Policy Competition in a Spatial Economy

David R. Agrawal* Tidiane V. Ly† Raphaël Parchet‡

March, 2026

Abstract

We incorporate policy competition among governments into a quantitative spatial model. Our new approach quantifies the interdependence of policymaking among a large number of competing jurisdictions, allowing us to fully characterize an endogenous network of potentially millions of bilateral strategic policy linkages. These linkages are summarized by the "policy impact" of each jurisdiction—the extent to which a jurisdiction changing its policy affects policy choices of others. Policy impact is heterogeneous across jurisdictions and the primary driver of the welfare effects of policy competition. We apply our model to a network of 3,109 U.S. counties competing in local sales taxes and evaluate several centralized interventions aimed at limiting tax competition. We find that (1) tax competition is harmful: federal interventions increase welfare, albeit heterogeneously across places; (2) ignoring endogenous policies from a quantitative spatial model underestimates welfare effects by up to 33%. To explore the underlying mechanisms, we rank counties by the magnitude of their policy impact. We show that interventions targeting high-policy impact jurisdictions raise welfare by six times more than targeting low-tax jurisdictions, the standard focus of minimum tax policies. Although policy impact is endogenous, we document that jurisdiction size acts as a strong proxy. Beyond taxation, our framework for endogenizing policy and analyzing its implications extends to tariffs and trade wars, environmental policy competition, regulatory policies, and spending competition.

Keywords: Quantitative spatial model; Tax competition; Tax havens; Trade; Commodity taxes; Public goods
JEL: H71; H72; F13; R50; R51

*University of California, Irvine, Department of Economics, 3151 Social Science Plaza Irvine, CA 92697-5100. Email: david.agrawal@uci.edu.; phone: 001-949-824-3521. Agrawal is also a Fellow of CESifo.
†Syracuse University, Department of Economics, 508 Eggers Hall, Syracuse, NY 13244 Email: tvly@syr.edu.
‡Institute of Economics (IdEP), Faculty of Economics, Università della Svizzera italiana, Lugano, Switzerland.

We thank Fabian Bald, Michael Baltensperger, Jan Brueckner, Marius Brülhart, Kristy Buzard, Gilles Duranton, Johannes Gaul, Mario Jametti, Priyaranjan Jha, Marcel Henkel, William Hoyt, Antoine Levy, Fernando Parro, Sonia Paty, James Poterba, Frédéric Robert-Nicoud, Stephen Ross, Alexander Rothenberg, Christopher Severen, Perry Singleton, Juan Carlos Suárez Serrato, Farid Toubal, Damian Vergara, Yves Zenou, Miguel Zerecero, conference and seminar participants at INRAE Dijon, the Università della Svizzera italiana, the Institute of Public Finance Conference, National Tax Association, Urban Economic Association. We thank Kenneth Tester for excellent research assistance. Tidiane Ly and Raphaël Parchet gratefully acknowledge funding from the National Bureau of Economic Research and the Swiss National Science Foundation (grant 182380). Researchers' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the NielsenIQ data are those of the researchers and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

1. Introduction

Given trends in globalization, relaxation of border controls and technological changes that enhance factor mobility, understanding the welfare effects of strategic policy setting remains one of the most elusive topics in economics. Paramount to this difficulty is the fact that both government policies and the network of competitors are endogenous. Moreover, spillover effects across jurisdictions are highly heterogeneous, depending on several factors such as size or proximity. The theoretical policy competition literature (Wilson, 1986) has struggled to capture heterogeneous effects due to reliance on symmetric jurisdictions. Quantitative spatial models featuring a public sector and heterogeneity (Fajgelbaum et al., 2019) have yet to incorporate strategic policymaking in a tractable way, especially for a large number of jurisdictions. The empirical literature (Agrawal et al., 2022) has been unable to cope with either problem. We relax and generