how to estimate mobility and congestion effects, welfare weights, and interjurisdictional externalities. Supplementary Material S.D derives a sufficient statistics approach and shows how it can be utilized in great detail, using the examples of education spending and property tax cuts. Supplementary Material S.E discusses the relation between the MCT and hiercharchical government structures. Supplementary Material S.F includes additional results for the analysis of how state institutions influence the MCT.

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Supplementary Material

Supplementary Material

Supplementary Material S.A
Extensions

S.A.1. Taxation of Nonresidents

The baseline model assumed that consumption and income taxes are sourced to the jurisdiction of residence. But, in practice, individuals engage in cross-border shopping and commuting between different jurisdictions. As a result, tax cuts in jurisdiction i may directly affect the willingness to pay of nonresidents living in j. While we have already seen how property tax changes can directly affect nonresident landlords, this appendix extends the baseline model and derives the MVPF formulas to the cases of origin-based commodity taxation (Supplementary Material S.A.2) and non-resident labor taxation (Supplementary Material S.A.3). Thus, these sections show that the model can be extended to capture direct spillovers of other taxes policies, beyond those commonly thought of for public goods.

Of course, there are many localities in the world that use the sourcing rules modeled in the paper. For example, state and local income taxes in many localities in the USA, and in all jurisdictions in Spain or Switzerland are residence based. However, in the absence of reciprocity agreements in the USA, nonresident commuters are taxed in the state of employment (Agrawal and Hoyt 2018). With respect to consumption taxes, there has been a push toward destination-based taxation of e-commerce, but physical cross-border shopping often remains origin-based (**agrawal2021taxing**).

S.A.2. Origin-Based Commodity Taxation

The MVPF formulas in the paper are derived assuming that the commodity tax follows the destination principle. That is, the residents of i pays a tax to i regardless of where the good is purchased from. While many commodity taxes legally following the destination principle, origin-based taxes arise in practice. For example, most individuals that cross-border shop in the USA pay the origin sales tax rate to the jurisdiction of purchase and similar rules apply to the VAT in Europe (Agrawal and Mardan 2019; Kanbur and Keen 1993). The origin-principle means that a resident of jurisdiction i who crosses the border to consume in (or import a good from) jurisdiction j pays a tax to j. The distinction between both tax principles is important when studying MVPFs in open economies because unlike destination-based taxes, origin-based commodity taxation in a given jurisdiction i has a direct external effect on the willingness to pay of non-residents living in j who shop and pay a commodity tax to i. It also entails a behavioral effect on the net cost incurred by other governments.

S.A.2.1. Model

The analysis of origin-based commodity taxation requires being able to identify the specific amounts of goods traded from across pairs of jurisdictions. To this aim, we now assume that the firms of each jurisdiction produces a specific variety of good x, following many commodity tax competition contributions (Haufler and Pflüger 2007; Lockwood 2001). The amount of the variety produced in jurisdiction j consumed by a resident of jurisdiction i is denoted x_{ij}. The representative resident of jurisdiction i has the following separable utility function:

$$U_i = U_i(\mathbf{x}_i, \ell_i, h_i, \mathbf{g}, e_i) \qquad \text{(S.A.1)}$$

where $\mathbf{x}_i \equiv (x_{i1}, \dots, x_{iI})$ is the vector of consumption of a freely tradeable, private numéraire good.[1] The budget constraint of a resident of jurisdiction i is:

$$p_i h_i + (1 + t_i^x) x_{ii} + \sum_{j \neq i} (1 + \alpha_j^o t_j^x + \alpha_i^d t_i^x + cc_{ij}) x_{ij} = y_i + (1 - t_i^\ell) w_i \ell_i - t_i^n \qquad \text{(S.A.2)}$$

where α_k^d $[\alpha_k^o]$ is equal to one if jurisdiction k applies destination-based [origin-based] taxation to purchases from outside the jurisdiction and zero if it does not. The novelty in (S.A.2) compared to the baseline framework is that the resident of i consumes a certain amount of the numéraire good in the other jurisdictions and thus she pays commodity taxes to other jurisdictions due to the origin-principle (if $\alpha_j^o = 1$ for some $j \neq i$). The indirect utility function is then

$$V_i = V_i(p_i, w_i, y_i, \mathbf{t}_i, \mathbf{t}_{-i}^x, \mathbf{g}, e_i) \qquad \text{(S.A.3)}$$

where $\mathbf{t}_i = (t_i^x, t_i^h, t_i^\ell, t_i^n)$ and $\mathbf{t}_{-i}^x \equiv (t_1^x, , \dots, t_{i-1}^x, t_{i+1}^x, \dots, t_I^x)$. The housing and labor market equilibria conditions in each jurisdiction i, are, respectively:

$$n_i h_i(p_i, w_i, y_i, \mathbf{t}_i, \mathbf{t}_{-i}^x, \mathbf{g}) = H_i(p_i), \qquad \text{(S.A.4a)} \quad n_i \ell_i(p_i, w_i, y_i, \mathbf{t}_i, \mathbf{t}_{-i}^x, \mathbf{g}) = m_i l_i(w_i, \mathbf{z}), \quad \text{(S.A.4b)}$$

Inter-jurisdictional mobility of households [firms] implies that the equilibrium number of residents

[1] In the baseline model, the vector $\mathbf{x}_i$ reduces to $x_i \equiv \sum_j x_{ij}$ because good x is not horizontally differentiated.

[firms] in each jurisdiction i are characterized by:

$$n_i = \Phi^n\Big(V_j(p_j, w_j, y_j, \mathbf{t}_j, \mathbf{t}^x_{-j}, \mathbf{g}_j)\ ;\ \forall j \in [1, I]\Big), \qquad m_i = \Phi^m\Big((1 - t^\pi_j)\pi_j(w_j, \mathbf{z})\ ;\ \forall j \in [1, I]\Big), \tag{S.A.5}$$

Again, the general equilibrium conditions determine the levels, in each jurisdiction i, of the wage, the rent, the population, the number of firms, the numéraire consumption, the housing consumption, the labor supply, the numéraire profit and the housing profit as a function of the aggregate policy instrument set $\mathbb{P}$.

S.A.2.2. Marginal Willingness to Pay

The equilibrium level of the deterministic indirect utility (2) can be written as:

$$V_j = U\left(\frac{1}{1+t^x_j}\left[y_j + (1-t^\ell_j)w_j\ell_j - \sum_{k\neq j}(1+\alpha^o_k t^x_k + \alpha^d_j t^x_j)x_{jk} - (1+t^h_j)p_j h_j - t^n_j\right], h_j, \ell_j, \mathbf{g}\right) \tag{S.A.6}$$

Differentiating (S.A.6) with respect to τ_i and applying the envelope theorem, we obtain the expression of the marginal willingness to pay of the residents of each j for $\tau_i \in P_i$,

$$WTP^j_{\tau_i} = \text{DE}^j_{\tau_i} + \text{IE}^j_{\tau_i} + \text{OE}^j_{\tau_i} \tag{S.A.7}$$

where the direct, disposable-income and ownership effects are as defined in (7), (8) and (9) except that the direct effects of a marginal increase in the commodity tax in i are now:

$$\text{DE}^i_{t^x_i} = -n_i\widetilde{x}_i \times \mathrm{d}t^x_i, \qquad \text{DE}^k_{t^x_i} = -\alpha^o_j n_j x_{ji} \times \mathrm{d}t^x_i, \quad k \neq i \tag{S.A.8}$$

where $\widetilde{x}_i \equiv x_{ii} + \alpha^d_i \sum_{j\neq i} x_{ij}$ is the per capita local commodity tax base. The important novelty is that the external effect $\text{DE}^k_{t^x_i}$ indicates that now a change in the commodity tax of a jurisdiction i using origin-based taxation ($\alpha^e_i > 0$) has a direct effect on willingness to pay of non-residents living in $j \neq i$. Jurisdiction i's commodity tax reduces the disposable income of the residents of j who shop in i. This highlights a direct tax spillover.

S.A.2.3. Marginal Net Government Cost

The commodity tax base in a given jurisdiction now includes purchases by residents from their home jurisdiction, purchases by residents from other jurisdictions subject to the destination principle, and purchases by nonresidents that are taxed under the origin principle. Jurisdiction j's NGC is:

$$NGC_j \equiv c_j(g_j, z_j, \mathbf{n}, \mathbf{m}) \overbrace{-n_j\left(t_j^\ell w_j \ell_j + t_j^h p_j h_j + t_j^x \widetilde{x}_j + t_j^n\right) - m_j t_j^\pi \pi_j}^{local} - \overbrace{\alpha_j^o t_j^x \sum_{k\neq j} n_k x_{kj}}^{external} \tag{S.A.9}$$

Differentiating (S.A.9), we obtain the local/external marginal net government cost in jurisdiction j resulting from a small change in the policy instrument $\tau_i \in P_i$ of jurisdiction i:

$$NGC_{\tau_i}^j = \text{ME}_{\tau_i}^j \underbrace{-n_j \mathbf{t}_j \mathbf{q}_j \frac{\partial \widetilde{\mathbf{x}}_j}{\partial \tau_i} \times \mathrm{d}\tau_i - \alpha_j^o t_j^x \sum_{k\neq j} n_k \frac{\partial x_{kj}}{\partial \tau_i} \times \mathrm{d}\tau_i}_{\text{BE}_{\tau_i}^j} \underbrace{-n_j \mathbf{t}_j \widetilde{\mathbf{x}}_j \frac{\partial \mathbf{q}_j}{\partial \tau_i} \times \mathrm{d}\tau_i}_{\text{PE}_{\tau_i}^j} + \pi\text{E}_{\tau_i}^j + \text{LE}_{\tau_i}^j \tag{S.A.10}$$

where $\widetilde{\mathbf{x}}_j' \equiv (\ell_j \;\; h_j \;\; \widetilde{x}_j \;\; 1)$ can be interpreted as the local consumption vector. The mechanical, profit and locational effects are as defined in (12). However, the mechanical effect of the commodity tax is now $\text{ME}_{t_i^x}^i = -n_i \widetilde{x}_i \times \mathrm{d}t_i^x$, which is consistent with the fact that the local mechanical effect of a household tax is always equal to its local direct effect.

The noticeable novelty in (S.A.10) is the term $\sum_{k\neq j} n_k t_j^x \partial x_{kj}/\partial \tau_i$ which indicates that jurisdiction j's NGC—and thus the fiscal externality on it—is affected by the private consumption behavior of non-residents due to cross-border shopping.

S.A.3. Non-resident labor taxation

Next, we investigate how the MVPF formulas are altered if the jurisdictions are allowed to tax the labor income of non-residents. While many states and localities around the world tax (e.g., in Spain and Switzerland) labor according to the residence principle, other countries including the USA may tax nonresident commuters in the employment state (Agrawal and Hoyt 2018). Such tax exporting can be observed when jurisdictions tax the income of nonresidents who commute to work in the taxing jurisdiction or when they tax nonresident teleworkers working for firms in the state. We assume that each resident of jurisdiction i can either work in i or in another jurisdictions $j \neq i$. Commuting implies that labor taxation in a given jurisdiction i has a direct effect on the willingness to pay of non-residents who work and pay a labor tax to jurisdiction i. Moreover, as the income taxpayers of jurisdiction i do not necessarily live in i, the net government cost of jurisdiction i will also be affected by non-residents labor supply decisions and employment location choice.

Beyond commuting, this case illustrates how the open economy MVPFs are calculated if households are heterogeneous within the jurisdictions. Here, heterogeneity comes from the fact that each jurisdiction is inhabited by households working in different jurisdictions. However, the results can be immediately extended to any exogenous heterogeneity (gender, education, abilities). For example, Appendix D considers heterogeneous households in terms of tenure status (renters and homeowners) that also requires to aggregate heterogeneous households similarly to what is done hereafter.

S.A.3.1. Model

The representative resident of jurisdiction i working in jurisdiction j has the following utility function $U_{ij} = U_{ij}(x_{ij}, \ell_{ij}, h_{ij}, \mathbf{g}, e_{ij})$, where $\mathbf{x}_i \equiv (x_{i1}, \ldots, x_{iI})$ is the consumption of a freely tradeable, private numéraire good, and e_{ij} is now the idiosyncratic taste for the residence-workplace pair (i, j) (Ahlfeldt, Redding, Sturm, and Wolf 2015). The budget constraint of a resident of i who works in j is:

$$p_i h_{ij} + (1 + t_i^x) x_{ij} = y_{ij} + \big(1 - \beta t_j^\ell - (1 - \beta) t_i^\ell\big) w_j \ell_{ij} - t_i^n \tag{S.A.11}$$

where $y_{ij} \equiv y_i - c_{ij}$ in which c_{ij} denotes commuting costs of commuting from i to j. Parameter $\beta = 0, 1$ is equal to one if the jurisdictions levy employment-based labor taxes, and zero otherwise if they levy residence-based taxes. As is the case in practice, all the jurisdictions of a federation are subject to either the residence principle or the employment principle. The baseline framework of the paper, considers jurisdictions whose labor taxation is set according to the residence principle, i.e. $\beta = 0$. This appendix extends this framework to show how the MVPF formulas are altered when labor taxes are set according to the employment principle. The indirect utility function is

$$V_{ij} = V_{ij}(p_i, w_j, y_i, \mathbf{t}_i, t_j^\ell, \mathbf{g}, e_{ij}) \tag{S.A.12}$$

where $\mathbf{t}_i = (t_i^x, t_i^h, t_i^\ell, t_i^n)$. The housing and labor markets equilibria clearing conditions, in each jurisdiction i, are respectively:

$$\sum_j n_{ij} h_{ij}(p_i, w_j, y_i, \mathbf{t}_i, t_j^\ell, \mathbf{g}) = H_i(p_i), \qquad \sum_j n_{ij} \ell_{ij}(p_i, w_j, y_i, \mathbf{t}_i, t_j^\ell, \mathbf{g}) = m_i l_i(w_i, \mathbf{z}), \tag{S.A.13}$$

in which the local demand for housing and local supply of labor aggregate over all the residents of jurisdiction i wherever they work. Inter-jurisdictional mobility of households [firms] implies that the equilibrium number of residents [firms] in each jurisdiction i are characterized by:

$$n_{ij} = \Phi^n\Big(V_{i'j'}(p_{i'}, w_{j'}, y_{i'}, \mathbf{t}_{i'}, t^\ell_{j'}, \mathbf{g}_j)\ ;\ \forall i', j' \in [1, I]\Big), \quad m_i = \Phi^m\Big((1 - t^\pi_j)\pi_j(w_j, \mathbf{z})\ ;\ \forall j \in [1, I]\Big),$$

Again, the general equilibrium characterizes the levels, in each jurisdiction i, of the wage, the rent, the population, the number of firms, the numéraire consumption, the housing consumption, the labor supply, the numéraire profit and the housing profit as a function of the aggregate policy instrument set $\mathbb{P}$.

S.A.3.2. Marginal Willingness to Pay

The aggregate indirect utility in jurisdiction j can be written as:

$$\sum_k n_{jk}V_{jk} = \sum_k n_{jk}U\left(\frac{1}{1+t^x_j}\left[y_{jk} + \big(1 - \beta t^\ell_k - (1-\beta)t^\ell_j\big)w_k\ell_{jk} - p_j h_{jk} - t^n_j\right], h_{jk}, \ell_{jk}, \mathbf{g}, e_{jk}\right) \tag{S.A.14}$$

where we aggregate all the residents of j regardless of the jurisdiction k in which they work. Differentiating with respect to τ_i and applying the envelope theorem, we obtain the expression of the marginal willingness to pay of the residents of each j for $\tau_i \in P_i$,

$$WTP^j_{\tau_i} \equiv \sum_k \frac{n_{jk}}{\lambda_{jk}}\frac{\partial V_{jk}}{\partial \tau_i} = \text{DE}^j_{\tau_i} + \text{IE}^j_{\tau_i} + \text{OE}^j_{\tau_i},$$

where $\lambda_{jk} \equiv \partial V_{jk}/\partial y_{jk}$. The first effect that determines the marginal willingness to pay is the direct effect. Its specific form depends on the policy instrument τ_i considered and whether the effect is in jurisdiction $j = i$ or $j \neq i$:

$$\begin{cases} \text{DE}^i_{t^b_i} = -\sum_k \text{B}^b_{ik} \times \mathrm{d}t^b_i, \\ \text{DE}^k_{t^{b'}_i} = 0, \quad k \neq i, \end{cases} \qquad \text{DE}^j_{g_i} = \sum_k \frac{n_{jk}}{\lambda_{jk}}\frac{\partial U_{jk}}{\partial g_i} \times \mathrm{d}g_i, \tag{S.A.15}$$

where $b = x, n$ indexes the commodity and head tax base, and $\text{B}^x_{ik} = n_{ik}x_{ik}$ and $\text{B}^n_{ik} = n_{ik}$ are the tax bases. The direct effect of the property tax (7b), that of the profit tax t^π_i and that of the public business services z_i are still defined as in (7c) and (7e). The direct effects in (S.A.15) extend those derived in the baseline model to the case of heterogeneous households, by summing over all the residents of a jurisdiction wherever they work. The local and external direct effects with respects to the labor tax are:

$$\text{DE}^i_{t^\ell_i} = -\left(\beta w_i L_{ii} + (1-\beta)\sum_k w_k L_{ik}\right) \times \mathrm{d}t^\ell_i, \qquad \text{DE}^k_{t^\ell_i} = -\beta w_i L_{ki} \times \mathrm{d}t^\ell_i, \quad k \neq i, \tag{S.A.16}$$

where $L_{jk} = n_{jk}\ell_{jk}$ is the amount of labor supplied by the residents of j who work in k. The important novelty is that the external effect $\text{DE}^k_{t^\ell_i}$ indicates that now a change in the labor tax of a jurisdiction i using employment-based taxation ($\beta > 0$) has a direct effect on the residents' willingness to pay of another jurisdiction $k \neq i$. Specifically, labor taxation in i reduces the disposable income of the residents of k who work in i. This highlights a new direct tax spillover.

The ownership effect $\text{OE}^j_{\tau_i}$ is defined as in (9). However, the disposable income effect is altered by the presence of commuting flows:

$$\text{IE}^j_{\tau_i} = \left(\sum_k \left(1 - \beta t^\ell_k - (1-\beta)t^\ell_j\right) L_{jk} \frac{\partial w_k}{\partial \tau_i} - H_j \frac{\partial p_j}{\partial \tau_i}\right) \times \mathrm{d}\tau_i, \tag{S.A.17}$$

The disposable income effect above highlights that due to commuting, the willingness to pay for a policy of the residents of jurisdiction j is now affected not only by changes in the local wage but also by capitalization in the wage of other jurisdictions in which the j's residents commute. Thus, to estimate the MVPF of local jurisdictions such as municipalities, it is likely that the researcher would need to get estimates of $\partial w_k/\partial \tau_i$, for i and k possibly different.

S.A.3.3. Marginal Net Government Cost

Jurisdiction j can raise labor income from residents, but also from non-resident commuters depending on the sourcing rules, so that its net government cost is:

$$NGC_j = c_j(g_j, z_j, \mathbf{n}, \mathbf{m}) - \sum_k \left[\beta t^\ell_j w_j n_{kj}\ell_{kj} + n_{jk}\left((1-\beta)t^\ell_j w_k \ell_{jk} + t^x_j x_{jk} + t^h_j p_j h_{jk} + t^n_j\right)\right] - m_j t^\pi_j \pi_j, \tag{S.A.18}$$

which indicates that if labor taxation is employment-based ($\beta = 1$), labor tax revenues are collected from households that works in j but live possibly in any jurisdictions k. This contrasts with our residence-based model ($\beta = 0$) in which labor tax revenues are raised from local residents only.

Differentiating (S.A.18), we obtain the local/external marginal net government cost of jurisdiction j resulting from a small change in the policy instrument $\tau_i \in P_i$ of jurisdiction i:

$$NGC^j_{\tau_i} = \text{ME}^j_{\tau_i} + \text{BE}^j_{\tau_i} + \text{PE}^j_{\tau_i} + \pi\text{E}^j_{\tau_i} + \text{LE}^j_{\tau_i}, \tag{S.A.19}$$

The mechanical effect is still defined as in (12). The behavioral effect is:

$$\text{BE}^j_{\tau_i} = -\left(\sum_k n_{jk}\left(t^x_j \frac{\partial x_{jk}}{\partial \tau_i} + t^h_j p_j \frac{\partial h_{jk}}{\partial \tau_i} + (1-\beta)t^\ell_i w_k \frac{\partial \ell_{jk}}{\partial \tau_i}\right) + \beta t^\ell_j w_j \sum_k n_{kj} \frac{\partial \ell_{kj}}{\partial \tau_i}\right) \times \mathrm{d}\tau_i, \quad \text{(S.A.20)}$$

where the first summation simply extends the baseline case (13) to the fact that j's residents have heterogeneous workplaces. The second summation in (S.A.20) is novel. It highlights that if employment-based labor taxation applies ($\beta = 1$), non-residents are taxed, so that a policy-induced change in the labor supply of non-residents who commute to work in j affects the tax revenues collected by j. For example, suppose that jurisdiction j provides a public business service $\mathrm{d}z_j > 0$ to its local firms which allows all the workers in j to work less. The behavioral cost of this program would be larger than the cost imposed by j's residents because nonresidents also reduce labor supply.

The price effects on government j's NGC are:

$$\text{PE}^j_{\tau_i} = -\left(t^h_j H_j \frac{\partial p_j}{\partial \tau_i} + (1-\beta)t^\ell_j \sum_k L_{jk} \frac{\partial w_k}{\partial \tau_i} + \beta t^\ell_j L_j \frac{\partial w_j}{\partial \tau_i}\right) \times \mathrm{d}\tau_i, \quad \text{(S.A.21)}$$

which simply extends the baseline case (14) to the fact that j's residents have heterogeneous workplaces. The locational effect is:

$$\text{LE}^j_{\tau_i} = \left(\frac{\partial c_j}{\partial \mathbf{n}} \frac{\partial \mathbf{n}}{\partial \tau_i} - \sum_k r_{jk} \frac{\partial n_{jk}}{\partial \tau_i} - \beta t^\ell_j w_j \sum_k \ell_{kj} \frac{\partial n_{kj}}{\partial \tau_i}\right) \times \mathrm{d}\tau_i + \left(\frac{\partial c_j}{\partial \mathbf{m}} \frac{\partial \mathbf{m}}{\partial \tau_i} - t^\pi_j \pi_j \frac{\partial m_j}{\partial \tau_i}\right) \times \mathrm{d}\tau_i, \quad \text{(S.A.22)}$$

where $r_{jk} \equiv (1-\beta)t^\ell_j w_k \ell_{jk} + t^h_j p_j h_{jk} + t^x_j x_{jk} + t^n_j$ is the overall residence-based tax paid by a resident of j. Compared to (11), the locational effect above simply extends the baseline case to households' heterogeneous workplaces.

S.A.3.4. Extension: Employment-based Taxation with a Minimum Tax Rule (Tax Credits)

In this subsection, we are interested in a minimum tax rule that usually accompanies employment-based taxation. The minimum tax rule that we consider follows U.S. state income taxation, as the resident of a high-tax state who commutes to work in a low-tax state pays not only the tax charged by the low-tax state, but she also pays to her state of residence, the difference between the tax she would have paid working in her home state and the tax she actually pays to the state she works in. This system is achieved by the state of residence offering nonrefundable tax credits for taxes paid to the source state (Agrawal and Hoyt 2018).

S.A.3.4.1 Model

For notation simplicity, we consider a two-jurisdiction economy in which the jurisdictions $i = 1, 2$ are endowed with a single tax which is an employment-based labor tax t_i^ℓ (i.e. $\beta = 1$) and provide public services g_i to households (exerting no spillover) but no public business services; profits accrue to absentee owners and households receive no other non-labor income. Suppose that jurisdiction 2 is the high-tax jurisdiction, i.e. $t_1^\ell < t_2^\ell$. The aggregate utility in jurisdictions 1 is:

$$\sum_{k=1,2} n_{1k} V_{1k} = \sum_{k=1,2} n_{1k} U\left((1 - t_k^\ell) w_k \ell_{1k} - p_1 h_{1k}, h_{1k}, \ell_{1k}, g_1, e_{1k}\right), \tag{S.A.23}$$

which is unchanged compared to the case without minimum tax rule, because the commuter residents of 1 cannot benefit from preferential tax rates elsewhere (recall that jurisdiction 1 is the low-tax jurisdiction). In other words, (S.A.23) is the standard local welfare with employment based taxation defined in (S.A.14) for $\beta = 1$. The residents of the high-tax jurisdiction 2 who work in 2 directly pay the t_2^ℓ. Those who work in 1 initially pay lower tax rates in 1. Thus, the minimum tax rule applies, so that the residents of 2 are subject to the tax rate t_2^ℓ wherever they work:

$$\sum_{k=1,2} n_{2k} V_{2k} = \sum_{k=1,2} n_{2k} U\left((1 - t_2^\ell) w_k \ell_{2k} - p_2 h_{2k}, h_{2k}, \ell_{2k}, g_2, e_{2k}\right), \tag{S.A.24}$$

which shows that the minimum-tax rule transforms the labor tax of the high tax jurisdiction 2 into a residence-based tax.

The net government cost in the low-tax jurisdiction 1 is not affected by the minimum-tax rule:

$$NGC_1 = c_1(g_1, n_1) - t_1^\ell w_1 \sum_{i=1,2} n_{i1} \ell_{i1}, \tag{S.A.25}$$

that is, government 1 simply collects tax revenues from all workers who work in its jurisdiction. Expression (S.A.25) is that of the standard net cost of a jurisdiction subject to employment-based taxation (S.A.18) for $\beta = 1$. However, the net government cost of the high-tax jurisdiction 2 is affected by the minimum tax rule:

$$NGC_2 = c_2(g_2, n_2) - t_2^\ell w_2 \sum_{i=1,2} n_{i2} \ell_{i2} - (t_2^\ell - t_1^\ell) w_1 n_{21} \ell_{21}, \tag{S.A.26}$$

which indicates that jurisdiction 2 collects tax revenues not only from all the workers who work in 2 but also from its residents who commute to the low-tax jurisdiction 1 and who are charged the differential tax rate $t_2^\ell - t_1^\ell$ by jurisdiction 2. Although the residents of jurisdiction 2 perceive the labor tax as a residence-based tax, this is not the case of government 2 because parts of the tax revenues paid by its residents accrue to government 1. That is, despite the minimum tax rule, the labor tax is still an employment-based tax from the view point of all governments: loosing workers is equivalent to loosing tax revenues.

S.A.3.4.2 Local Effects

Let us start with a tax change $\mathrm{d}t_1^\ell$ implemented in jurisdiction 1. Expressions (S.A.23) and (S.A.25) make it clear that the marginal willingness to pay and the marginal net government cost of the low-tax jurisdiction 1 are, as expected, not affected by the minimum-tax rule:

$$LWTP_{t_1^\ell} = \mathrm{DE}^1_{t_1^\ell} + \mathrm{IE}^1_{t_1^\ell}, \qquad LNGC_{t_1^\ell} = \mathrm{ME}^1_{t_1^\ell} + \mathrm{BE}^1_{t_1^\ell} + \mathrm{PE}^1_{t_1^\ell} + \mathrm{LE}^1_{t_1^\ell},$$

The effects on the marginal willingness to pay of the residents of 1 induced by t_i^ℓ, $i = 1, 2$:

$$\mathrm{DE}^1_{t_1^\ell} = -w_1 L_{11} \times \mathrm{d}t_1^\ell, \qquad \mathrm{IE}^1_{t_1^\ell} = \left(\sum_k (1 - t_k^\ell) L_{1k} \frac{\partial w_k}{\partial t_1^\ell} - H_1 \frac{\partial p_1}{\partial t_1^\ell} \right) \times \mathrm{d}t_1^\ell,$$

which are the standard effects with employment-based taxation (S.A.16) and (S.A.17) for $\beta = 1$. The effects on the net costs of government 1 are:

$$\mathrm{ME}^1_{t_1^\ell} = -w_1 L_1 \times \mathrm{d}t_1^\ell, \qquad \mathrm{BE}^1_{t_1^\ell} = -t_1^\ell w_1 \sum_{i=1,2} n_{i1} \frac{\partial \ell_{i1}}{\partial t_1^\ell} \times \mathrm{d}t_1^\ell, \tag{S.A.27}$$

$$\mathrm{PE}^1_{t_i^\ell} = -\left(t_1^\ell L_1 \frac{\partial w_1}{\partial t_1^\ell} + t_1^h H_1 \frac{\partial p_1}{\partial t_i^\ell} \right) \times \mathrm{d}t_1^\ell, \quad \mathrm{LE}^1_{t_1^\ell} = \left(\frac{\partial c_1}{\partial n_1} \frac{\partial n_1}{\partial t_1^\ell} - t_1^\ell w_1 \sum_{i=1,2} \ell_{i1} \frac{\partial n_{i1}}{\partial t_1^\ell} \right) \times \mathrm{d}t_1^\ell, \tag{S.A.28}$$

which are also the standard effects with employment based taxation (S.A.20)–(S.A.22) for $\beta = 1$. In sum, as expected, if a minimum tax rule is implemented, the local MVPF of a low-tax jurisdiction whose residents do not commute to work to even lower-tax jurisdictions is not altered.

Let us now turn to government 2's policy. However, expressions (S.A.24) and (S.A.26) indicate that:

$$LWTP_{t_2^\ell} = \text{DE}^2_{t_2^\ell} + \text{IE}^2_{t_2^\ell}, \qquad LNGC_{t_2^\ell} = \text{ME}^2_{t_2^\ell} + \text{BE}^2_{t_2^\ell} + \text{PE}^2_{t_2^\ell} + \text{LE}^2_{t_2^\ell},$$

where the direct effect and the disposable income effect are equal to:

$$\text{DE}^2_{t_2^\ell} = -\sum_k n_{2k} w_k \ell_{2k} \times \mathrm{d}t_2^\ell, \qquad \text{IE}^2_{t_i^\ell} = \left(\sum_k (1-t_2^\ell) L_{2k} \frac{\partial w_k}{\partial t_2^\ell} - H_2 \frac{\partial p_2}{\partial t_2^\ell}\right) \times \mathrm{d}t_2^\ell,$$

As discussed above, the compensation mechanism turns jurisdiction 2's income tax into a residence-based tax for 2's residents. This explains why the direct effect is that of a standard residence-based income tax as in (S.A.16) for $\beta = 0$. As expected, we can notice that the disposable income effect is not affected by the compensation mechanism. The mechanical effect is:

$$\text{ME}^2_{t_2^\ell} = -\left(w_2 L_2 + w_1 L_{21}\right) \times \mathrm{d}t_2^\ell$$

which differ from the mechanical effect in jurisdiction 1, (S.A.27), by the addition of the term $w_1 L_{21} \mathrm{d}t_2^\ell$. This extra term captures the fact that the residents of jurisdiction 2 who commute to work in jurisdiction 1 have to play the marginal tax $\mathrm{d}t_2^\ell$ of jurisdiction 2 due to the compensation mechanism.

The behavioral effect, the price price effect and the locational effects are:

$$\begin{aligned}
\text{BE}^2_{t_2^\ell} &= -\left(t_2^\ell w_2 \sum_{i=1,2} n_{i2} \frac{\partial \ell_{i2}}{\partial t_2^\ell} + (t_2^\ell - t_1^\ell) w_1 n_{21} \frac{\partial \ell_{21}}{\partial t_i^\ell}\right) \times \mathrm{d}t_2^\ell \\
\text{PE}^2_{t_2^\ell} &= -\left(t_2^\ell L_2 \frac{\partial w_2}{\partial t_2^\ell} + (t_2^\ell - t_1^\ell) n_{21} \ell_{21} \frac{\partial w_1}{\partial t_2^\ell}\right) \times \mathrm{d}t_2^\ell \\
\text{LE}^2_{t_2^\ell} &= \left(\frac{\partial c_2}{\partial n_2} \frac{\partial n_2}{\partial t_2^\ell} - t_2^\ell w_2 \sum_{i=1,2} \ell_{i2} \frac{\partial n_{i2}}{\partial t_2^\ell} - (t_2^\ell - t_1^\ell) w_1 \ell_{21} \frac{\partial n_{21}}{\partial t_2^\ell}\right) \times \mathrm{d}t_2^\ell
\end{aligned}$$

which have the specificity that they account for the marginal tax revenues change for jurisdiction 2 collected from its residents commuting to jurisdiction 1 who each pay $(t_2^\ell - t_1^\ell) w_1$ to jurisdiction 2.

S.A.3.4.3 External Effects

Consider a tax change $\mathrm{d}t_1^\ell$ implemented in jurisdiction 1.

$$EWTP_{t_1^\ell} = \text{IE}^2_{t_1^\ell}, \qquad ENGC_{t_1^\ell} = \text{ME}^2_{t_1^\ell} + \text{BE}^2_{t_1^\ell} + \text{PE}^2_{t_1^\ell} + \text{LE}^2_{t_1^\ell},$$

There is no direct external effect because the residents of jurisdiction 2 are always subject to government 2's tax rate. The disposable income effect is:

$$\text{IE}^2_{t_1^\ell} = \left(\sum_k (1 - t_2^\ell) L_{2k} \frac{\partial w_k}{\partial t_1^\ell} - H_2 \frac{\partial p_2}{\partial t_1^\ell} \right) \times \mathrm{d}t_1^\ell$$

which is the standard external disposable income effect due to wage and house price capitalization generated by any policy. Interestingly, due to the compensation mechanism, jurisdiction 1's policy creates an external mechanical effect in jurisdiction 2:

$$\text{ME}^1_{t_1^\ell} = w_1 L_{21} \times \mathrm{d}t_1^\ell$$

This effect captures the fact that as the low-tax jurisdiction 1 increases its tax rate, jurisdiction 2 receives a smaller compensation, which is represents a net budgetary cost. The external behavioral, price and locational effects in jurisdiction 2 are:

$$\begin{aligned}
\text{BE}^2_{t_1^\ell} &= -\left(t_2^\ell w_2 \sum_{i=1,2} n_{i2} \frac{\partial \ell_{i2}}{\partial t_1^\ell} + (t_2^\ell - t_1^\ell) w_1 n_{21} \frac{\partial \ell_{21}}{\partial t_1^\ell} \right) \times \mathrm{d}t_1^\ell \\
\text{PE}^2_{t_1^\ell} &= -\left(t_2^\ell L_2 \frac{\partial w_2}{\partial t_1^\ell} + (t_2^\ell - t_1^\ell) n_{21} \ell_{21} \frac{\partial w_1}{\partial t_1^\ell} \right) \times \mathrm{d}t_i^\ell \\
\text{LE}^2_{t_1^\ell} &= \left(\frac{\partial c_2}{\partial n_2} \frac{\partial n_2}{\partial t_1^\ell} - t_2^\ell w_2 \sum_{i=1,2} \ell_{i2} \frac{\partial n_{i2}}{\partial t_1^\ell} - (t_2^\ell - t_1^\ell) w_1 \ell_{21} \frac{\partial n_{21}}{\partial t_1^\ell} \right) \times \mathrm{d}t_1^\ell
\end{aligned}$$

which are, again, standardard to the expection of the tax paid by jurisdiction 2's commuters.

Let us now turn to government 2's policy. We have:

$$EWTP_{t_2^\ell} = \text{DE}^1_{t_2^\ell} + \text{IE}^1_{t_2^\ell} \qquad ENGC_{t_2^\ell} = \text{BE}^1_{t_2^\ell} + \text{PE}^1_{t_2^\ell} + \text{LE}^1_{t_2^\ell},$$

The effects on the marginal willingness to pay of the residents of 1 induced by a change in t_2^ℓ are:

$$\text{DE}^1_{t_2^\ell} = -w_2 L_{12} \times \mathrm{d}t_2^\ell, \qquad \text{IE}^1_{t_2^\ell} = \left(\sum_k (1 - t_k^\ell) L_{1k} \frac{\partial w_k}{\partial t_2^\ell} - H_1 \frac{\partial p_1}{\partial t_2^\ell} \right) \times \mathrm{d}t_2^\ell,$$

which are the standard effects with employment-based taxation (S.A.16) and (S.A.17) for $\beta = 1$. The effects on the net costs of government 1 are:

$$\text{BE}^1_{t_2^\ell} = -t_1^\ell w_1 \sum_{i=1,2} n_{i1} \frac{\partial \ell_{i1}}{\partial t_2^\ell} \times \mathrm{d}t_2^\ell,$$

$$\text{PE}^1_{t_2^\ell} = -\left(t_1^\ell L_1 \frac{\partial w_1}{\partial t_2^\ell} + t_1^h H_1 \frac{\partial p_1}{\partial t_2^\ell} \right) \times \mathrm{d}t_2^\ell, \qquad \text{LE}^1_{t_2^\ell} = \left(\frac{\partial c_2}{\partial n_2} \frac{\partial n_2}{\partial t_2^\ell} - t_1^\ell w_1 \sum_{i=1,2} \ell_{i1} \frac{\partial n_{i1}}{\partial t_2^\ell} \right) \times \mathrm{d}t_2^\ell,$$

which are also the standard effects with employment based taxation (S.A.20)–(S.A.22) for $\beta = 1$. In sum, as expected, if a minimum tax rule is implemented, the local MVPF of a low-tax jurisdiction whose residents do not commute to work to even lower-tax jurisdictions is not altered.

Supplementary Material S.B

Local MVPF, Social MVPF as Welfare Measures

In this appendix, we establish the formal links between the three main measures introduced in the paper, local MVPF, social MVPF, and welfare. Supplementary Material S.B.2 establishes the link between local MVPF and local welfare. Supplementary Material S.B.3 demonstrate the link between social MVPF and social welfare.

S.B.1. Marginal Corrective and a Pigouvian Subsidy

Because the MCT is the subsidy based on the observed policy, in general, it will not be equal to a Pigouvian tax or subsidy which is determined at the socially-optimal policy, the local policy that would be chosen by a social planner. However, we wish to show that a property of the MCT is that it reduces to a Pigouvian transfer at the social optimal policy, τ_i^*. First we consider the case where τ_i^* can be financed via a lump-sum transfer T_i which because they are non-distortionary have $SMVPF_{\tau_i} = 1$. As shown in Hendren and Sprung-Keyser (2020), to increase social welfare, a government will want to fund policy τ_i^* if $SMVPF_{\tau_i} \geq SMVPF_{T_i} = 1$. Thus, with lump sum taxes, $SMVPF_{\tau_i}(\tau_i^*) = 1$.

Proposition S.B.1. *Let policy τ_i^* be such that $SWTP_{\tau_i}(\tau_i^*) - SNGC_{\tau_i}(\tau_i^*) = 0$ or, equivalently, $SMVPF(\tau_i^*) = 1$. The MCT evaluated at τ_i^* is $MCT = \frac{S_{\tau_i}(\tau_i^*)}{LNGC_{\tau_i}(\tau_i^*)} = 1 - \frac{LMPVF(\tau_i^*)}{SMVPF(\tau_i^*)}$. Then it follows that Pigouvian tax/subsidy of $S_{\tau_i}(\tau_i^*) = EWTP_{\tau_i}(\tau_i^*) - ENGC_{\tau_i}(\tau_i^*)$ is equal to the transfer (\$) implied by the $MCT(\tau_i^*)$.*

Proof. We can evaluate $MCT(\tau_i^*)$ at $SMVPF(\tau_i^*) = 1$ gives $S_{\tau_i}(\tau_i^*) = LNGC_{\tau_i}(\tau_i^*) - LWTP_{\tau_i}(\tau_i^*)$ Then by adding $SWTP_{\tau_i}(\tau_i^*) - SNGC_{\tau_i}(\tau_i^*) = 0$ to the right side of gives

$$S_{\tau_i}(\tau_i^*) = SWTP_{\tau_i}(\tau_i^*) - LWTP_{\tau_i}(\tau_i^*) - (SNGC_{\tau_i}(\tau_i^*) - LNGC_{\tau_i}(\tau_i^*)) = EWTP_{\tau_i}(\tau_i^*) - ENGC_{\tau_i}(\tau_i^*)$$

□

Discussion. In words, the MCT formula reduces to a Pigouvian tax or subsidy at the socially-optimal policy. More generally, because the MCT , like the $MVPF$, is based on the observed policy and not the optimal policy, the Pigouvian transfer will not equal the marginal correct transfer MCT when the local policy is not at the social optimum. However, as shown in the prior section, the MCT

will increase social welfare at the margin. Practically, the advantage of the MCT over Pigouvian transfer is that the social optimal policy is not observable and the plethora of causal effects estimated in the empirical literature are the responses policies that are, in general, not socially-optimal.

Now consider when lump sum taxes or transfers are not available. Then for a distortionary tax policy, T_i, $SMVPF_{\tau_i} = k\left(T_i\right) \neq 1$ where $k\left(T_i\right)$ might be interpreted as the marginal cost of funds associated with tax T_i. Then if $SMVPF_{\tau_i} \geq SMVPF_{T_i}$ a social plan will want to increase τ_i and increase T_i to finance the policy until the point where $SMVPF_{\tau_i} = k^* = SMVPF_{T_i}$ where k^* is the marginal cost of funds that equalized the $SMVPF$ of both policies.[2] Then in this case we have

$$\begin{aligned} k^* S_{\tau_i}\left(\tau_i^*\right) &= SWTP_{\tau_i}\left(\tau_i^*\right) - LWTP_{\tau_i}\left(\tau_i^*\right) - k^*\left(SNGC_{\tau_i}\left(\tau_i^*\right) - LNGC_{\tau_i}\left(\tau_i^*\right)\right) \\ &= EWTP_{\tau_i}\left(\tau_i^*\right) - k^* ENGC_{\tau_i}\left(\tau_i^*\right). \end{aligned} \quad \text{(S.B.1)}$$

where the optimal policy τ_i^* is not the same policy as obtain with non-distortionary transfers. As the Pigouvian transfer is no longer financed with a non-distortionary tax, the transfer associated with the MCT is adjusted to reflect the cost of raising revenue to finance it and therefore is equal to $k^* S_{\tau_i}\left(\tau_i^*\right)$, the Pigouvian transfer adjusted for the cost of raising revenue.

S.B.2. Local MVPF and Welfare

One attraction of the MVPF concept is that it can easily be converted from a welfare measure in monetary terms into a welfare measure in utility terms. To see this, notice that the local welfare in jurisdiction i is $n_i V_i$ because all individuals receive the same level of deterministic utility in i. Denote LMW_{τ_i} as the local marginal welfare with respect to τ_i, that is, the effect on local welfare per dollar of policy $\mathrm{d}\tau_i$ on jurisdiction i. It can be shown that (Supplementary Material S.B.2.1):

$$LMW^i_{\tau_i} = \lambda_i LMVPF_{\tau_i}, \quad \text{(S.B.2)}$$

where λ_i is the equilibrium level of the marginal utility of income in i. Importantly, λ_i is independent of the small change in policy, $\mathrm{d}\tau_i$; it only depends on the current levels of the different policy instruments. As a consequence, condition (S.B.2) indicates that in the presence of identical households in jurisdiction i (as assumed in our model), it is sufficient for government i to compare the

[2] Note that it may not always be the case that there exists a tax change that equalizes the $SMVPF's$ of the two policies. Intuitively this may arise if the spillovers from the tax policy are such that T_i actually lowers the $SMVPF_{\tau_i}$.

LMVPF of two different policies to be able to rank their marginal welfare impact on its residents. Indeed, for two policies A_i and B_i of jurisdiction i, we have:

Proposition S.B.2. *For two policies A and B implemented in locality i, we have:*

$$LMVPF_{A_i} > LMVPF_{B_i} \iff (\textit{Jurisdiction } i \textit{ marginally prefers policy } A_i \textit{ to policy } B_i), \tag{S.B.3}$$

where "A_i is marginally preferred to B_i" means that government i would increase the welfare of its residents by marginally reducing the size of policy B_i and marginally increasing the size of policy A_i so as to keep its budget balanced. This result is in line with the approach in Hendren and Sprung-Keyser (2020) of directly comparing the MVPFs of different policies to rank their welfare impacts.

S.B.2.1. Proof of LMVPF condition (S.B.2)

Under the assumption of ex ante measures of welfare (Gordon and Cullen 2012), local governments account for the welfare of the households residing in their boundaries before the policy change, the local welfare of jurisdiction i is:

$$LW_i \equiv \bar{n}_i V_i \tag{S.B.4}$$

where $\bar{n}_i$ is the exogenous initial population of the jurisdiction. As we are interested in small policy changes, the initial population $\bar{n}_i$ will ex-post coincide with the equilibrium population. Differentiating (S.B.4), it follows that the net impact of a change in the policy instrument τ_i on the local welfare is:

$$\frac{\partial LW_i}{\partial \tau_i} = \lambda_i \frac{\bar{n}_i}{\lambda_i} \frac{\partial V_i}{\partial \tau_i} = \lambda_i WTP^i_{\tau_i} \tag{S.B.5}$$

where λ_i is the marginal utility of income of the residents of i and $WTP^i_{\tau_i}$ is their marginal willingness to pay for policy $\mathrm{d}\tau_i$. It follows that the local marginal welfare is proportional to the marginal willingness to pay. Denoting, again, NGC_i the local net government cost of jurisdiction i, the marginal net government cost of jurisdiction i is as denoted previously:

$$\frac{\partial NGC_i}{\partial \tau_i} = NGC^i_{\tau_i}$$

Combining equations (S.B.5) and (S.B.2.1), the effect on local welfare per dollar of policy $d\tau_i$ on policy i is:

$$LMW^i_{\tau_i} \equiv \frac{\frac{\partial LW_i}{\partial \tau_i}}{\frac{\partial NGC_i}{\partial \tau_i}} = \lambda_i MVPF^i_{\tau_i}, \tag{S.B.6}$$

which proves condition (S.B.2).

S.B.3. Social MVPF and Welfare

The federal planner's social welfare function is a weighted sum of utilities over all jurisdictions in the federation given by $\sum_j \psi_j n_j V_j$ where ψ_j are positive social weights with unitary mean, i.e. $\sum_j \psi_j / I = 1$. Like in the local MVPF case, it is straightforward to convert the social MVPF from monetary units to social welfare units. To this aim, denote SMW_{τ_i} the social marginal welfare, that is, the effect on social welfare per additional dollar spent on policy $d\tau_i$. It can be shown that (Supplementary Material S.B.3.1):

$$SMW_{\tau_i} = \eta_{\tau_i} SMVPF_{\tau_i}, \tag{S.B.7}$$

where $\eta_{\tau_i} \equiv \sum_j \psi_j \lambda_j \sigma^j_{\tau_i}$ is the social weight of policy $d\tau_i$ which is calculated as the average social marginal utilities of income, $\psi_j \lambda_j$, of all the jurisdictions' representative individuals, weighted by their relative willingness to pay $\sigma^j_{\tau_i} \equiv WTP^j_{\tau_i} / \sum_k WTP^k_{\tau_i}$. A policy $d\tau_i$ conducted in i having effects on other jurisdictions j has a higher social weight η_{τ_i} if the jurisdictions which are willing to pay for policy change (high $\sigma^j_{\tau_i}$) are also those with a larger social marginal utility of income (high $\psi_j \lambda_j$). Intuitively, the planner will value a policy more if the jurisdictions that are willing to pay more for it are also those for which a dollar represents a high level of social utility. For example, suppose a municipality makes a \$1 marginal expenditure in schooling and other municipalities in the metropolitan area have positive marginal WTP for this policy of \$0.2. Then, the social weight of this policy will be higher if these municipalities are inhabited by relatively poor residents—relative to outside the metropolitan area—for whom \$0.2 has a high value (high λ_j) or if the federal planner values these municipalities more (high ψ_j).

The discussion above makes clear that, in general, the average marginal social utility of income of two different policies implemented in jurisdiction i, say A_i and B_i, need not be equal, i.e. $\eta_{A_i} \neq \eta_{B_i}$. Therefore, to make welfare statements about these policies, the federal planner needs to know not only the MVPF but also the social weights of both policies, relying on the decision rule:

Proposition S.B.3. *For two policies A and B implemented in locality i, we have:*

$$\eta_{A_i} SMVPF_{A_i} > \eta_{B_i} SMVPF_{B_i} \iff (\textit{The planner prefers marginal policy } A_i \textit{ to marginal policy } B_i),$$

which is similar to decision rules established in earlier literature (Hendren 2016; Hendren and Sprung-Keyser 2020). The statement "socially preferred" is interpreted the similarly to "locally preferred", but now taking the viewpoint of the federal planner: by reducing the size of policy B_i and increasing that of policy A_i while it maintains a balanced-budget, the planner would increase social welfare.

Proposition S.B.3 shows that in the absence of available estimates for the social weights η_{τ_i}, drawing welfare implications from the mere comparison of social MVPFs requires further assumptions. However, possible empirical analogs to these weights exist. In Supplementary Material S.C.4, we discuss possible strategies to empirically estimate the marginal social utility of income in a multi-jurisdictional economy. Alternatively, it is possible to make direct SMVPF comparisons by combining the three following assumptions: 1) the federal planner is utilitarian, implying that the social weights ψ_j are equal across jurisdictions; 2) utility is quasi-linear in private consumption; and 3) commodity tax rates are similar across jurisdictions. Then, recalling that the marginal utility of income λ_j is equal to $[1/(1 + \mathbb{t}_j^x)] \times \partial U_j/\partial x_j$, these three assumptions imply that the λ's are equal across jurisdictions. Under these assumptions, the average social utilities of income, η_{τ_i}, are equal across policies and Proposition S.B.3 becomes:

Proposition S.B.4. *For two policies A and B implemented in locality i, we have:*

$$SMVPF_{A_i} > SMVPF_{B_i} \iff (\textit{The planner prefers marginal policy } A_i \textit{ to marginal policy } B_i).$$

Thus, under the three assumptions above, it is possible to make direct social welfare statements by comparing the social MVPFs of different policies.

S.B.3.1. Proof of SMVPF condition (S.B.7)

The social welfare function is:

$$SW = \sum_j \psi_i \bar{n}_j V_j \tag{S.B.9}$$

Differentiating it with respect to τ_i, we obtain:

$$\frac{\partial SW}{\partial \tau_i} = \sum_j \psi_j \lambda_j \frac{\bar{n}_j}{\lambda_j} \frac{\partial V_j}{\partial \tau_i} = \sum_j \psi_j \lambda_j WTP^j_{\tau_i} = \sum_j \psi_j \lambda_j \sigma^j_{\tau_i} \sum_k WTP^k_{\tau_i}$$

where $\sigma^j_{\tau_i} \equiv WTP^j_{\tau_i} / \sum_k WTP^k_{\tau_i}$ is the share of jurisdiction j in the aggregate willingness to pay of the economy. Then:

$$\frac{\partial SW}{\partial \tau_i} = \eta_{\tau_i} \sum_j WTP^j_{\tau_i} \tag{S.B.10}$$

where the average social marginal utility of the beneficiaries of the policy is denoted:

$$\eta_{\tau_i} \equiv \sum_j \psi_j \lambda_j \sigma^j_{\tau_i}. \tag{S.B.11}$$

Denoting, again, $SG = \sum_j NGC_j + NGC_{\text{F}}$ as the aggregation of government costs of all jurisdictions j plus the net government costs of the federal government budget, the marginal social net government cost is derived as:

$$\frac{\partial SG}{\partial \tau_i} = \sum_j \frac{\partial NGC_j}{\partial \tau_i} + \frac{\partial NGC_{\text{F}}}{\partial \tau_i} = \sum_j NGC^j_{\tau_i} + NGC^{\text{F}}_{\tau_i} \tag{S.B.12}$$

Combining equations (S.B.10) and (S.B.12), the effect on social welfare per dollar of policy $\mathrm{d}\tau_i$ on policy j is:

$$SMW_{\tau_i} \equiv \frac{\frac{\partial SW}{\partial \tau_i}}{\frac{\partial SG}{\partial \tau_i}} = \eta_{\tau_i} SMVPF_{\tau_i} \tag{S.B.13}$$

which proves condition (S.B.7).

Supplementary Material S.C

Frequently Asked Questions: From Theory to Practice

The inclusion of mobility effects in the calculation of the MVPF necessitates care when selecting what causal estimates to utilize for the MVPF. This appendix provides some guidance. Supplementary Material S.C.1 discusses estimation of mobility and capitalization effects. Supplementary Material S.C.2 describes how congestion effects have been estimated in the literature. Supplementary Material S.C.3 discusses how fiscal externalities and public services spillover effects can be estimated. Supplementary Material S.C.4 proposes an approach to estimating social weights necessary to convert the MVPFs into welfare terms.

S.C.1. How to Estimate Mobility and Capitalization Effects?

S.C.1.1. Can Behavioral and Mobility Effects Be Estimated Jointly?

Initially, consider a case with a single taxing instrument on labor ([)as in][]Hendren2020 or alternatively assume that any cross-base effects are negligible. Does the researcher need to estimate labor supply and mobility effects separately or jointly? In the absence of congestible public goods, both effects can be used to calculate the fiscal externality. To see this, note that the mechanical effect, the behavioral effect, the price effect, and the locational effect can be combined into $-n_i w_i \ell_i - n_i t_i^\ell w_i \frac{\partial \ell_i}{\partial t_i^\ell} - n_i t_i^\ell \ell_i \frac{\partial w_i}{\partial t_i^\ell} - t_i^\ell w_i \ell_i \frac{\partial n_i}{\partial t_i^\ell}$. Applying the product rule, one can easily see that this is the derivative of labor tax revenues or alternatively of the labor tax base: $\frac{\partial (t_i^\ell n_i w_i \ell_i)}{\partial t_i^\ell} = n_i w_i \ell_i + t_i^\ell \frac{\partial (n_i w_i \ell_i)}{\partial t_i^\ell}$. Thus, ignoring the mechanical effect, estimating the denominator of the MVPF could be done with aggregate data or alternatively, researchers could use disaggregated data to estimate $\frac{\partial (w_i \ell_i)}{\partial t_i^\ell}$ and $\frac{\partial n_i}{\partial t_i^\ell}$ separately. However, in the presence of congestion effects on the public services, the researcher will need to estimate the effect of the tax on changes in the number of beneficiaries to the program. This mobility effect will then need to be scaled by the effect of changes in the number of beneficiaries or population on public service costs.

However, neither using aggregate data to estimate the total effect or using disaggregated data to separately estimate the effect on mobility and $w_i \ell_i$ will allow the researcher to calculate the numerator of the MVPF. Here, researchers must estimate the effect of the policy on prices directly. Later, we discuss how to estimate the willingness to pay of jurisdictions.

The same logic can easily be extended to multiple tax instruments. The fiscal externality on other tax bases can be estimated aggregated or disaggregated.

S.C.1.2. Individual Data vs. Aggregate Data

Again, consider the behavioral responses to a labor income tax, although the points we make below apply more generally. A common way of capturing the behavioral responses to labor income taxes is by estimation of the elasticity of taxable income, or ETI (Saez, Slemrod, and Giertz 2012). There are three ways a researcher could estimate this elasticity. First, the researcher could utilize individual data and estimate taxable income responses holding constant the wage rate faced by the individual. Second, also utilizing individual data, the researcher might not control for wages in the specification. Finally, the researcher could utilize aggregate data on hours worked in the economy to estimate the response.

With respect to the first two approaches, the second approach is preferred because responses are general equilibrium concepts inclusive of any price adjustments. Using aggregate data also allows prices to change as well. The first approach is feasible for estimating the MVPF, but when controlling for wages, the researcher needs to take care to include the additional necessary terms.

Critically, calculation of the MVPF relies on uncompensated elasticites. But, in a federal system, how these elasticities are estimated determines whether the elasticity includes mobility effects or not. If using state-level administrative data on taxfilers, it is likely the ETI would be estimated using individuals who appear in the data before and after the tax reform. Including individuals who leave the state's data would require knowledge about whether it was a result of a move, death of a taxpayer, or simply a result of losing contact with tax administration. In this case, mobility responses would not be included in the ETI. Now one might expect this problem could be overcome by accessing federal tax return data. And while this is true, studies of the ETI traditionally drop movers to avoid complex changes resulting from different state tax systems. Again, the ETI would exclude mobility responses, necessitating their separate estimation.

This stands in contrast to aggregate data. When using aggregate data on total taxable income (or labor supply), the researcher is essentially studying the number of taxpayers times average taxable income. In this way, aggregate data will capture both real labor supply responses and declines in the number of workers (both extensive and intensive margin effects).

Critically, in the presence of congestion effects, our MVPF formula makes it clear that the researcher will need to estimate the labor supply and mobility responses *separately*. Critically, changes in the number of individuals also influences the congestion costs of providing the local public services, while labor supply or price response do not.

S.C.1.3. Do Mobility Effects on Prices Need to Be Estimated Separately?

Calculation of the MVPF also requires separate information on the pricing effect because the willingness to pay depends only on the price and not the quantity effect of the policy. Again, using the example of labor supply, wages may change for two reasons. First, behavioral effects on labor supply may changes to labor supply via standard general equilibrium pricing effects. Second, mobility of workers across jurisdictions may also change wages. Critically, our MVPF makes it clear that price changes do not need to be decomposed into whether they are a result of mobility or not. In other words, the reason why prices are changing is irrelevant to determine the fiscal externality or the change in willingness to pay. As a result, standard reduced form estimates of pricing effects suffice.

S.C.1.4. Should Behavioral Effects Control for Prices or Are They Equilibrium Concepts?

Although the derivatives in (13) are partial derivatives, section 2.5 makes it clear that all of the equilibrium variables are a function of the policy instrument set. Any behavioral (or mobility) change can be viewed as an equilibrium concept rather than a standard partial equilibrium elasticity. In turn, the relevant change in the quantities in (13) are the direct effect of the policy on the choice variable as well as any indirect effect via price changes in the economy. To correctly estimate the behavioral responses, when prices are not constant, the researcher need not control for prices. If controlling for prices, for example, as would be done in a standard log-log estimating equation of labor supply on the net-of-tax rate and wages, the researcher would obtain only a partial equilibrium behavioral response. In those cases, the researcher would need to augment this response with a separate estimation of any indirect effects of prices on quantities. In contrast, if the labor supply equation is only estimated with the inclusion of the tax or after-tax rate, the coefficient reflects both the direct effect of tax on labor supply and an indirect effect through general equilibrium wage and other prices changes. While the difference may be innocuous in some case, in other circumstances, the equilibrium response and partial equilibrium responses may diverge substantially.

S.C.1.5. Are Price Effects be Double Counted?

Consider the case of imperfect capitalization and one jurisdiction's policies affect property values in other jurisdictions.[3] With incomplete capitalization $|\mathrm{DE}^{i}_{\tau_i}| > H_i|\frac{\partial p_i}{\partial \tau_i}\mathrm{d}\tau_i|$. Even if there are spillovers, but all residents in both jurisdictions are homeowners, the price effects cancel in both jurisdictions as homeowners are both renters and owners of the property. Then as with no spillover effects, the direct effect is sufficient for both the social and local WTP. But when one jurisdiction's policies affects property values in other jurisdictions similar issues arise when there is cross-jurisdiction ownership. With property values affected in both jurisdictions and cross-jurisdiction ownership, price changes in jurisdiction j will now also the WTP to the extent that residents of i own property in j. The WTP captures the effects of properties in j and price appreciation in i affecting landlords owning property there. The direct effect is not sufficient to capture the WTP.

S.C.2. How to Estimate Congestion Costs?

Estimates of the effect of population size on the costs of public service production often follow a structural approach (**borcherding1972demand**; **bergstrom1973private**; **brueckner1981congested**; **oates1988measurement**; **duncombe1993analysis**). These studies estimate a multiplicative demand function that contains the population of the jurisdiction as one of its arguments. From the estimated coefficient on population and the price elasticity, the researcher can then estimate a congestion parameter that measures the effect of the increase in population on the public service. As a simple example, the relationship between public service consumption and population might take the form $g_i = s_i n_i^{-\kappa}$ where s_i is the number of units provided by locality i and g_i is a final output of interest to residents or the amount of the good consumed by an individual (what enters into the utility function). Then, $\kappa = 0$ for a public good and $\kappa = 1$ for a private good. Traditionally, studies, assume that this congestion parameter is the same for all communities, but not across goods. Obviously, more complex functions and structural approaches might lead to less bias from a misspecification of the form. The older literature might not be considered as causal, but this approach could be extended using modern tools of demand function estimation from the IO literature. Such cost functions have often been omitted from recent structural models. We suggest that including such congestion may be a critical way to model public services if seeking to utilize

[3] A good example of these cross-jurisdiction price effects arises when jurisdictions have "market power," that is, they are a significant share of the labor or housing market. In this case, there is incomplete capitalization of their policies into their own housing prices with housing prices in other jurisdictions affected as well.

the MVPF.

As an alternative, assume that public services provided by local governments have a cost function of the form, $c(n, z)$ that depends on the number of residents and the amount of public services z. Note that many public services have the special form $c(n, z) = nz$ so that the marginal cost of providing services to one additional resident is the same as the others. This constant cost assumption, allows for an easy interpretation to the marginal congestion cost. For many public services, such as a per-head subsidy to local residents, might reasonably take this functional form.

S.C.3. How to Estimate Interjurisdictional Externalities?

S.C.3.1. Estimating Fiscal Externalities

The literature (Buettner 2003; Agrawal, Foremny, and Martínez-Toledano 2024) has estimated cross-jurisdiction effects, but more work is needed in this area. Calculating the social MVPF requires calculating the interjurisdictional fiscal externalities. At first glance, estimating all the necessary components may seem complicated. Researchers need to know the effect of jurisdiction i's policy on every other jurisdiction's budget individually. One might initially believe that this implies the researcher needs to estimate the effect of the policy on $I - 1$ other jurisdiction in the country separately. But only the total interjurisdictional externality—aggregated to all other jurisdictions in the system—is needed. Further, in this section and in the section on sufficient statistics approaches, we argue that one can make reasonable assumptions that allow researchers to estimate the aggregate effect on other jurisdictions. Of course, as noted in Finkelstein and Hendren (2020), estimating the effect of a policy that spills over onto non-beneficiaries is challenging, and so too is the case for cross-jurisdiction effects.

There are two different approaches to estimating fiscal externalities common in the empirical literature: controlling for other jurisdictions' policy reactions and not controlling for other jurisdictions' policy reactions. We believe the latter approach estimating general equilibrium concepts is simpler, but we discuss both approaches in turn.

First, in cases where mobility is localized to nearby jurisdictions, the researcher can assume that fiscal externalities on far away jurisdictions are negligible. This might be the case for elementary schooling if individuals choose from school districts within a common metropolitan area. Notice that a tax base or expenditure for jurisdiction j can be written as $b_j = b(\tau_j, \boldsymbol{\tau}_{-j}, X_j)$, where τ_j is the policy in the jurisdiction, $\boldsymbol{\tau}_{-j}$ is the full vector of policies in all other jurisdictions other than j, and X_j are jurisdiction characteristics. If the base is locally mobile, then the researcher can simplify by noting the base only will depend on nearby policies. In this case, following Buettner (2003), the researcher might estimate an equation of the form, which because it controls for other jurisdictional policies, estimates are partial equilibrium effect:

$$b_{jt} = \alpha \tau_{jt} + \sum_{k \neq j} \beta_k \tau_{kt} + X_{jt} \gamma + \epsilon_{jt} \tag{S.C.1}$$

where b_{it} is the tax base in jurisdiction j and year t, and X_{it} are controls including appropriator fixed effects. Alternatively, the researcher might use revenue data rather than base data. The researcher must take care to find a causal identification strategy, perhaps instruments to resolve endogeneity concerns. Then consider a policy such as education spending, τ_{jt}. By controlling for own-jurisdiction spending, the researcher accounts for the fact that high-education spending at home will expand the own jurisdiction's tax base and revenues ($\alpha > 0$). Then, keeping in mind that the researcher has assumed mobility is only among nearby jurisdictions within the metro area, the summation $\sum_{k \neq j} \beta_k \tau_k$ may be restricted to only the proximate set of towns. A sufficient number of exogenous sources of variation and a large number of observations may not exist in practice. Then, assumptions can be made such that $\sum_{k \neq j} \beta_k \tau_k = \beta \overline{\tau}_{-jt}$ where the right hand side denotes the (weighted) average of education spending in the metropolitan area but not in jurisdiction i. Theory might provide insight on the weights: if all jurisdictions are equally attractive, then a raw average suffices. If moving costs increase with distance, then inverse distance weights might be appropriate. In general form, $\overline{\tau}_{-jt} = \sum_{j \neq i} w_{ji} \tau_j$ where w_{ji} are the weights given to each jurisdiction.Then, an increase in spending of nearby jurisdictions ($i \neq j$) will shrink the tax base of jurisdiction j (i.e., $\beta < 0$) via an outflow of mobility. If the outcome variable is revenue, then β pins down the interjurisdictional fiscal externality. However, note that because $\overline{\tau}_{-jt}$ is an average, it tells us the effect of a one unit increase in spending in all nearby jurisdictions. If one wishes to study the effect of a one unit increase in a single jurisdiction, one must appropriately rescale it by the weights used to construct the average. Finally, note that if the researcher uses tax base data or prices, the estimates need to be multiplied by the tax rate of the jurisdiction to determine the fiscal externality.

We need to place an important caveat on such an estimating equation because it estimates partial equilibrium rather than general equilibrium effects. If competitive forces are at work, researchers can simply estimate the MVPF using general equilibrium responses to a jurisdiction's policy. Under this approach, researchers would not want to control for the competitive jurisdiction tax rates on the right hand side of (S.C.1). If controlling for competitor tax rates, then the research would need to construct the MVPF. Under the general equilibrium approach, researchers simply need to estimate:

$$b_{jt} = \alpha \tau_{jt} + X_{jt}\gamma + \epsilon_{jt}, \tag{S.C.2}$$

which eliminates many of the uncertainties above with respect to specifying spatial weight matrices. In this case, researchers simply need to estimate the slope of the strategic reaction function to calculate the additional competitive direct and mechanical effects.

Second, in cases where mobility may be global, one may wish to identify these effects by exploiting how state-level revenue data in all other jurisdictions changes following a policy change in one state. Note that the sum of external effects $\sum_{j \neq i} E^j_{\tau_i}$ can be rewritten as $(I-1)\overline{E}_{\tau_i}$ where $\overline{E}_{\tau_i}$ is the mean external effect and I is the total number of jurisdictions in the economy. Then, the researcher needs to simply take care to estimate the average fiscal externality and multiply by the number of other states to obtain the total fiscal externality. Of course, such a strategy may require accounting for policy changes happening across multiple states at various points in time.

If the external effects on any one other state are small, a third approach taken in Agrawal, Foremny, and Martínez-Toledano (2024), exploits the estimation of own-jurisdiction effects to reverse engineer the fiscal externality. Here estimation is best explained using their specific example: following fiscal decentralization of wealth taxes in Spain, the region of Madrid lowered its wealth tax rate to zero; all other jurisdictions maintained high tax rates. The authors use this salient deviation to causally estimate the migration to Madrid. Then, assuming that Spain is a closed economy without international flows being altered by the tax, any increase in Madrid's population caused by the wealth tax decrease must be a loss elsewhere. If all other regions levied identical tax rates, then obtaining the fiscal externality is trivial. Given other regional tax rates differ, assumptions must be made. The authors apportion their causal effect using the pair-specific regional migration changes (post- minus pre-reform) and then reassign movers randomly back to their home region, which allows them to calculate the precise loss of in the tax base of each other region. The authors then use microdata on taxes actually paid, plus a tax simulator to calculate the counterfactual lost wealth, labor income, and capital income taxes resulting from this mobility. Summing across region then gives the total interjurisdictional fiscal externality due to mobility necessary for the MVPF. Under this third approach, the researcher uses the migration into the jurisdiction making the policy change, and reasonable assumptions on where it originates from, to infer the fiscal externality on all other states.

S.C.3.2. Estimating Competitive Effects

Estimating the MVPF in the presence of tax competition or fiscal competition is facilitated by the plethora of estimates of strategic reaction functions.

However, the elegant expressions of the competitive direct and mechanical effects in the main text require empirical models that calculate all responses *inclusive* of general equilibrium effects. Empirical models that control for taxes in competitor jurisdictions will not satisfy this requirement. This means that all estimates of fiscal externalities, price responses, or quantity response used to construct the MVPF should not control for the policies in other competitor jurisdictions. This is an especially important point, because as noted above, many of the interjurisdictional fiscal externalities estimated above do control for taxes elsewhere by using (S.C.1) instead of the general equilibirum variant (S.C.2).

Nonetheless, we can generalize the model to apply to estimates that control for policies in competitor jurisdictions. However, this approach requires estimation of several additional terms. Thus, our preferred approach is in the prior subsections. Instead, researchers should empirically estimate general equilibrium concepts so as to only need to to estimate the competitive mechanical and direct effects.

S.C.3.3. Estimating Spillover Benefits?

While the existence of spillovers has long been acknowledged in the public finance literature, quantifying these benefits and costs has proven to be a challenge with few examples found in the literature. What might be an approach to estimating the extent of these spillovers? We suggest the possibility of employing hedonic estimation. A standard use of hedonics is to relate property values in a jurisdiction to the taxes and public services in that jurisdiction by estimating equation of the form:

$$V_{hj} = \alpha + \beta g_j + \gamma t_j + \delta X_{hj} + \varepsilon_{hj}, \tag{S.C.3a}$$

where V_{hj} is the value of house h in jurisdiction j or more frequently the log of property value; g_j is the level of public service, t_j is the property tax rate; and X_{hj} are characteristics of the house. Then, if the jurisdiction has a small share of the federation's population its policies will have a negligible effect on property values in other jurisdictions and the coefficient on g_j, β, will provide an estimate of the marginal willingness to pay for g_j.

We can apply the same procedure to estimate the "spillover" benefits from public goods provided in neighboring jurisdictions. Then, amend (S.C.3a) to include public goods in other jurisdictions:

$$V_{hj} = \alpha + \beta_j g_j + \sum_{k \neq j} \beta_k g_k + \gamma t_j + \delta X_{hj} + \varepsilon_{hj}, \tag{S.C.3b}$$

In (S.C.3b) the coefficients β_k are the estimates of the marginal willingness to pay for the spillover benefits, $\text{DE}^{j}_{g_k}$. The summation of neighboring policies could also take a weighted average of the policies if identifying the effect of many jurisdictions is difficult (Supplementary Material S.C.3.1).

As an alternative to this estimation-based approach, we also outline a model-based approach that outlines the assumptions necessary to infer the price effects in other regions based on the capitalization effects in the jurisdiction enacting the policy. Intuitively, in a metropolitan area, the price effects in one jurisdiction are negatively related to the price effects elsewhere via the housing supply elasticities. This approach is especially useful to construct the MCT in cases where the researcher only has own-jurisdiction price effects and is willing to make mild model-based assumptions.

S.C.4. How to Estimate the Social Welfare Weights?

In the text, when deriving the MCT we assumed equal social weights across jurisdictions. But, there may be circumstances where this does not hold. In these cases, converting the MVPF and MCT into social welfare (Section 3.3) requires taking a stance on the weight that the federal planner assigns to each jurisdiction: the jurisdiction-specific marginal social utility of income η_i. As discussed in Supplementary Material S.C.1.5, even in the absence of direct spillover benefits with ownership of firms and profits throughout the federation, local policies will affect resident utility in other jurisdictions via general equilibrium effects on prices and wages. This necessitates assigning welfare weights for jurisdictions throughout the federation if the social planner cares about different communities differently.

How might these welfare weights be chosen? Hendren (2020) offers one approach, "inverse-optimum weights". Intuitively, Hendren (2020) argues that we might infer the welfare weights chosen by policy makers via observation of what is presumably an optimal policy.

The logic behind Hendren's approach to inferring these optimal welfare weights is straightforward: to determine the welfare weight associated with a particular income y, we need to determine the cost, $g(y)$, of giving that group a tax cut of \$1. Absent any behavioral effects of tax cut the cost is simply $1. However, the tax cut is likely to change behavior – those with incomes below y may increase their labor efforts to obtain the cut while those with income above y may reduce labor efforts. Then $g(y) = 1 + FE(y)$ where $FE(y)$ is the fiscal externality associated with tax cut. How, then, are the optimal social welfare weights obtained? From Hendren (2020) (p. 4) the (first order) conditions for optimal social welfare weights can be expressed as

$$\frac{\eta^*(y)}{g(y)} = \kappa, \ \forall \ y \tag{S.C.4}$$

From (S.C.4) it follows that the social welfare weight associated with income of y, $\eta^*(y)$, is inversely related to the cost of providing those with income y a tax cut of $1. And the ratio must equal a constant, κ. One approach Hendren follows to operationalize this measure employs estimates of taxable income elasticities. Following this approach Hendren estimates $1 tax cut for high incomes has costs about $0.65 while at the lower end of the income distribution a tax cut (expansion in EITC) cost about $1.15, Then based on (S.C.4), the social welfare weight on low income households is 1.77 times greater than that for the high income household.

Hendren's (2020) application determines social welfare weights for households of differing income. Our interest, however, is not in comparing welfare across individuals but across jurisdictions as required to determine the $SMVPF$ and MCT. One way of extending Hendren (2020)'s approach to welfare weights for jurisdictions is to assume local populations are relatively homogeneous—as with Tiebout sorting—and to obtain the welfare weights obtained by Hendren (2020) based on the average income in the jurisdiction, $\eta_i \equiv \eta^*\left(\overline{y_i}\right)$ where $\overline{y_i}$ is the average income in the jurisdiction. Alternatively, one could determine the average social welfare weight in the jurisdiction, $\eta_i \equiv \int_{\underline{y}}^{\overline{y}} f(y)\eta^i\left(y\right)dy$ where $f(y)$ is the probability density function of the jurisdiction income distribution. This approach requires information on the distribution of income in the jurisdiction, and thus will be more of a data challenge.[4] **embree2023revealing** conducts a similar exercise for U.S. states.

[4] Wildasin (1986) and Mirrlees (1972) demonstrate that individuals with equal incomes and levels of utility may have different marginal utilities of income ($\lambda_j(y)$). In their models, these differences arise because of spatial differences, which give rise to rent and commuting costs. More generally, differences in amenities and land rents will generate differences in $\lambda_j(y)$. These differences in $\lambda_j(y)$ across jurisdictions is not accounted for in the approach of Hendren (2020).

Supplementary Material S.D
A Quantitative Framework for Analyzing Local Policies: Toward a Sufficient Statistic Approach

This appendix describes how we tailor our general but abstract framework developed in Section 2 of the main paper to quantiatively analyzing the welfare effects of state and local public policies. Supplementary Material S.D.1 describes precisely the quantiative model we use to obtain the numeric results reported in the main paper for the K-12 example Section 6.2 and for the porperty tax example Section 6.3. This quantitative model includes essential realistic features that are not introduced in the general framework of Supplementary Material 2 but that need to be taken into account to bring the model to data: differentiation between homeowners and renters, number dependent persons in a households (e.g. children) affected by the policy, realistic tax instrument sets, etc.. Supplementary Material S.D.2 reports the resulting MVPF formulas used in these empirical applications. Then, we determine the minimal set of data and elasticities that are sufficient statistics for quantifying the local MVPF, the social MVPF and the MCT in Supplementary Material S.D.3. In particular, it shows that under few reasonable conditions, the housing price elasticity with respect to the policy is a sufficient statistics for quantifying the MVPFs and the MCT. In addition, Appendix D describes a reasonable numerical calibration of the model based on this sufficient statistics approach.

S.D.1. Framework

The economy consists of a MSA in which i denotes the locality (e.g. school district) conducting a policy $\mathrm{d}\tau_i$ and j, the aggregate of other localities in the MSA. The local policy may be education spending or a property tax. The MSA is included in state $\textsc{s}$ which is part of a federation $\textsc{f}$.

To assess the welfare effects of early-life intervention programs like schooling policies, special care should be given to children's future earnings. Thus, we consider the following simple two-period model (Hendren and Sprung-Keyser 2020). In the first period, the households include, without distinction the parents and the children. They benefit from the policy and respond rationally to it. In the second period, the children potentially enjoy higher earnings which increase their tax liability and thus brings additional tax revenue to the governments.

Local policies are specific compared to national policies for two main reasons. First, they trigger households' migration responses in the first period. Moreover, in the second period, the grown children do not necessarily work, live and pay taxes in the locality where they grew up and studied. To highlight these specificities, we first introduce the households' behavior in the first period (section S.D.1.1). Then, we describe the children's behavior as adult in the second period (section S.D.1.2). The taxes paid by the households and the grown children to the localities, the state and the federal government are summarized in the inter-temporal net government costs (section S.D.1.3).

S.D.1.1. Households

Let us start with the first period. Locality i is inhabited by n_i households including a total of n_i^c children.[5] Among these n_i households, n_i^r are renters and n_i^o are homeowners; these two tenure types are indexed by $\kappa = r, o$. As is standard in the local public finance literature (Epple and Sieg 1999), we assume that households freely choose their location *within* the metropolitan area but do not migrate outside of the MSA. The individual housing demand h_i and labor supply ℓ_i are assumed inelastic, and are normalized to unity so that p_i^r represents the rent of a rental house, p_i^o is the rental value of a homeowner's dwelling,[6] w_i is the wage earned by the parents and w_i^c is the present value of the future labor earnings of a child, which depends on the location of where the child obtains schooling. As the focus of this appendix is on household policies, we assume the following simplified numéraire production sector. Following (Hendren and Sprung-Keyser 2020), we assume that the numéraire good is produced under constant returns to scale in each locality. Formally, in locality i, the numéraire good is produced from the production function $f_i(n_i) = \omega_i n_i$ where ω_i is the exogenous local productivity of a worker in i. This technology implies that the wage in locality i is exogenously fixed at the worker's productivity level, $w_i = \omega_i$.

The public good g_i represents school spending per child. We assume that there is no direct benefit spillover of schooling across school districts, that is, nonresidents cannot attend schools outside their district. Composite consumption is divided between non-taxable consumption χ_i^κ and taxable consumption x_i^κ. The utility function of a household of type κ, living in i is $\chi_i^\kappa + U_i(x_i, g_i)$ which assumes quasi-linearity to get rid of second-order income effects.[7] The increase in the household's utility resulting from an increase in per capita schooling expenditure, $\partial U_i/\partial g_i > 0$, includes for example, the expected increase in the children's earnings.

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5 To avoid redundancies, this section describes the variables in locality i, but the variables in j are defined similarly.

6 Appendix D explains how the rental value of a a homeowner's house is calculated based on its market value.

7 We assume that a child's utility is included in her parents' utility. Modelling children as a household-specific public good in their parents' utility is a common practice in family economics (Browning, Chiappori, and Weiss 2014).

In the first period, the household pays a local property tax t_i^h, a local [state] sales tax t_i^x [t_{S}^x], a state [federal] income tax on labor income t_{S}^ℓ [t_{F}^ℓ], and a state [federal] income tax on housing rental income t_{S}^h [t_{F}^h].[8] Thus, the total tax rates are $\mathbb{t}_i^x = t_i^x + t_{\text{S}}^x$, $\mathbb{t}_i^\ell = t_{\text{S}}^\ell + t_{\text{F}}^\ell$ and $\mathbb{t}_{\text{J}}^h = t_{\text{J}}^h + t_{\text{S}}^h + t_{\text{F}}^h$. The budget constraint of a renter in i is $\chi_i^r + (1+\mathbb{t}_i^x)x_i + p_i^r = y_i + (1-\mathbb{t}_i^\ell)w_i$ and that of a homeowner household is $\chi_i^o + (1+\mathbb{t}_i^x)x_i + t_i^h \rho_i^o = y_i + (1-\mathbb{t}_i^\ell)w_i$. Unlike renters, homeowners pay the local property tax on the assessed value their house but they do not pay for the rental cost (equivalently, they pay it to themselves). The individual non-labor income is $y_i = \sum_{\text{J}=i,j} \theta_{i\text{J}}^h \pi_{\text{J}}^h / n_i$ in which $\pi_{\text{J}}^h = (1-\mathbb{t}_{\text{J}}^h)p_{\text{J}}^r H_{\text{J}}^r - c_{\text{J}}^h(H_{\text{J}}^r)$ is the profit generated by the rental housing sector in jurisdiction J, and $\theta_{i\text{J}}^h$ is the share of rental properties in J owned by the residents of i. Individual income makes it clear that we assume that all properties in i and j are owned by residents of the MSA, which is a likely approximation in practice. Thus, the indirect utility of the renter household is:

$$V_i^r = y_i + (1-\mathbb{t}_i^\ell)w_i - p_i^r - (1+\mathbb{t}_i^x)x_i + U_i\big(x_i, g_i\big), \tag{S.D.1}$$

where x_i is now the equilibrium value of the taxable consumption that depends on the levels of the policy instruments in all localities of the MSA. Similarly, the indirect utility of a homeowner household is $V_i^o = y_i + (1-\mathbb{t}_i^\ell)w_i - t_i^h \rho_i^o - (1+\mathbb{t}_i^x)x_i + U_i\big(x_i, g_i\big)$. Perfect residential mobility of households rules out utility differentials, so that in the equilibrium $V_i^\kappa = V_j^\kappa$, for $\kappa = r, o$.

S.D.1.2. Children

Let us now turn to the second period. As adults, the n_i^c children who grew up and studied in jurisdiction i may choose to live and work in any jurisdiction of the MSA or potentially any jurisdiction outside of it. This mobility in labor supply ensures that the wage the children receive depends only on the level of education, not where they work and live. In other words, the wage depends only on the location that their parents choose and thus where they were educated, and does not depend on their choice of residence. Denote n_{ij}^c the number of children who live in i as child and settle in j as adult, so that $n_i^c = n_{ii}^c + n_{ij}^c$. The same is true for the n_j^c children who grew up in j, so that $n_j^c = n_{jj}^c + n_{ji}^c$. The residential location of the children as adult is not related to the particular policy $\mathrm{d}\tau_i$ we are interested. Thus, for all $k = i, j$ and $k' = i, j$, $n_{kk'}$ is exogenous to our model.

[8] The effective local property tax rate t_i^h is defined as $t_i^h = \alpha \tau_i^h$, where τ_i^h is the observed tax rate and α is a parameter which transforms housing rent into taxable assessed value (Poterba 1992). However, notice that the observed state and federal income tax rates on rental income, t_{S}^h and t_{S}^h, are directly paid out of the rental value of the house, and thus need not be multiplied by α.

The future earnings (in present value terms), w_i^c, of a child who studied in i is pinned down by her human capital endowment, which might be increased by a first-period education spending. In the second period, if she lives in jurisdiction k, the child pays the labor income tax $\mathbb{t}_k^\ell w_k^c$ dollars of labor income tax and $\mathbb{t}_k^x x_k^c$ dollars of sales taxes, where x_k^c denotes the present value of her second period consumption.[9] To be exhaustive, we should also mention that the child will also pay property taxes to both jurisdictions. However, we reasonably assume that the second-period housing prices are not significantly affected by the first-period policy, that is, the migration of the children in older age does not have additional capitalization effects.

S.D.1.3. Governments

Local government $k = i, j$ collects tax revenues from property taxes and sales taxes, so that its intertemporal net government cost is:

$$NGC_k = c(g_k, n_k^c) - \left(t_k^h(\rho_k^r n_k^r + \rho_k^o n_k^o) + t_k^x(x_k n_k + x_k^c n_{ik}^c + x_j^c n_{jk}^c) \right), \tag{S.D.2}$$

where $c(g_k, n_k^c) = n_k^c g_k$ is the cost of spending g_k dollars per student on education. The state government levies tax revenues from income taxes on labor and property income of landlords, and from sales taxes. Thus, its net government cost is:

$$NGC_{\text{S}} = c_{\text{S}} - \sum_{\text{J}=i,j} \left(t_{\text{S}}^\ell(wn_{\text{J}} + w_{\text{J}}^c n_{\text{J}}^c) + t_{\text{S}}^h p_{\text{J}}^r n_{\text{J}}^r + t_{\text{S}}^x(x_{\text{J}} n_{\text{J}} + x_{\text{J}}^c n_{\text{J}}^c) \right), \tag{S.D.3}$$

where c_{S} is the cost of providing the public services; it is exogenous as the total population of the state remains unchanged. Similarly, the net government cost of the federal government is:

$$NGC_{\text{F}} = c_{\text{F}} - \sum_{\text{J}=i,j} \left(t_{\text{F}}^\ell(wn_{\text{J}} + w_{\text{J}}^c n_{\text{J}}^c) + t_{\text{F}}^h p_{\text{J}}^r n_{\text{J}}^r \right), \tag{S.D.4}$$

recalling that the federal government does not levy sales taxes.

[9] Following the standard approach of the MVPF literature (Hendren and Sprung-Keyser 2020), we assume that children's future earnings will be taxed at the currently observed income tax rate.

S.D.2. MVPF

We now derive the expressions of the components of the local and social MVPFs. A small policy reform $\mathrm{d}\tau_i$ in jurisdiction i, which might be a change in school spending $\mathrm{d}g_i > 0$ or a property tax cut $\mathrm{d}t_i^h < 0$. In addition to the economic responses of the private economy (housing price, population location, consumption, etc.), we assume that the policy reform in i can trigger policy reactions in j. Specifically, government j can change its property tax rate as a response to government i's change in property tax rate. However, we assume that spending in public j's public services are exogenous. This asymmetry reflects the assumption that the Nash game is in taxes and not in public services.

S.D.2.1. Local and External WTP

First, let us consider the local and external marginal willingness to pay. Assume that all governments account for the utility of the parents, but do not directly account for the future utility of the children. Thus, a government only accounts for children's benefits of education through their parents utility ($\partial U_i/\partial g_i > 0$), but it does not also count the direct effect of the earning $\partial w_i^c/\partial g_i$ increase on the child's utility. In that sense, the government does not double count this earning benefit which is likely internalized by the parents' utility. The local and external marginal willingness to pay are:

$$LWTP_{\tau_i} = \text{DE}^i_{\tau_i} + \text{IE}^i_{\tau_i} + \text{OE}^i_{\tau_i}, \quad \text{(S.D.5a)} \qquad EWTP_{\tau_i} = \text{DE}^j_{\tau_i} + \text{CDE}^j_{\tau_i} + \text{IE}^j_{\tau_i} + \text{OE}^j_{\tau_i}, \quad \text{(S.D.5b)}$$

where for each jurisdiction $k = i, j$, $\text{DE}^k_{\tau_i}$ is the direct effect (7), $\text{IE}^k_{\tau_i}$ is the disposable income effect (8) and $\text{OE}^k_{\tau_i}$ is the ownership effect (9). Moreover, $\text{CDE}^j_{\tau_i}$ is the competitive direct effect on j's residents due to the policy response of j to i's policy. In the context of the economy described in Supplementary Material S.D.1, for the change schooling expenditure $\mathrm{d}g_i > 0$ and for the property tax cut $\mathrm{d}\tau_i < 0$, these effects take the forms described below.

Let us start with the direct effects of the schooling expenditure. First, notice that in the absence of direct spillovers of schooling, the direct external effect in j, i.e. $\text{DE}^j_{g_i} = 0$. Moreover, as public services are not used as a strategic policy instrument, there is also no competitive direct effect due to j's policy reaction, i.e. $\text{CDE}^j_{g_i} = 0$. Quantifying the local direct marginal benefit of schooling, $\text{DE}_{g_i} = n_i \partial U_i/\partial g_i$, is the most challenging part, because estimates of the marginal utility by parents of schooling policies are challenging to obtain. However, it can be assessed by using the following revealed preference argument. As households are mobile across districts, any increase in utility due to an increase in public good in district i needs to be compensated by an increase in the cost of living in i or a cut in the cost of living in j. Otherwise households would keep migrating to i. Formally, from the expression of the indirect utility (S.D.1), differentiating the renters' migration condition $V_i^\kappa = V_j^\kappa$ with respect to g_i, we get $\partial U_i^\kappa/\partial g_i = \partial p_i^\kappa/\partial g_i - \partial p_j^\kappa/\partial g_i$ and multiplying by n_i, Therefore, we get formula (S.D.6a) below:[10]

$$\text{DE}^i_{g_i} = \sum_{\kappa=r,o} n_i^\kappa \left(\frac{\partial p_i^\kappa}{\partial g_i} - \frac{\partial p_j^\kappa}{\partial g_i} \right) \times \mathrm{d}g_i, \qquad \text{(S.D.6a)} \qquad\qquad \text{DE}^j_{g_i} = \text{CDE}^j_{g_i} = 0, \qquad \text{(S.D.6b)}$$

In words, condition (S.D.6a) states that the parents' valuation, $\partial U_i/\partial g_i$, for a small schooling expenditure is reflected by the local housing rent capitalization $\partial p_i^r/\partial g_i > 0$ induced by the attraction of new families in i, net of the housing rent cut in j, $\partial p_j^r/\partial g_j < 0$ generated by the fact that these families leave j. For the purpose of quantifying the local MVPF, condition (S.D.6a) makes it clear that the marginal utility of public good can be fully calculated from capitalization estimates only.

The quantification of the local and external direct effects of a property tax cut (S.D.7) is straightforward, as it only requires us to observe the rental costs of housing, the population and the shares of properties in i owned by the residents of $k = i, j$:

$$\text{DE}^i_{t_i^h} = -(\theta_{ii}\rho_i^r n_i^r + \rho_i^o n_i^o) \times \mathrm{d}t_i^h, \qquad \text{(S.D.7a)} \qquad\qquad \text{DE}^j_{t_i^h} = -\theta_{ji}\rho_i^r n_i^r \times \mathrm{d}t_i^h, \qquad \text{(S.D.7b)}$$

Expression (S.D.7) states that for a tax cut of $|\mathrm{d}t_i^h|$, the landlords living in k who own $100 \times \theta_{ki}\%$ of the rental housing in i (there are $H_i^r = n_i^r$ units of rental housing in i because each renter household consumes a single unit of housing) benefit from a direct increase in their property revenue of $\theta_{ki}\rho_i^r n_i^r \times |\mathrm{d}t_i^h|$. (S.D.7a) shows that the direct benefit of the property tax cut exceeds the landlords' gains because the tax cut also allows each of the n_i^o homeowners in i to save $\rho_i^o \times |\mathrm{d}t_i^h|$ dollars.

Unlike the direct effects, the competitive direct effect $\text{CDE}^j_{t_i^h}$ induced by j's tax reaction to i's policy is not directly observable from the data. Indeed, its expression:

$$\text{CDE}^j_{t_i^h} = -(\theta_{jj}\rho_j^r n_j^r + \rho_j^o n_j^o) \times \frac{\partial t_j^h}{\partial t_i^h}\, \mathrm{d}t_i^h, \qquad \text{(S.D.8)}$$

indicates that we also need an estimate of the slope $\partial t_j^h/\partial t_i^h$ of the tax reaction function $t_j^h(t_i^h)$. There are a plethora of empirical estimates of this slope in the tax competition literature. Regarding

[10] The changes in non-labor income, y_i and y_j from (S.D.6a), are absent because we assume that households ignore changes in the value of their housing asset portfolio as they migrate.

local property taxes in the U.S., most studies find positive slopes (Appendix D). In this case, the competitive direct effect (S.D.8) is interpreted as follows. The tax competition pressure of i cutting its tax rate by $|\mathrm{d}t_i^h|$ spurs j to also cut its tax rate by $(\partial t_j^h/\partial t_i^h)|\mathrm{d}t_i^h|$. By doing so, government j directly improves the welfare of its residents by $\theta_{jj}\rho_j^r n_j^r + \rho_j^o n_j^o$ for each unit of tax it cuts.

Parents internalize the utility of their children and, consequently, their children's future wages. Therefore, the only price effects that we need to consider to estimate the willingness to pay are those of the parents. As the parent's wage is fixed as there is productivity level, the disposable income effect on the willingness to pay of the residents of $k = i, j$ reduces to the effect on housing rents, the capitalization of the policy. Formally, for both policies $\mathrm{d}\tau_i = \mathrm{d}t_i^h < 0$ and $\mathrm{d}\tau_i = \mathrm{d}g_i > 0$, the local and external disposable income effects are:

$$\mathrm{IE}_{\tau_i}^k = -n_k^r \frac{\partial p_k^r}{\partial \tau_i} \times \mathrm{d}\tau_i, \tag{S.D.9}$$

recalling that the individual housing consumption is equal to one. Both policies are likely to increase [reduce] the rental cost of housing in i [j]. Thus, the disposable income effect (S.D.9) will be negative in i due to the increasing cost for renters of paying more expensive rents. On the other hand, in j, this effect is positive as the residents enjoys lower rents there.

With respect to the ownership effect, as landlords benefit [suffer] from the increase [decrease] in house rents in i [j]. Formally, the ownership effect on WTP of the residents of $k = i, j$ is:

$$\mathrm{OE}_{\tau_i}^k = \left(\sum_{\mathrm{J}=i,j} (1 - \mathbb{t}_{\mathrm{J}}^h) \theta_{k\mathrm{J}}^h \frac{\partial p_{\mathrm{J}}^r}{\partial \tau_i} n_{\mathrm{J}}^r - t_k^h \frac{\partial \rho_k^o}{\partial \tau_i} n_{\mathrm{J}}^o \right) \times \mathrm{d}\tau_i, \tag{S.D.10}$$

As the residents of k potentially own rental properties both in i and in j (i.e. $\theta_{ki}^h \geq 0$ and $\theta_{kj}^h \geq 0$), the policy alters their income due to price changes. Higher initial levels of the property taxes and of those of the state and federal income taxes on rental property income reduce the impact of the house rent changes, because it limits the income received [lost] in case of a rent increase [decrease].

S.D.2.2. Local and External NGC

Now, let us turn to the local and external marginal net government costs. As there are three different level of governments (local, state and federal), the policy conducted in i has effects not only on the budget of the other localities of the MSA, but also on the state and federal government budgets. Section S.D.2.2.1 describes the local effects and section S.D.2.2.2 describes the state and federal effects.

S.D.2.2.1 Net Government Cost of the Localities

The local marginal net government cost of locality i which conducts the education spending $\mathrm{d}\tau_i = \mathrm{d}g_i > 0$ or the property tax cut $\mathrm{d}\tau_i = \mathrm{d}t_i^h < 0$ is:[11]

$$LNGC_{\tau_i} = \text{ME}_{\tau_i}^i + \text{BE}_{\tau_i}^i + \text{PE}_{\tau_i}^i + \text{LE}_{\tau_i}^i, \tag{S.D.11}$$

and is composed of a mechanical effect $\text{ME}_{\tau_i}^i$, a behavioral effect $\text{BE}_{\tau_i}^i$, a price effect $\text{PE}_{\tau_i}^i$ and a locational effect $\text{LE}_{\tau_i}^i$. The external marginal NGC of the other individual localities of the MSA is:[11]

$$ENGC_{\tau_i}^{\text{L}} = \text{CME}_{\tau_i}^j + \text{BE}_{\tau_i}^j + \text{PE}_{\tau_i}^j + \text{LE}_{\tau_i}^j, \tag{S.D.12}$$

which include the same effects as the local NGC, except that the mechanical effect is now replaced by a competitive mechanical effect. The interpretation is that the localities in j incur a mechanical effect only if they respond strategically to i's policy by changing their own policies. In the case of i cutting it= tax rate, j incurs a mechanical cost only if it also decide to cut its own tax rate.

Formally, the local mechanical effect and the external competitive mechanical effects induced by a schooling expenditure $\mathrm{d}g_i > 0$ in i are:

$$\text{ME}_{g_i}^i = \frac{\partial c_i}{\partial g_i} \times \mathrm{d}g_i, \tag{S.D.13a}$$

$$\text{CME}_{g_i}^j = 0, \tag{S.D.13b}$$

where, recalling that $c_i(g_i, n_i^c) = n_i^c g_i$, the marginal cost of of one extra dollar spent per student, $\partial c_i / \partial g_i$, is simply the number of students, n_i^c, in i. The mechanical and competitive mechanical effects for a property tax cut $\mathrm{d}t_i^h < 0$ in i are:

$$\text{ME}_{t_i^h}^i = -(\rho_i^r n_i^r + \rho_i^o n_i^o) \times \mathrm{d}t_i^h, \tag{S.D.14a}$$

$$\text{CME}_{t_i^h}^j = -(\rho_j^r n_j^r + \rho_j^o n_j^o) \times \frac{\partial t_j^h}{\partial t_i^h} \, \mathrm{d}t_i^h, \tag{S.D.14b}$$

where (S.D.14a) states that a cut in the property tax rate of $|\mathrm{d}t_i^h|$ induces a cost for government i of $\rho_i^r \times |\mathrm{d}t_i^h|$ for each of the n_i^r rental properties and a cost of $\rho_i^o \times |\mathrm{d}t_i^h|$ for each of the n_i^o homeowner properties. Similarly, the competitive mechanical effect (S.D.14b) states that if jurisdiction j cuts

[11] The marginal NGC are obtained by differentiating the expressions of the government costs with respect to i's policy instrument τ_i. Specifically, $LNGC_{\tau_i}$ is the derivative of (S.D.2) setting $k = i$, $ENGC_{\tau_i}^{\text{L}}$ is the derivative of (S.D.2) setting $k = j$, $ENGC_{\tau_i}^{\text{S}}$ is the derivative of (S.D.3), and $ENGC_{\tau_i}^{\text{L}}$ is the derivative of (S.D.4).

its tax rate in response to i's tax cut, the cost for government j is $(\rho_j^r n_j^r + \rho_j^o n_j^o) \times |\mathrm{d}t_j^h|$ where $\mathrm{d}t_j^h = (\partial t_j^h / \partial t_i^h) \times \mathrm{d}t_i^h$ is the tax rate change in j.

As individual housing demands and labor supplies are fixed in standard metropolitan models, the behavioral effects reduce to the impacts of the policy on taxable composite consumption x. These consumption changes alter net government costs by via changes in sales tax revenues. The policy possibly affects both the parents' current consumption and the children's future consumption. In particular, schooling expenditure in i may improve the human capital of the children who grew up and studied in i so that they would earn higher earnings in the future and thus consume more and pay more sales taxes. Formally, the local and external behavioral effects are, for $k = i, j$:[12]

$$\text{BE}_{\tau_i}^k = -t_k^x \left(n_k \frac{\partial x_k}{\partial \tau_i} + n_{ik}^c \frac{\partial x_i^c}{\partial \tau_i} \right) \times \mathrm{d}\tau_i. \tag{S.D.15}$$

Sales tax revenues in k change if the policy affects the current household consumption $\partial x_k / \partial \tau_i$ or if it alters the future consumption of the children educated in i and settle in k as adults, $\partial x_k^c / \partial \tau_i$.

Localities do not to tax labor, so that the price effects on localities' NGC reduce to the effect of housing price capitalization on property tax revenues. Thus, the price effects are, for $k = i, j$:

$$\text{PE}_{\tau_i}^k = -t_k^h \left(n_k^r \frac{\partial \rho_k^r}{\partial \tau_i} + n_k^o \frac{\partial \rho_k^o}{\partial \tau_i} \right) \times \mathrm{d}\tau_i, \tag{S.D.16}$$

that is, if the policy increases the price of each of the n_k properties located in k by $(\partial \rho_k / \partial \tau_i) \times \mathrm{d}\tau_i$ dollars, then the net government cost of k decreases by $-t_k^h n_k (\partial \rho_k / \partial \tau_i) \times \mathrm{d}\tau_i$ dollars.

The local and external locational effects are, for $k = i, j$:

$$\text{LE}_{\tau_i}^k = \left(\frac{\partial c_k}{\partial n_k} \frac{\partial n_k}{\partial \tau_i} - \sum_{\kappa = r, o} (t_k^h \rho_k^\kappa + t_k^x x_k) \frac{\partial n_k^\kappa}{\partial \tau_i} \right) \times \mathrm{d}\tau_i, \tag{S.D.17}$$

where, recalling that $c_k(g_k, n_k^c) = n_k^c g_k$, the marginal congestion cost of hosting a new household is $\partial c_k / \partial n_k = g_k \times \partial n_k^c / \partial n_k$: the per student schooling expenditure of jurisdiction k multiplied by the number of children the new households include. The locational effect (S.D.17) states that,

[12] Recall that we assume that there is no direct cross-jurisdiction spillover of schooling. In particular, this means that no child living in j go to school in i. This explains why the effect due to the change in consumption of children who grew up in j are absent from (S.D.15). Formally, as $\partial x_j^c / \partial \tau_i = 0$, we have $-t_i^x n_{ji}^c \partial x_j^c / \partial \tau_i = -t_j^x n_{jj}^c \partial x_j^c / \partial \tau_i = 0$ in (S.D.15). This assumption could be relaxed if the number of students in i living in other localities of the MSA is observed in the data, but practically speaking, in the USA students attend public schools where they live. Notice that this number from n_{ji}^c which is the number of children who study in j and worked in i as adults.

following i's policy, households could be attracted to or repelled from jurisdiction k. Each new family that settles in k increases the NGC as its children entail additional schooling expenditures for the locality. This cost is more or less offset by the property tax $t_k^h \rho_k^r$ and sales tax $t_k^x x_k$ paid by these new families.

S.D.2.2.2 Net Government Costs of the State and Federal Planners

To determine the level of its marginal corrective transfer to the localities, an upper government (state or federal) accounts not only for the benefits and costs of the policy to the localities, but it also accounts for the effects of the policy on its own (state or federal) budget. The external marginal net government cost of the state induced by the local policy $\mathrm{d}\tau_i$ is:[11]

$$ENGC^{\text{S}}_{\tau_i} = ENGC^{\text{L}}_{\tau_i} + \underbrace{\text{BE}^{\text{S}}_{\tau_i} + \text{PE}^{\text{S}}_{\tau_i} + \text{LE}^{\text{S}}_{\tau_i}}_{\text{VE}^{\text{S}}_{\tau_i}}. \tag{S.D.18}$$

It is composed of the external NGC of the localities, $ENGC^{\text{L}}_{\tau_i}$, and of the vertical effect on the state budget, $\text{VE}^{\text{S}}_{\tau_i}$, which includes a behavioral effect, $\text{BE}^{\text{S}}_{\tau_i}$, a price effect, $\text{PE}^{\text{S}}_{\tau_i}$, and a locational effect, $\text{LE}^{\text{S}}_{\tau_i}$. Similarly, the external marginal net government costs of the federal government is:[11]

$$ENGC^{\text{F}}_{\tau_i} = ENGC^{\text{S}}_{\tau_i} + \underbrace{\text{PE}^{\text{F}}_{\tau_i} + \text{LE}^{\text{F}}_{\tau_i}}_{\text{VE}^{\text{F}}_{\tau_i}}, \tag{S.D.19}$$

which has no federal behavioral effect because there is no federal sales tax, and individual labor supply is assumed fixed, so it does not distort the income tax revenues via changes in labor supply.

The vertical behavioral effect of the state is:

$$\text{BE}^{\text{S}}_{\tau_i} = -t^x_{\text{S}} \left(\sum_{\text{J}=i,j} n_{\text{J}} \frac{\partial x_{\text{J}}}{\partial \tau_i} + n_i^c \frac{\partial x_i^c}{\partial \tau_i} \right) \times \mathrm{d}\tau_i, \tag{S.D.20}$$

which, represents the sales tax revenue gains and losses for the state induced by the changes in the current consumption of the households and the future consumption of the children.[13]

[13] Notice that as we assume that the future consumption of the children only changes because of increases in wages from human capital formation due to a schooling policy, $\mathrm{d}g_i$, the consumption response of those children $\partial x_i^c/\partial \tau_i$ is independent of the locality they settle in as adult. But the tax rates applied to that response may differ.

The vertical price effects of the state (S) and federal governments (F) are, for $\text{X} = \text{S}, \text{F}$:

$$\text{PE}^{\text{X}}_{\tau_i} = -\left(t^h_{\text{X}} \sum_{\text{J}=i,j} n^r_{\text{J}} \frac{\partial p^r_{\text{J}}}{\partial \tau_i} + t^\ell_{\text{X}} n^c_i \frac{\partial w^c_i}{\partial \tau_i} \right) \times \mathrm{d}\tau_i, \tag{S.D.21}$$

These price effects on the state and federal net government costs are the change in income tax revenues—both on labor income and on housing rental income—resulting from the changes in housing rents and wages induced by the policy. Here the wage changes are a result of human capital formulation rather than changes in prices due to wage incidence.[14]

The vertical locational effect of the state is:

$$\text{LE}^{\text{S}}_{\tau_i} = -\sum_{\kappa=r,o} \left(t^\ell_{\text{S}}(w_i - w_j) + t^h_{\text{S}}(p^\kappa_i - p^\kappa_j) + t^x_{\text{S}}(x_i - x_j) \right) \frac{\partial n^\kappa_i}{\partial \tau_i} \times \mathrm{d}\tau_i, \tag{S.D.22}$$

which states that as households relocate from one locality to another, their state tax liabilities may change because they may earn higher/lower wages, pay higher/lower rent or consume more/less in their new localities than in their locality of origin. In practice, the magnitude of these locational effects may be negligible if localities are similar. The vertical locational effect of the federal government is similar:

$$\text{LE}^{\text{F}}_{\tau_i} = -\sum_{\kappa=r,o} \left(t^\ell_{\text{F}}(w_i - w_j) + t^h_{\text{F}}(p^\kappa_i - p^\kappa_j) \right) \frac{\partial n^\kappa_i}{\partial \tau_i} \times \mathrm{d}\tau_i, \tag{S.D.23}$$

recalling that the federal government is assumed not to tax sales, as is the case in the U.S.

S.D.3. From Theory to Data: A Sufficient Statistics Approach

This appendix formalizes the discussion in Section 5. Assessing the welfare effects of local policies based on their local/social MVPFs and MCTs potentially requires us to quantify all terms in equations (S.D.5)–(S.D.23). A priori, this might seem like a daunting task given the complexity of the expressions. However, inspecting these expressions, it appears that although they involve numerous effects, only limited data and a small number of elasticities are necessary to quantify all of these effects. In this section, we summarize the necessary data (section S.D.3.1) and the required elasticities (section S.D.3.2) that are sufficient statistics for assessing all the local/social MVPFs and MCT.

[14] In practice, it is possible the earnings response includes changes in wage and changes in labor supply as individuals move to better jobs, but we include all these earnings responses in this single term.

Section S.D.3.3 shows that under a few additional—and reasonable—assumptions, the elasticity of the housing price of the jurisdiction conducting the policy is the *unique* sufficient statistics required.

S.D.3.1. Necessary Observable Data

What minimum set of data do we need to assess the components in Supplementary Material S.D.2? First, scaling most of the effects requires population variables. Specifically, we need the numbers of households, n_i [n_j], and children, n_i^c [n_j^c], in locality i which conducts the policy [in the rest of the MSA].

Second, data on housing prices/rents are key to assess the housing price/rent responses to the policy which are present in almost all the terms of the local and social MVPFs. The imputed rent of a homeowner's house, p_i^o, is not observed but can be easily assessed based on the observed price of a homeowner's house, using Poterba (1992), as practically implemented in Appendix D.

Third, we obviously need data on the initial levels of the policy instruments of all the jurisdictions at stake. Specifically, for the locality which conducts the policy i, we need to observe its per student schooling expenditure, g_i, its property tax rate, t_i^h and its sales tax rate, t_i^x. The same policy instruments need to be observed for a representative locality j of the rest of the MSA: g_j, t_j^h and t_j^x may represent the average levels in the other localities of the MSA. We also need to observe the state sales tax rate, t_{S}^x, its income tax rate on labor income, t_{S}^ℓ, and its tax rate on rental property income, t_{S}^h. The latter two tax rates also need to be observed at the federal level: t_{F}^ℓ and t_{F}^h.

Fourth, assessing locational effects requires to observe households' taxable consumption, x_k, $k = i, j$, which might be obtained from detailed household survey data. An issue is that these surveys might not distinguish between taxable and non-taxable consumption. An alternative approach adopted hereafter, common the to literature on sales taxation, is to use state-level sales tax base data and divide the states tax base by the aggregate individual income of the state residents. We obtain the share, β, of a representative residents' income devoted to taxable consumption. Assuming that β is constant across individuals allows us to proxy the taxable consumption of a resident of jurisdiction k as $x_k = \beta Y_k$ where Y_k is the average individual income in k. Thus, the only local-level data that is necessary is the individual income which is easily accessible from the Census.

Fifth, schooling policies may increase the future earnings of children who then do not necessarily work in the jurisdiction where they studied. Therefore, in order to assess the price effect of this type of early-life interventions, we need information on the location of children as adults. In the context of section S.D.1, we need to know among the n_i^c children who studied in locality i which implemented the policy, how many will work there as adult (n^c_{ii}), and how many will work in j (n^c_{ij}).[15]

Finally, to quantify the income ownership effects of any policy and to evaluate the direct effects of property tax changes, we need information on the housing ownership shares $\theta_{kk'}$. How much of the housing stock of $k = i, j$ is owned by the residents of $k' = i, j$?

S.D.3.2. Four Fundamental Elasticities

To quantify all the effects in (S.D.5)–(S.D.23), which compose the local/social MVPFs and the MCTs, it is sufficient to have four elasticities often estimated in the literature.

The first one is the elasticity of the local housing price p_i (capitalization) with respect to the policy $\tau_i = g_i, t^h_i$, denoted $\varepsilon_{p,\tau}$. Interestingly, as we will prove below, researchers only need to observe capitalization in the jurisdiction enacting the policy. This estimate can be used to obtained the price effects in other localities in the MSA. The second elasticity is that of the local housing stock H_i with respect to the policy τ_i, denoted $\varepsilon_{H,\tau}$. The third elasticity is that of children's present value of future earning w^c_i with respect to education spending g_i. More precisely, the literature provides information on the marginal impact $\partial w^c_i / \partial g_i$ rather than the elasticity itself. The fourth the elasticity necessary if governments engage in strategic property tax competition is the responsiveness of another jurisdiction's property tax rate, t^h_j, with respect to the property tax rate, t^h_i, of jurisdiction i which implements the policy (slope of the strategic reaction function). Here also, the literature provides the marginal effects $\partial t^h_j / \partial t^h_i$. This tax reaction slope is (exclusively) used to compute (1) the competitive direct effect (S.D.8) on the willingness to pay of j's residents of a tax change in i, and (2) the competitive mechanical effect (S.D.14b) on the j's net government cost.

Let us show how all the economic responses to the policy in (S.D.5)–(S.D.23) can be obtained from these elasticities. First, several of the effects above require us to calculate local capitalization of the policy $\mathrm{d}\tau_i$ into the housing rents, $\partial p^r_i / \partial \tau_i$. By definition, this response to the policy is equal to:

$$\frac{\partial p^r_i}{\partial \tau_i} \times \mathrm{d}\tau_i = \varepsilon_{p,\tau} \frac{p^r_i}{\tau_i} \times \mathrm{d}\tau_i \qquad > 0 \qquad \text{(S.D.24a)}$$

[15] For illustration, Appendix D assumes a uniform distribution of the future workers across jurisdictions. However, in the higher education application (Section 6.1) we use specific empirical estimates provided in Simon (2021). However, notice that given that local sales tax rates are usually small, these external behavioral effects are relatively small and could possibly even be ignored.

in which the sign follows from the fact that reliable estimates of $\varepsilon_{p,\tau}$ are positive, recalling that the policy $\mathrm{d}\tau_i$ represents a schooling expenditure or a property tax cut. Therefore, once we have an estimate for $\varepsilon_{p,\tau}$, it is sufficient to have data on the housing rent and the initial level of the policy (e.g. per capita schooling expenditure) to recover $\partial p_i^r/\partial \tau_i$.

To quantify inter-jurisdiction spillovers, we also need to quantify the cross-jurisdiction capitalization $\partial p_j/\partial \tau_i$. One might initially expect that these external effects need to be directly estimated. Certainly, direct estimation of spillovers using hedonic models is possible (as we proposed in Supplementary Material S.C.3.3), but the literature only has a limited number of these estimates. However, the standard metropolitan model we have used to motivate this example allows is to calculate these external price effects directly. To do so, we exploit the general properties of our model. Specifically, replacing the housing market equilibria $n_i^r = H_i(p_i^r)$ and $n_j^r = H_j^r(p_j^r)$ into the population constraint $n_i^r + n_j^r = N^r$ and differentiating with respect to τ_i, we get $(\partial H_i^r/\partial p_i^r) \times (\partial p_i^r/\partial \tau_i) + (\partial H_j^r/\partial p_j^r) \times (\partial p_j^r/\partial \tau_i)$ which is equivalent to:

$$\frac{\partial p_j^r}{\partial \tau_i} \times \mathrm{d}\tau_i = -\frac{\varepsilon_{H,p}^i}{\varepsilon_{H,p}^j} \frac{p_j^r}{p_i^r} \frac{n_i^r}{n_j^r} \frac{\partial p_i^r}{\partial \tau_i} \times \mathrm{d}\tau_i = -\frac{n_i^r}{n_j^r} \varepsilon_{p,\tau} \frac{p_j^r}{\tau_i} \times \mathrm{d}\tau_i \qquad < 0 \qquad \text{(S.D.24b)}$$

where the last equality is obtained by inserting (S.D.24a) and by assuming that the elasticity of housing supply with respect to the housing rent is constant across school districts: $\varepsilon_{H,p}^i = \varepsilon_{H,p}^j \equiv \varepsilon_{H,p}^j$. This assumption is common in most empirical models with a log-log functional form. The negative sign of $\partial p_j^r/\partial \tau_i$ results from the likely positive sign of $\varepsilon_{p,\tau}$ discussed above. Intuitively, an expenditure policy in i makes j less attractive and thus reduces the housing price there. Equation (S.D.24b) highlights the following useful results for quantifying the social MVPF. By representing the MSA as a two-jurisdiction economy (i.e. the local jurisdiction which implements the policy and the rest of the MSA), the housing rent spillover $\partial p_j^r/\partial \tau_i$ can be assessed using only the own-jurisdiction price elasticity in the jurisdiction enacting the policy, $\varepsilon_{p,\tau}$, of the local housing rent p_i with respect to to the local policy τ_i. The literature offers plenty of estimates of this elasticity for numerous policies.

Quantifying the locational effects on the net government costs requires us to assess the migration responses $\partial n_i/\partial \tau_i$ and $\partial n_j/\partial \tau_i$. As the individual housing demand is assumed to be inelastic, the elasticity of the population n_k is equal to that of the housing stock $H_k(p_k)$. Formally, differentiating $n_k = H_k(p_k)$ with respect to τ_i, we obtain for each jurisdiction $k = i, j$:

$$\frac{\partial n_i^r}{\partial \tau_i} \times \mathrm{d}\tau_i = \varepsilon_{H,p} \frac{n_i^r}{p_i^r} \frac{\partial p_i^r}{\partial \tau_i} \times \mathrm{d}\tau_i \quad > 0, \tag{S.D.25a}$$

$$\frac{\partial n_j^r}{\partial \tau_i} \times \mathrm{d}\tau_i = \varepsilon_{H,p} \frac{n_j^r}{p_j^r} \frac{\partial p_j^r}{\partial \tau_i} \times \mathrm{d}\tau_i \quad < 0, \tag{S.D.25b}$$

which can be directly computed from the existing estimates of the housing supply elasticity with respect to the housing price, assuming that $\partial p_k^r / \partial \tau_i$ has already been quantified from (S.D.24). The signs in (S.D.25) come from the likely positive sign of the housing supply elasticity estimate, $\varepsilon_{H,p}$ and from the signs in (S.D.24). Intuitively, an expenditure policy in i attracts households from j to i.

The congestion cost on the locational effect can be directly inferred from the above locational responses and by assuming that each household of the MSA has ϕ children. Indeed, the cost of providing g_k dollars per child in k is $c(g_k, n_k^c) = g_k n_k^c = g_k \times \phi n_k = g_k \times \phi(n_k^r + n_k^o)$. It follows that the congestion cost in k induced by policy $\mathrm{d}\tau_i$ is:

$$\phi g_k \frac{\partial n_k^r}{\partial \tau_i} \times \mathrm{d}\tau_i \tag{S.D.26}$$

which is likely positive in i and negative in j. Indeed, by the expenditure policy in i attracts new residents which exert congestion costs in i, while by leaving j they reduce congestion there.

Finally, the behavioral effects on the net government costs require us to assess the effects of the policy on taxable consumption. As explained in section S.D.3.1, this can be made particularly easy by assuming that taxable consumption of the household is a constant share, β, of its income, $x_i \equiv \beta(w_i + \widetilde{y}_i) \equiv \beta Y_i$ where $\widetilde{y}_i$ is the before tax non-labor income (i.e. y_i with $\mathbb{t}_i^h = 0$), and that the future consumption of the children is also a constant share of its future earning, and $x_i^c \equiv \beta w_i^c$. Recalling that the metropolitan wage is exogenous and differentiating, we obtain:

$$\frac{\partial x_i^c}{\partial \tau_i} \times \mathrm{d}\tau_i = \beta \frac{\partial w_i^c}{\partial \tau_i} \times \mathrm{d}\tau_i, \tag{S.D.27a}$$

$$\frac{\partial x_k}{\partial \tau_i} \times \mathrm{d}\tau_i = \beta \sum_{\mathrm{J}=i,j} \frac{\theta_{k\mathrm{J}}^h}{n_k} \frac{\partial p_{\mathrm{J}}^r}{\partial \tau_i} n_{\mathrm{J}} \times \mathrm{d}\tau_i \tag{S.D.27b}$$

where (S.D.27b) represents the marginal impact of the policy on the non-labor income of an infra-marginal household living in k. Again, all the terms can be quantified given the the elasticity of the housing price and of the children's future earnings with respect to the policy.

S.D.3.3. The Housing Price Elasticity as a Sufficient Statistic

Now, we argue that under additional mild assumptions, these four sufficient statistics can be reduced to a single one—namely, the elasticity of the local housing price/rent with respect to the policy—if one only needs to compute the the local MVPF *and* the external effects on other local governments. If one wants to capture the effects on federal revenues, researchers additionally need a program evaluation of the policy (the effect of additional schooling on wages).

Let us proceed by elimination and explain why or under which assumptions the three other elasticities are not necessary for assessing the local MVPF or the external effects on other localities. We will need (1) The property tax to fund the bulk of local revenues so that local sales/income taxes are a negligible share of revenue, (2) marginal costs of attracting new houses offset the taxes paid by the household, which follows if local governments raise revenue from primarily taxing residential households, and (3) governments do not set fiscal policies strategically.

First, consider the housing supply elasticity, $\varepsilon_{H,p}$. It allows to assess the locational response, $\partial n_i/\partial \tau_i$, in (S.D.25), necessary to quantify the locational effect in i's (S.D.17). However, under the assumption that the marginal cost of attracting a new household exactly offset the sales and property tax revenues paid by this marginal household, the local locational effect is zero, whatever the value of the elasticity $\varepsilon_{H,p}$. Under what conditions does the marginal households generate no net cost? This typically occurs if the schooling expenditures are initially completely financed by the household taxes paid by residents, i.e. $\phi n_i g_i - t_i^h p_i n_i - t_i^x x_i n_i = 0$. In this case, marginal households, $\mathrm{d}n_i > 0$, do not generate net government costs. If this assumption holds for i, then it also holds for $j \neq i$.

Second, consider the children's future earning response, $\partial w_i^c/\partial \tau_i$. First, notice that this effect is specific to schooling expenditure, $\mathrm{d}\tau_i = \mathrm{d}g_i$, and can legitimately be ignored for most other local policies, including property tax cuts, $\mathrm{d}\tau_i = \mathrm{d}t_i^h$. Now, focusing on schooling expenditure, in which case can $\partial w_i^c/\partial g_i$ be ignored in the computation of the local MVPF? Inspection of the all the effects in (S.D.2) indicates that given that localities do not tax labor income, the future earning response is only necessary to compute the local behavioral effect (S.D.15). Indeed, higher earnings spur the children to consume more as adult and thus pay more sales taxes, which reduces the intertemporal net government cost. However, in practice, the sales tax rates of localities are usually particularly low (often zero) in the U.S. and in most other countries sales are not taxed at the local level. Most localities in the U.S. also do not have access to an income tax. It follows that if the interest is on one of these numerous localities with no sales tax, the earning response, $\partial w_i^c / \partial \tau_i$, does not enter the computation of the local MVPF. Again, this also holds for the external effects on other localities.

Last, obviously, the property tax rate reaction in j, $\partial t_j^h / \partial t_i^h$, is an external effect which therefore does not enter the computation of the local MVPF.

In sum, the local housing price elasticity with respect to the policy is a sufficient statistics for assessing the local MVPF and the external effects on other localities if (1) the local taxes paid by the households fully finance the public services they use, and (2) the locality does not tax sales.

But, to calculate the social MVPF, we also need to know the effect on state and federal income tax revenues. Obviously, states and federal governments rely more heavily on these taxes, breaking the link with house prices and tax revenues. Thus, to calculate the federal fiscal externalities, one also needs a program evaluation of the effect of school policies on earnings. The literature is filled with numerous examples and the recent literature has also identified the mobility patterns of college graduates in order to precisely determine the appropriate average tax rate.

S.D.4. A Framework for Higher Education Scholarship Programs

The higher education spending application (Section 6.1) differs from the K-12 application (Section 6.2) in two significant dimensions.

Firstly, unlike the K-12 application which is interested in a spending directly affecting the amount of provided public goods/services (e.g. increase in the size of a school or hiring of new teachers), the higher education spending is a cut in tuition fees provided to students. Although these two spendings may induce many similar *indirect* effects: on housing prices, on earnings, and consequently on government budget, their direct effects are substantially different. The effect of the K-12 public good provision on the WTP is not directly observable and needs to be deduced in directly from housing price capitalization as described in Supplementary Material S.D.2. In contrast, the effect of a cut in tuition fee on the beneficiaries' willingness to pay is directly observable: the amount of dollars saved per student.

Secondly, while our K-12 application does not apply to a particular geography or historical reform, the higher example described in Section 6.1 represents a the specific cut in tuition fee that occurred in the community college of Austin in Texas. As we have access to a detailed school-district-level dataset for the treated and non-treated districts, we do not need to assume a two-jurisdiction economy as in the K-12 application. Instead, adapting our general framework, we are able to compute local MVPFs, social MVPFs and MCTs that account for this stong heterogeneity. More generally, this higher education application shows how our MVPF and MCT formulas can easily be taken to real datasets incorporating a lot of heterogeneity.

Thus, the theoretical framework described in Supplementary Material S.D.1 cannot be applied to this higher education spending program directly. Hereafter, we describe in detail how our general framework (Section 2) must be adapted to study the effect of a cut in tuition fees like the one that occurred in Texas. We also explain how each subeffect is quantified.

S.D.4.1. The Economy

The districts in the MSA are indexed by $k \in \mathcal{A}$, where $\mathcal{A}$ is the set of districts in the MSA. Let $\mathcal{L}$ denote the set of treated districts which benefit from the cut in tuition fee, indexed by $i \in \mathcal{L}$, and denote $\mathcal{E}$ the set of non-treated districts of the MSA, indexed by $j \in \mathcal{E}$. In the annexed districts, $i \in \mathcal{L}$, n_i^S is the total number of students, $\mathrm{d}n_i^S$ is number of students induced to go to community college by the policy, $\mathrm{d}n_{iA}^S$ is the number of students induced to go to college by the policy and who stay and work in the annexed areas after graduation.

Like in the K-12 application, we assume that rental properties are owned according to the shares θ_{ij}^h described in Table D.1. We have explored sensitivity to the assumptions of polar cases including all absentee landlords outside of the MSA and all owner-occupied housing in the MSA.

Hereafter, we investigate the effects of a dollar cut in the tuition fee. We assume that each student in the treated school districts benefited from a tuition reduction of $\mathrm{d}\overline{\tau} = \mathrm{d}\tau / \sum_i n_i^S$. In Denning (2017), the causal effects estimated are for a \$1000 change, but the change in tuition in Austin (after accounting for financial aid) was large. Thus, we let $\mathrm{d}\tau$ be the estimate \$1,540 reduction they received (Table E.2), which we rescale so that the total mechanical cost of the policy is normalized to one dollar. Again, this rescaling does not alter the values of the MVPFs, MCTs and match rate, it only aims at making the different sub-effects comparable to other applications.

S.D.4.2. Local MVPF

The local MVPF of the treated districts from a cut in tuition fee of $\mathrm{d}\tau$ dollars is:

$$LMVPF = \frac{LWTP}{LNGC} = \frac{\sum_{i \in \mathcal{L}} (\mathrm{DE}^i + \mathrm{IE}^i + \mathrm{OE}^i)}{\sum_{i \in \mathcal{L}} (\mathrm{ME}^i + \mathrm{BE}^i + \mathrm{PE}^i)} \tag{S.D.28}$$

in which the numerator is the sum of the willingness to pay of the treated districts $i \in \mathcal{L}$ and the denominator is the sum of their net government costs. The different effects are described below.

S.D.4.2.1 Local Marginal Willingness to Pay

The local marginal WTP includes the direct effect on each treated school district $i \in \mathcal{L}$:

$$\text{DE}^i = n_i^S \times \mathrm{d}\overline{\tau} + (\mathrm{d}w - \mathrm{f})\frac{\mathrm{d}n_i^S}{\mathrm{d}\tau} \times \mathrm{d}\overline{\tau} \tag{S.D.29}$$

which includes two direct benefits. The first is the saved tuition fees for the n_i^S students living in the treated district already involved in college. Aggregating over all the treated districts, this effects is $\sum_{i\in\mathcal{L}} n_i^S \times \mathrm{d}\overline{\tau} = \$1$ which is equal to the direct expenditure of the program, as expected. The second benefit is the wage gain for the $\mathrm{d}n_i^S$ students involved in college because of the program: $(\mathrm{d}w-\mathrm{f})\sum_{i\in\mathcal{L}}(\mathrm{d}n_i^S/\mathrm{d}\tau)\times\mathrm{d}\overline{\tau} = \$2.72$, where $\mathrm{d}w$ is the wage gain and f is the student's contribution to tuition. This wage change is a change in earnings from the treatment of marginal individuals, this is not the incidence on wages in our income effect. In sum, the local direct effect is $\sum_{i\in\mathcal{L}} \text{DE}^i = \$3.72$.

Given, we have included the direct benefit of the program, including all of the capitalization effects would be double counting. However, as the rise in rents is a loss of income to renters, we must account for this portion. The disposable income effect in district $i \in \mathcal{L}$ is:

$$\text{IE}^i = -n_i^r \frac{\mathrm{d}p_i^r}{\mathrm{d}\tau} \times \mathrm{d}\overline{\tau} \tag{S.D.30}$$

which is the reduction in the n_i^r renters' disposable income effect due to the increase in the rent, $\mathrm{d}p_i^r/\mathrm{d}\tau$, resulting from the greater attractiveness of the treated districts. Aggregating over all the treated districts, we obtain: $\sum_{i\in\mathcal{L}} \text{IE}^i = -\$1.371$. In other words, higher rental prices—prorated for the share of renters—erodes some of the direct benefits of the program.

The ownership effect in district $i \in \mathcal{L}$ is:

$$\text{OE}^i = \left(\sum_{k\in\mathcal{A}} \theta_{ik}(1 - t_k^h - t_{\text{F}}^h) n_k^r \frac{\mathrm{d}p_k^r}{\mathrm{d}\tau} - t_i^h n_i^o \frac{\mathrm{d}p_i^o}{\mathrm{d}\tau}\right) \times \mathrm{d}\overline{\tau} \tag{S.D.31}$$

recalling that θ_i is the share of housing in any district k owned by the residents of district i, the ownership effect states that a change in the housing price of k changes the values of all n_k^r rental properties and thus the income of the landlords who live, in part, in district i. The federal government taxes rental income under the personal income tax but it does not tax increases in homeowner's house values. However, the districts tax both rental and homeowners properties based on their assessed values (included in our definition of the property tax rate t_k^h). We obtain $\sum_{i\in\mathcal{L}} \text{OE}^i = -\$0.949$. This negative ownership effect reflects the fact that as the price of their property increase, homeowners have to pay more property tax. Some of this effect arises from ownership of properties in external—not annexed districts. As the ownership of properties becomes more absentee, such as by out of state commercial firms, this effect declines in magnitude. In sum, the local marginal willingness to pay of the annexed districts for the cut in tuition fee is $LWTP = \$1.399$.

S.D.4.2.2 Local Marginal Net Government Cost

We assume that the costs of the program for students from the annexed district accrue to these communities, via the tax program linked to annexation. If we did not make this assumption and assumed that the costs accrue to the community college district (perhaps the special district is viewed as a higher level of government), then local communities should also want to be annexed as there is no direct cost to them. This is unrealistic, as the cost is passed on via the local taxes raised. The local marginal NGC includes the mechanical effect in district i:

$$\text{ME}^i = n_i^S \times \mathrm{d}\overline{\tau} + c\frac{\mathrm{d}n_i^S}{\mathrm{d}\tau} \times \mathrm{d}\overline{\tau} \tag{S.D.32}$$

which has two sub-effects. The first is the direct expenditure due to cutting the tuition fees. It is the \$1 initial expenditure, $\sum_{i\in\mathcal{L}} n_i^S \times \mathrm{d}\overline{\tau} = \$1$, which is equal to the direct effect on the local WTP. The second part of the mechanical effect is the direct costs due to increased educational attainment, including both the direct costs of the program and the added costs of community college educating another student, $c\sum_{i\in\mathcal{L}}(\mathrm{d}n_i^S/\mathrm{d}\tau) \times \mathrm{d}\overline{\tau} = \$1.339$.[16] The mechanical effect is $\sum_{i\in\mathcal{L}} \text{ME}^i = \$2.339$.

The behavioral effect in district i is:

$$\text{BE}^i = -t_i^x \mathrm{d}x \frac{\mathrm{d}n_{iA}^S}{\mathrm{d}\tau} \times \mathrm{d}\overline{\tau} \tag{S.D.33}$$

which is the additional local sales tax revenue generated by the program. Indeed, the additional students enrolled in college earn higher wages in the future, and thus consume more taxable goods. Aggregating these effects, we obtain $\sum_{i\in\mathcal{L}} \text{BE}^i = -\$0.0021$.

The price effect in the treated district i is:

$$\text{PE}^i = -t_i^h \left(n_i^r \frac{\mathrm{d}p^r}{\mathrm{d}\tau} + n_i^o \frac{\mathrm{d}p_i^o}{\mathrm{d}\tau} \right) \times \mathrm{d}\overline{\tau} \tag{S.D.34}$$

[16] The c term has similarities to the congestion of public services, but we include it in the direct effect here because it is due to added take-up of the program, rather than migration necessarily.

which is the additional property tax revenues collected from the capitalization of the housing prices of both rental properties and homeowners' ones. Aggregating, we obtain $\sum_{i\in\mathcal{L}} \text{PE}^i = -\$1.715$. Summing all these effects, we obtain $LNGC = \$0.622$ and $LMVPF = 2.249$.

S.D.4.3. Social MVPF and MCT

We consider the social MVPF of the state government of Texas, TX, and that of the federal government, F, which are respectively defined as:

$$SMVPF^{\text{TX}} = \frac{LWTP + EWTP^{\text{TX}}}{LNGC + ENGC^{\text{TX}}} \qquad SMVPF^{\text{F}} = \frac{LWTP + EWTP^{\text{F}}}{LNGC + ENGC^{\text{F}}} \tag{S.D.35}$$

S.D.4.3.1 External Marginal Willingness to Pay

The external marginal willingness to pay is the sum of the marginal WTP of all the residents living in non-treated areas in Texas and of those living elsewhere in the federation which are, respectively:

$$EWTP^{\text{TX}} = \sum_{j\in\mathcal{E}} (\text{IE}^j + \text{OE}^j) + \text{OE}^{\text{TX}} \qquad EWTP^{\text{F}} = EWTP^{\text{TX}} + \text{OE}^{\text{F}} \tag{S.D.36}$$

The disposable-income and ownership effects in the non-treated district $j \in \mathcal{E}$ are respectively:

$$\text{IE}^j = -n_j^r \frac{\mathrm{d}p_j^r}{\mathrm{d}\tau} \times \mathrm{d}\overline{\tau}, \qquad \text{OE}^j = \left(\sum_{k\in\mathcal{A}} \theta_{jk}(1 - t_k^h - t_{\text{F}}^h) \frac{\mathrm{d}p_k^r}{\mathrm{d}\tau} n_k^r - t_j^h \frac{\mathrm{d}p_j^o}{\mathrm{d}\tau} n_j^o \right) \times \mathrm{d}\overline{\tau}. \tag{S.D.37}$$

Aggregating over all non-treated districts of the MSA, we obtain $\sum_{j\in\mathcal{E}} \text{IE}^j = \$1.132$ and $\sum_{j\in\mathcal{E}} \text{OE}^j = \$0.532$. Naturally, the sign of the disposable income is now positive because the house rents globally decrease in the non-treated districts. The sign of the external ownership effect is the opposite as the sign of the local ownership effect, because the house prices decrease in the non-treated districts, so that the homeowners have to pay lower property tax rates. Some properties of the MSA are also owned by landlords living elsewhere in Texas who also benefit from an ownership effect $\text{OE}^{\text{TX}} = \$0.0051$. Similarly, landlords living elsewhere in the federation benefit from an ownership effect of $\text{OE}^{\text{F}} = \$0.0165$. In sum, $EWTP^{\text{TX}} = \$1.66854$ and $EWTP^{\text{F}} = \$1.68502$. As in Simon (2021) we assume no external effects on municipalities outside of the MSA.

S.D.4.3.2 External Marginal Net Government Cost

The external marginal net government costs of Texas and of the federal government are respectively:

$$ENGC^{\text{TX}} = \underbrace{\sum_{j\in\mathcal{E}} \text{PE}^j}_{ENGC^{\text{L}}} + \underbrace{\text{BE}^{\text{TX}}}_{\text{VE}^{\text{TX}}}, \qquad ENGC^{\text{F}} = ENGC^{\text{TX}} + \underbrace{\text{BE}^{\text{S}} + \text{PE}^{\text{S}} + \text{PE}^{\text{F}}}_{\text{VE}^{\text{F}}}, \tag{S.D.38}$$

where PE^j is the price effect on property tax revenues of the non-treated district j of the MSA, VE^{TX} is the vertical fiscal externality of the program on the state of Texas; it only includes the behavioral effect BE^{TX} on the sales tax base and not any revenue from higher wages because there is no personal income tax in Texas. In addition to ENGC of Texas, the ENGC of the federal government includes its own vertical fiscal externality VE^{F} on federal income tax revenues from higher wages. In addition, we assume higher level governments care about local governments, so this terms also includes fiscal effects in other states, including income tax changes from newly induced college students moving there as well as added sales tax revenue from those movers.

The first component of the marginal NGC of Texas is the marginal NGC of the non-treated districts of the MSA, $ENGC^{\text{L}}$, which is the effect of house price changes on their tax revenues. Specifically, the price effect on a non-treated district $j \in \mathcal{E}$ in the MSA is:

$$\text{PE}^j = -t_j^h \left(n_j^r \frac{\mathrm{d}p_j^r}{\mathrm{d}\tau} + n_j^o \frac{\mathrm{d}p_j^o}{\mathrm{d}\tau} \right) \times \mathrm{d}\overline{\tau} \tag{S.D.39}$$

that is, the property tax revenues district j looses because of the cut in property values there. Aggregating, we obtain: $\sum_{j\in\mathcal{E}} \text{PE}^j = \$1.12057$ which is a positive government cost.

In addition to the external marginal NGC of the districts of the MSA, the program allows the state of Texas to collect sales tax revenues as stated in:

$$\text{BE}^{\text{TX}} = -\sum_{i\in\mathcal{L}} \left(t^x_{\text{TX}} \mathrm{d}x \frac{\mathrm{d}n^S_{iA}}{\mathrm{d}\tau} + t^x_{\text{TX}\notin A} \mathrm{d}x \frac{\mathrm{d}n^S_{i,\text{TX}\notin A}}{\mathrm{d}\tau} \right) \times \mathrm{d}\overline{\tau} \tag{S.D.40}$$

which results from some of the students who took up the program—and thus enjoy an increase in their earnings—also moving outside of the Austin area, consuming $\mathrm{d}x$ more, and paying local and state sale taxes. They also pay the local sales taxes to those other municipalities. Of course, those individuals who stay in the metro area also pay sales taxes. Thus, each of the $\mathrm{d}n^S_{iA}$ students who stay and work in Austin pays $t^x_{\text{TX}}\mathrm{d}x$ to the state of Texas. Similarly, each of the $\mathrm{d}n^S_{i,\text{TX}\notin A}$ students who work in Texas outside of Austin pays $t^x_{\text{TX}\notin A}\mathrm{d}x$ to the state of Texas and the locality she settles in. We compute that this behavioral effect amounts to $\textsc{be}^{\textsc{tx}} = -\$0.05995$, so that the external marginal NGC of the state of Texas is $ENGC^{\textsc{tx}} = 1.06062$. It follows that the social MVPF of the Texas is $SMVPF^{\textsc{tx}} = 1.82291$, $MCT^{\textsc{tx}} = -22.7\%$ and its match rate is $M^{\textsc{tx}} = -0.185$.

Let us now turn to the federal government. The federal vertical fiscal externality of the program includes the same behavioral effects from added sales tax revenue in states other than Texas, resulting from people induced to go to college moving there:

$$\textsc{be}^{\textsc{s}} = -\sum_{i\in\mathcal{L}} t^{x}_{\textsc{s}\notin\textsc{tx}} \mathrm{d}x \frac{\mathrm{d}n^{S}_{i,\textsc{s}\notin\textsc{tx}}}{\mathrm{d}\tau} \times \mathrm{d}\overline{\tau} \tag{S.D.41}$$

which have the same interpretation as the behavioral effect of the state of Texas above; only the tax rates and number of students differ. We measure a small behavioral effect of $\textsc{be}^{\textsc{s}} = -\$0.0151385$, because only few students leave Texas.

Unlike Texas, other states levy income taxes, so that they will be able to tax the earning increase, $\mathrm{d}w$, of the $\sum_{i\in\mathcal{L}} \mathrm{d}n^{S}_{i,\textsc{s}\notin\textsc{tx}}$ students who benefited from the program and will locate there as workers. This gives rise to the following price effect:

$$\textsc{pe}^{\textsc{s}} = -\sum_{i\in\mathcal{L}} t^{\ell}_{\textsc{s}\notin\textsc{tx}} \mathrm{d}w \frac{\mathrm{d}n^{S}_{i,\textsc{s}\notin\textsc{tx}}}{\mathrm{d}\tau} \times \mathrm{d}\overline{\tau} \tag{S.D.42}$$

which is equal to $\textsc{pe}^{\textsc{s}} = -\$0.026341$. Similarly, the federal government also taxes these additional labor earnings. However, in addition, it will collect tax revenues from its income tax $t^{h}_{\textsc{f}}$ on rental income even if those landlords live in Texas. This is summarized in the price effect:

$$\textsc{pe}^{\textsc{f}} = -\sum_{i\in\mathcal{L}} \left(t^{\ell}_{\textsc{f}} \mathrm{d}w \frac{\mathrm{d}n^{S}_{i}}{\mathrm{d}\tau} + t^{h}_{\textsc{f}} n^{r}_{i} \frac{\mathrm{d}p^{r}_{i}}{\mathrm{d}\tau} \right) \times \mathrm{d}\overline{\tau} \tag{S.D.43}$$

which amounts to a price effect of $\textsc{pe}^{\textsc{f}} = -\$0.662904$. The external marginal NGC of the federal government is $ENGC^{\textsc{f}} = 0.35624$, its social NGC is $SNGC^{\textsc{f}} = 0.978433$. The social MVPF of the federation is $SMVPF^{\textsc{f}} = 3.15$, its MCT is $MCT^{\textsc{f}} = 28.66\%$ and its match rate is $M^{\textsc{f}} = 0.4018$.

Supplementary Material S.E
MCT and Hierarchical Governments

This appendix discusses the relationship between the marginal corrective transfer and other common transfers. Supplementary Material S.E.1 discusses multi-level transfers in hierarchical federal systems.

S.E.1. Multi-Level Transfers

The empirical applications in Section 6 often assume that either the state or the federal government unilaterally provide the MCT to the locality. The presence of a single higher level government might be reasonable for state-federal relationships, but when local governments set policies they may receive transfers from both the state and federal government. However, as each of these higher government levels have specific interjurisdictional externalities to internalize, it is likely that these two governments will both provide different MCTs to the locality. Thus, if both the state and federal government provide simultaneously MCTs to the locality without accounting for each others' MCTs, the locality would clearly not be provided with the correct incentive to internalize the state or federal externalities. Formally, this sub-optimal pattern can easily be understood. Denote $S^{\text{FL}}_{\tau_i}$ as the grant provided by the federal government to the locality and denote $S^{\text{SL}}_{\tau_i}$ the grant from the state to the locality. These two grants are characterized respectively by:

$$\frac{LWTP_{\tau_i}}{LNGC_{\tau_i} - S^{\text{FL}}_{\tau_i}} = SMVPF^{\text{F}}_{\tau_i}, \qquad \frac{LWTP_{\tau_i}}{LNGC_{\tau_i} - S^{\text{SL}}_{\tau_i}} = SMVPF^{\text{S}}_{\tau_i}, \tag{S.E.1}$$

where $SMVPF^{\text{S}}_{\tau_i}$ is the MVPF of the state and $SMVPF^{\text{F}}_{\tau_i}$ is the MVPF of the federation. By choosing their subsidies according to (S.E.1) the state and the federal government each erroneously believes it is the only grant provider to the locality. Yet, the locality receives two grants and its corrected MVPF is actually:

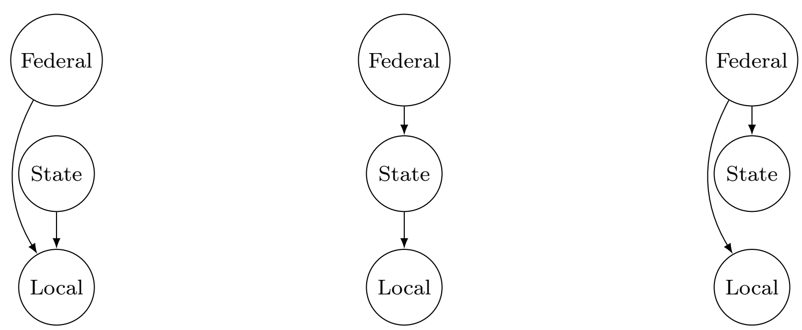
$$\frac{LWTP_{\tau_i}}{LNGC_{\tau_i} - S^{\text{FL}}_{\tau_i} - S^{\text{SL}}_{\tau_i}} \tag{S.E.2}$$

which will, in general, differ both from $SMVPF^{\text{F}}_{\tau_i}$ and $SMVPF^{\text{S}}_{\tau_i}$, as $S^{\text{FL}}_{\tau_i}$ and $S^{\text{SL}}_{\tau_i}$ are chosen according to (S.E.1). This transfer pattern is clearly a sub-optimal outcome both for the state and for the federal government as it does not induce the locality to set the policy such that the MVPF is equal to either the state or federal social valuation; it is represented in Figure S.E.1a.

In particular, this double subsidy scheme is socially (i.e. federally) sub-optimal. However, there is no reason for the federal government to systematically ignore the state's transfer to the locality when setting its policy. Instead, the federal government could provide the state with a transfer that induces the state to provide a socially optimal transfer to the locality. In this appendix, we describe two such configurations that achieve this goal.

The first configuration is depicted in Figure S.E.1b. The federal government can let the state be the only level of government that directly provides the MCT to the locality, but the federal government provides the state with a federal-to-state MCT which spurs the state to choose a socially optimal level of state-to-local MCT. For example, the federal-to-state MCT could be designed as a match rate on the state-to-local match rate. In other words, the federal MCT is a match on the state match rate.

The second configuration is depicted in Figure S.E.1c. The federal government can choose to mute the state, by providing it with a federal-to-state transfer which induces it to not provide any funds to the local government. Then, the federal government can provide the socially optimal MCT directly to the local government.



(a) Sub-optimal transfer pattern: double transfer to the locality.

(b) Optimal transfer pattern: (1) from the federal to state and (2) from the state to the locality.

(c) Optimal transfer pattern: from the federal government (1) to the state and (2) to the locality.

Figure S.E.1. Different transfer patterns in a hierarchical federal system.

S.E.1.1. Chain Transfers: MCT^{FS} and MCT^{SL}

Consider the transfer pattern represented in Figure S.E.1b which represents a "chain transfer" in which the federal government provides a MCT to the state, $MCT^{\text{FS}}_{\tau_i}$, and the state provides a MCT to the locality, $MCT^{\text{SL}}_{\tau_i}$. To determine the expressions of these MCTs, let us denote by $S^{\text{SL}}_{\tau_i}$ the transfer from the state to the locality, which equalizes the local MVPF to the state MVPF (inclusive of the federal-to-state subisdy). And, let us denote by $S^{\text{FS}}_{\tau_i}$ the transfer from the federal government to the state, which equalizes the state MVPF to the federal MVPF, $SMVPF^{\text{F}}_{\tau_i}$. In sum, the marginal subsidies (or taxes) $S^{\text{SL}}_{\tau_i}$ and $S^{\text{FS}}_{\tau_i}$ are characterized by:

$$\frac{LWTP_{\tau_i}}{LNGC_{\tau_i} - S^{\text{SL}}_{\tau_i}} = \frac{SWTP^{\text{S}}_{\tau_i}}{SNGC^{\text{S}}_{\tau_i} - S^{\text{FS}}_{\tau_i}} = SMVPF^{\text{F}}_{\tau_i}. \tag{S.E.3}$$

That is, the federal-to-state transfer, $S^{\text{FS}}_{\tau_i}$, is chosen by the federal government so that the federal MVPF, $SMVPF^{\text{F}}_{\tau_i}$ is equal to the state corrected MVPF, $SWTP^{\text{S}}_{\tau_i}/(SNGC^{\text{S}}_{\tau_i} - S^{\text{FS}}_{\tau_i})$. And the state-to-local transfer, $S^{\text{SL}}_{\tau_i}$, is chosen by the state (after accounting for the federal-state transfer) so that the local corrected MVPF, $LWTP_{\tau_i}/(LNGC_{\tau_i} - S^{\text{SL}}_{\tau_i})$, is equal to the state corrected MVPF, $SWTP^{\text{S}}_{\tau_i}/(SNGC^{\text{S}}_{\tau_i} - S^{\text{FS}}_{\tau_i})$.

Equations (S.E.3) allow us to immediately determine the expressions of the state-to-locality MCT, MCT^{SL}, and that of the federation-to-state MCT, MCT^{FS}. From equation (S.E.3), we have:

$$\frac{LWTP_{\tau_i}}{LNGC_{\tau_i} - S^{\text{SL}}_{\tau_i}} = SMVPF^{\text{F}}_{\tau_i} \iff MCT^{\text{SL}}_{\tau_i} = \frac{S^{\text{SL}}_{\tau_i}}{LNGC_{\tau_i}} = 1 - \frac{LMVPF_{\tau_i}}{SMVPF^{\text{F}}_{\tau_i}}. \tag{S.E.4}$$

This indicates that the state-to-local MCT is induced to become the standard federal-to-local MCT defined in the paper. This is not surprising because the federal government's transfer to the state precisely aims to spur the state to provide the socially optimal MCT by implicitly providing the state with appropriate fund to induce it to choose this transfer.

Moreover, from equation (S.E.3), we also have:

$$\frac{SWTP^{\text{S}}_{\tau_i}}{SNGC^{\text{S}}_{\tau_i} - S^{\text{FS}}_{\tau_i}} = SMVPF^{\text{F}}_{\tau_i} \iff MCT^{\text{FS}}_{\tau_i} = \frac{S^{\text{FS}}_{\tau_i}}{SNGC^{\text{S}}_{\tau_i}} = 1 - \frac{SMVPF^{\text{S}}_{\tau_i}}{SMVPF^{\text{F}}_{\tau_i}}, \tag{S.E.5}$$

which reveals a new particularly intuitive formula. In a hierarchical system, the optimal transfer from the federal government to the state government is simply the relative "wedge" between the social MVPF of the federation and the social MVPF of the state.

Federal match rate on the state match rate. In practice, there may be a strong institutional link between $MCT^{\text{SL}}_{\tau_i}$ and $MCT^{\text{FS}}_{\tau_i}$: the match rate of the federal-to-state subsidy is based on the match rate of the state-to-local subsidy. Let us see how to define such a federal match rate on the state match rate, denoted m^{FS}. From equation (22) (Section 4.1), we know that:

$$M^{\text{SL}}_{\tau_i} = \frac{MCT^{\text{SL}}_{\tau_i}}{1 - MCT^{\text{SL}}_{\tau_i}}, \tag{S.E.6}$$

is the expression for the match rate of the state to the local government: for each dollar spent by the local government, the state gives M^{SL} extra dollars to finance the project of the locality. Similarly, we have:

$$M^{\text{FS}}_{\tau_i} = \frac{MCT^{\text{FS}}_{\tau_i}}{1 - MCT^{\text{FS}}_{\tau_i}}, \tag{S.E.7}$$

as the expression for the match rate of the federal government to the state: for each dollar spent by the state government the federal government gives $M^{\text{FS}}_{\tau_i}$ extra dollars to finance the project of the locality. It follows that the match rate of the federal government on the match rate of the state government, $m^{\text{FS}}_{\tau_i}$, is denied as:

$$(1 + m^{\text{FS}}_{\tau_i}) \equiv \frac{M^{\text{FS}}_{\tau_i}}{M^{\text{SL}}_{\tau_i}} \iff m^{\text{FS}}_{\tau_i} = \frac{M^{\text{FS}}_{\tau_i} - M^{\text{SL}}_{\tau_i}}{M^{\text{SL}}_{\tau_i}}. \tag{S.E.8}$$

In other words, under this system of hierarchical transfers, the federal-state transfer can be viewed as a match on the state's match that induces the state to set the socially optimal transfer rather than the one that is in the interest of the state.

S.E.1.2. Mute the State: MCT^{FS} and MCT^{FL}

Now, consider the transfer pattern represented in Figure S.E.1c which represents a two-part federal transfer. The first part is a federal-to-local subsidy, $S^{\text{FL}}_{\tau_i}$, which is simply the socially optimal MCT to the locality. And the second part is a federal-to-state subsidy, $S^{\text{FS}}_{\tau_i}$, which aims at muting the state so it has no incentive to provide any state-to-local transfer. Formally, these two marginal subsidies are respectively defined by:

$$\frac{LWTP_{\tau_i}}{LNGC_{\tau_i} - S^{\text{FL}}_{\tau_i}} = SMVPF^{\text{F}}_{\tau_i}, \qquad \frac{LWTP_{\tau_i}}{LNGC_{\tau_i} - S^{\text{FL}}_{\tau_i}} = \frac{SWTP^{\text{S}}_{\tau_i}}{SNGC^{\text{S}}_{\tau_i} - S^{\text{FS}}_{\tau_i}}. \tag{S.E.9}$$

Interesting, these transfers are quantitatively equivalent to those derived in the above chain-transfer case. To make this clear, notice that (S.E.9) is equivalent to:

$$\frac{LWTP_{\tau_i}}{LNGC_{\tau_i} - S^{\text{FL}}_{\tau_i}} = \frac{SWTP^{\text{S}}_{\tau_i}}{SNGC^{\text{S}}_{\tau_i} - S^{\text{FS}}_{\tau_i}} = SMVPF^{\text{F}}_{\tau_i}. \tag{S.E.10}$$

This is identical to (S.E.3) with the exception that, as expected, the state-to-local transfer is simply replaced by the federal-to-local transfer. Notice that these two alternative transfers are equal, which reflects the fact that the transfer received by the locality is socially optimal both in the chain-transfer case and in the two-part-transfer case.

Finally, by analogy, the MCT formulas (S.E.4) and (S.E.5) can also be directly extended as:

$$MCT^{\text{FL}}_{\tau_i} = \frac{S^{\text{FL}}_{\tau_i}}{LNGC_{\tau_i}} = 1 - \frac{LMVPF_{\tau_i}}{SMVPF^{\text{F}}_{\tau_i}}, \tag{S.E.11}$$

$$MCT^{\text{FS}}_{\tau_i} = \frac{S^{\text{FS}}_{\tau_i}}{SNGC^{\text{S}}_{\tau_i}} = 1 - \frac{SMVPF^{\text{S}}_{\tau_i}}{SMVPF^{\text{F}}_{\tau_i}}, \tag{S.E.12}$$

Interestingly, compared to the chain-transfers MCTs, the federal government provides the exact same MCT to the state: indeed, (S.E.5) and (S.E.12) are strictly identical. The only distinction is in terms of the distribution of the public resources involved by each government. In both cases, the state receives the same grant from the federal government and the locality receives the same grant either from the state (chain-transfer case) or from the federal government (two-part-grant case). Thus, the only difference is who the locality receives its grant from, that is, who pays for it.

S.E.1.3. An Example

To make these two different schemes transparent, let us consider a numerical example. in which $LWTP_{\tau_i} = 10$, $LNGC_{\tau_i} = 30$, $SNGC^{\text{S}}_{\tau_i} = 10$, , $SWTP^{\text{S}}_{\tau_i} = 30$, and $SMVPF^{\text{F}}_{\tau_i} = 30$. It follows that under chain-transfer the case, we have:

$$S^{\text{FL}}_{\tau_i} = 0, \qquad S^{\text{SL}}_{\tau_i} = 29.7, \qquad S^{\text{FS}}_{\tau_i} = 9,$$

so that for each unit of marginal policy $d\tau_i$, the locality receives \$29.7 among which \$9 are simply transferred by the state from the federal budget to the locality; and $29.7 - 9 = 20.7$ dollars are direct expenditure from the state budget to the locality.

However, under the two-part-grant case, we have:

$$S^{\text{FL}}_{\tau_i} = 29.7, \qquad S^{\text{SL}}_{\tau_i} = 0, \qquad S^{\text{FS}}_{\tau_i} = 9,$$

so that the locality still receives \$29.7 however it receives it directly from the federal budget. Now, the state receives a positive subsidy of \$9 from the federal budget to make sure the state does not distort the locality's incentive with a state subsidy. In this second scenario, the large expenditure from the federal government (\$29.7) suggests that residents outside of the state are more likely to contribute a significant amount to the local program. The example makes it clear that the two different approaches have different distributional effects in terms of who pays for the transfers (state residents vs. out-of-state residents).

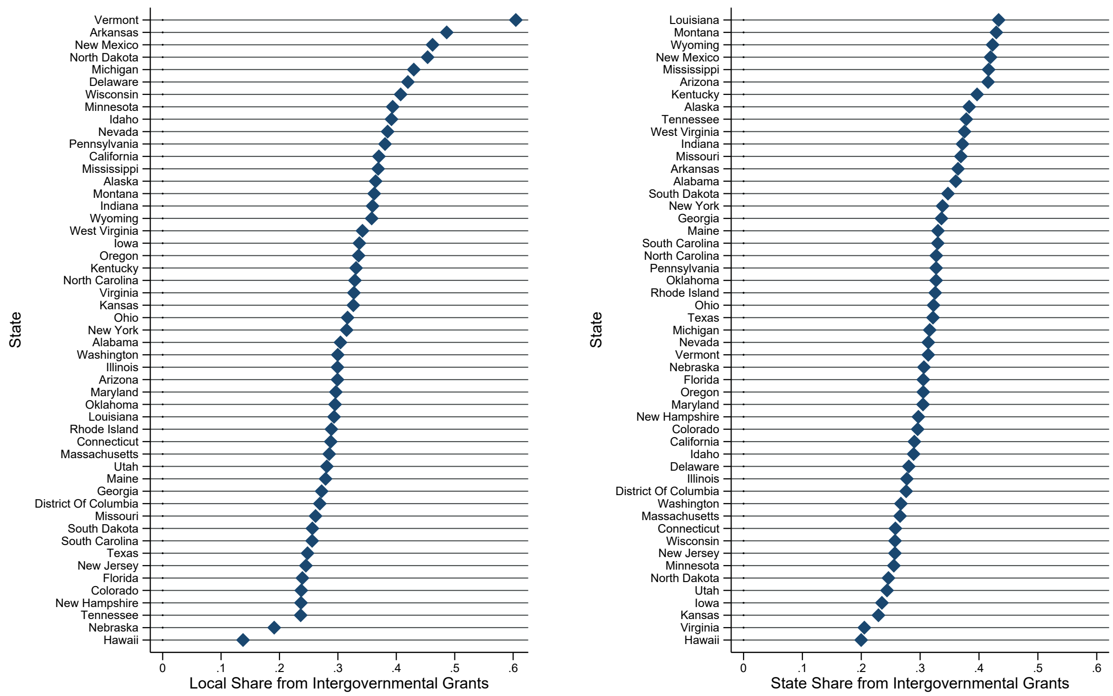
Supplementary Material S.F

State Institutions

In this section, we show additional results from our state institutional analysis. Supplementary Material S.F.1 describes intergovernemntal transfers in the U.S.

S.F.1. Stylized Facts Regarding Intergovernmental Transfers

Intergovernmental transfers are an important part of federal and state spending. In particular, states and localities obtain substantial resources from other levels of government. Using the 2017 Census of Governments, we construct measures of intergovernmental transfers as a share of revenue. Figure S.F.1a shows intergovernmental grants as a share of total revenue and Figure S.F.1b shows federal transfers to the states as a share of total state revenues.



(a) Grants as a Share of Local Revenue

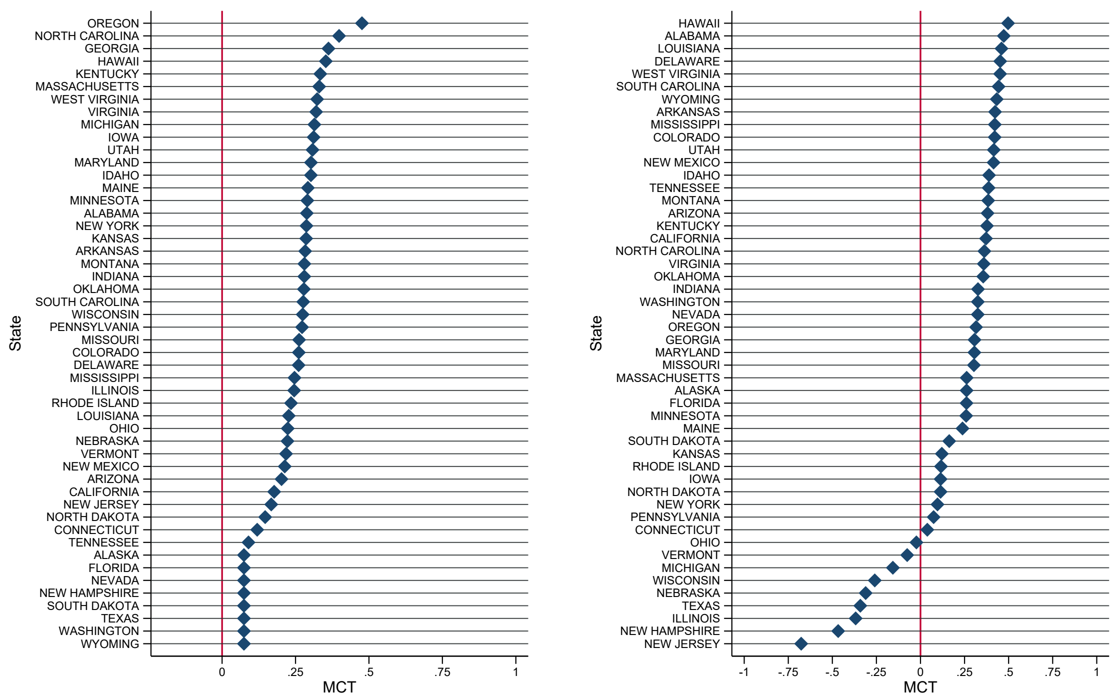
(b) Grants as a Share of State Revenue

Figure S.F.1. Importance of Intergovernmental Grants.

Notes: This figure uses Census of Government data to calculate federal grants to the states as a share of state revenue and total grants to localities from the federal or state governments as a share of local revenue.

S.F.2. State Institutions and the MCT

Figure S.F.2 shows how the state level MCT differs if we perturb only one tax rate within a state, holding constant all other taxes at the national average. We first adjust the state income tax rate applied to the life-cycle of increased earnings from spending more on K-12 education, as calculated using NBER TAXSIM. Next, we change the (weighted) average property tax rate in the state. To do this we use U.S. Census data to calculate the effective property tax rate by dividing aggregated property tax payments by aggregated reported house valuations in the state. It is well-known that households generally over-report the valuation of their properties in the U.S. Census, so we use the adjustment factors in Twait and Haveman (2015) to adjust these effective tax rates upward. In both of these figures, we hold constant all other taxes and prices across states.

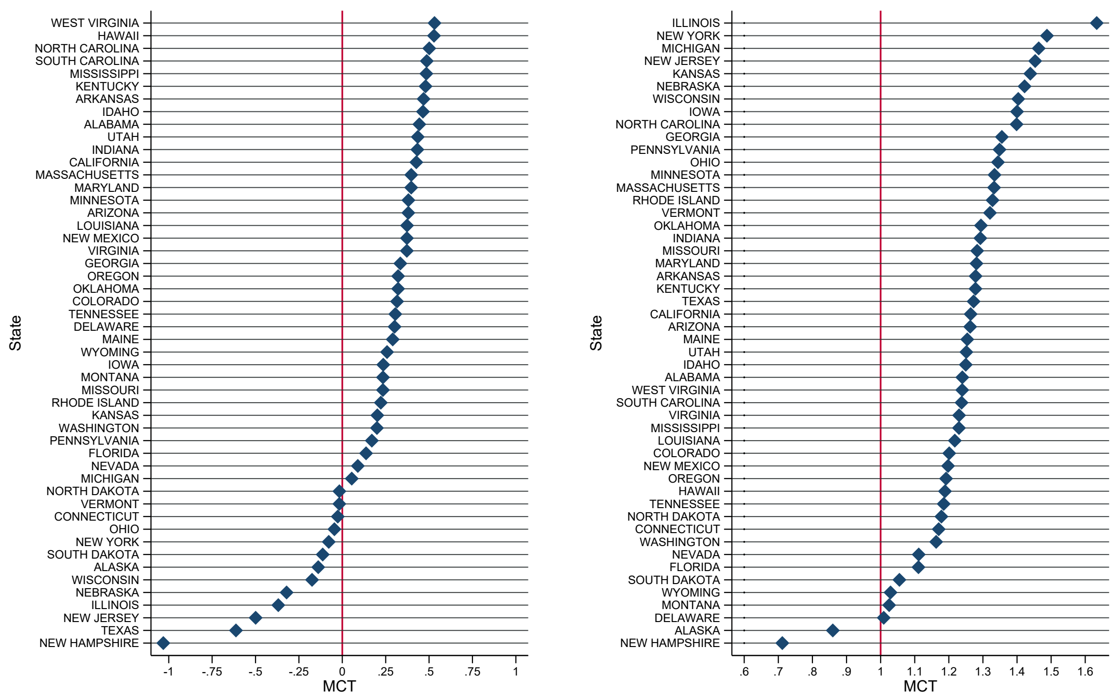


(a) State MCT Allowing Income Taxes to Vary **(b)** State MCT Allowing Property Taxes to Vary

Figure S.F.2. How the K-12 MCT Changes if One State Tax Policy Changes
Notes: The first panel shows how the MCT for K-12 education spending varies by state depending on the observed income tax rate in the state, holding constant all other taxes. The second panel shows how the MCT for K-12 education spending varied by state depending on the observed property tax rate in the state, holding constant all other taxes in the state. We assume the property tax rate applies to all municipalities in the state.

Next, Figure S.F.3, shows the states ranked by the MCT calculated if all state institutions (local sales taxes, state sales taxes, local property taxes, and state income taxes) are allowed to vary. The left panel plots the state MCT, while the right panel plots the federal MCT. Recall that because the

LMVPF varies, the federal MCT will also vary because it is the wedge between the federal MVPF and the local MVPF of the jurisdiction enacting the policy. For most states the federal MCT is greater than unity, implying no finite match rate exists to internalize the spillovers. However, as noted in the main text, if the ratio EWTP/LWTP is constant, the MCT can be used to prioritize policies, in this case, the state to which the federal government can earmark education funds toward. In this case, the EWTP/LWTP is approximately constant—differing slightly across states due to the after-tax income effects of landlords differing due to differences in state taxes. Given that this variation in WTP is dwarfed by that of net government costs, the ranking in the figure can be used by the federal government to determine which states should receive more or less education funding.



(a) State MCT

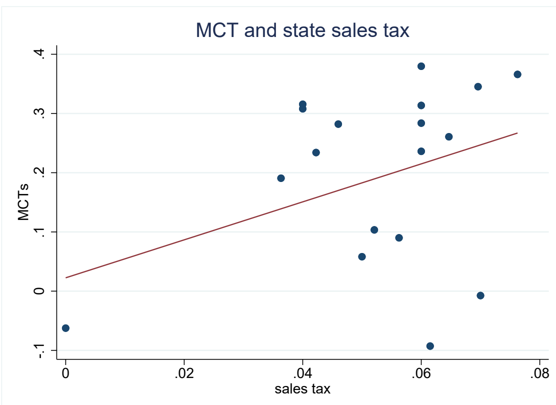
(b) Federal MCT

Figure S.F.3. How the K-12 MCT Changes if All State Tax Policies Change

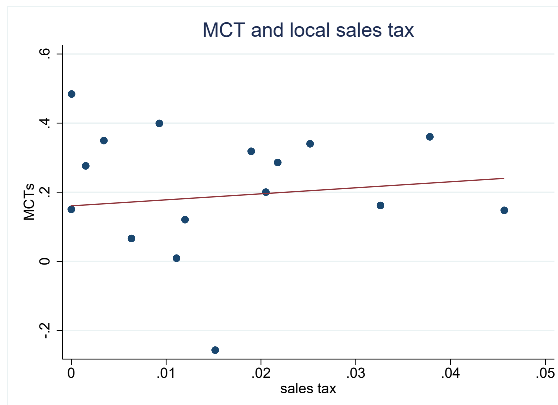
Notes: This figure allows all state policies on income, sales, and property taxes to change simultaneously. The left panel then plots the state MCT while the right panel plots the federal MCT.

An important thing to note is that high-income tax rates should not be conflated with progressivity of the state tax system. Although some states have very progressive tax rates, they may still have relatively low tax rates applied to the added wages from additional education spending. The reason is that state income taxes apply to the typical student receiving K-12 educational benefits and not necessarily to the highest earning workers. Thus, the shape of the tax function lower in the income distribution and not at the top of the distribution is critical.

Figure S.F.4 is analogous to the binned scatter plots in the main text, showing the correlation of the state level MCT with the state sales tax rate and the local sales tax rate. Higher state taxes are again positively correlated with the MCT. Generally, local taxes and negatively correlated with the MCT but there is no relationship here. In part, this is because local sales taxes are low and apply only to a small share of consumption. As a result, and small negative effect on the MCT is likely not apparent because the local sales tax may be positively correlated with the state rate.



(a) State MCT and State Sales Taxes



(b) State MCT and Local Sales Taxes

Figure S.F.4. MCTs and Observed Higher Level Government Subsidies

Notes: The first panel shows the correlation between the state MCT and observed state sales tax rates. The second panel shows the correlation with the local sales tax rate.

References for the Supplementary Material

Agrawal, David R., Dirk Foremny, and Clara Martínez-Toledano (2024). *Wealth Tax Mobility and Tax Coordination. American Economic Journal: Applied Economics.*

Agrawal, David R. and William H. Hoyt (2018). *Commuting and Taxes: Theory, Empirics, and Welfare Implications. Economic Journal* 128.616, 2969–3007.

Agrawal, David R. and Mohammed Mardan (2019). *Will Destination-based Taxes Be Fully Exploited When Available? An Application to the U.S. Commodity Tax System. Journal of Public Economics* 169, 128–143.

Ahlfeldt, Gabriel M, Stephen J Redding, Daniel M Sturm, and Nikolaus Wolf (2015). *The Economics of Density: Evidence from the Berlin Wall. Econometrica* 83.6, 2127–2189.

Browning, Martin, Pierre-André Chiappori, and Yoram Weiss (2014). *Economics of the Family.* Cambridge University Press.

Buettner, Thiess (2003). *Tax Base Effects and Fiscal Externalities of Local Capital Taxation: Evidence from a Panel of German Jurisdictions. Journal of Urban Economics* 54.1, 110–128.

Denning, Jeffrey T. (2017). *College on the Cheap: Consequences of Community College Tuition Reductions. American Economic Journal: Economic Policy* 9.2, 155–88.

Epple, Dennis and Holger Sieg (1999). *Estimating Equilibrium Models of Local Jurisdictions. Journal of Political Economy* 107.4, 645–681.

Finkelstein, Amy and Nathaniel Hendren (2020). *Welfare Analysis Meets Causal Inference. Journal of Economic Perspectives* 34.4, 146–67.

Gordon, Roger H. and Julie Berry Cullen (2012). *Income Redistribution in a Federal System of Governments. Journal of Public Economics* 96.11-12, 1100–1109.

Haufler, Andreas and Michael Pflüger (2007). *International Oligopoly and the Taxation of Commerce with Revenue-Constrained Governments. Economica* 74.295, 451–473.

Hendren, Nathaniel (2016). *The Policy Elasticity. Tax Policy and the Economy* 30.1, 51–89.

— (2020). *Measuring Economic Efficiency Using Inverse-Optimum Weights. Journal of Public Economics* 187, 104198.

Hendren, Nathaniel and Ben Sprung-Keyser (2020). *A Unified Welfare Analysis of Government Policies. The Quarterly Journal of Economics* 135.3, 1209–1318.

Kanbur, Ravi and Michael Keen (1993). *Jeux Sans Frontières: Tax Competition and Tax Coordination When Countries Differ in Size. American Economic Review* 83.4, 877–892.

Lockwood, Ben (2001). *Tax Competition and Tax Coordination Under Destination and Origin Principles: A Synthesis. Journal of Public Economics* 81, 279–319.

Mirrlees, James A. (1972). *The Optimum Town. Swedish Journal of Economics* 74.1, 114–135.

Poterba, James M. (1992). *Taxation and Housing: Old Questions, New Answers. The American Economic Review* 82.2, 237–242.

Saez, Emmanuel, Joel Slemrod, and Seth H. Giertz (2012). *The Elasticity of Taxable Income with Respect to Marginal Tax Rates: A Critical Review. Journal of Economic Literature* 50.1, 3–50.

Simon, Andrew (Aug. 2021). *Costly Centralization: Evidence from Community College Expansions.* Working Paper.

Twait, Aaron and Mark Haveman (2015). *Evaluating the Accuracy of American Community Survey Data on Housing Values and Property Taxes.* Lincoln Institute of Land Policy.

Wildasin, David (1986). *Spatial Variation of the Marginal Utility of Income and Unequal Treatment of Equals. Journal of Urban Economics* 19, 125–129.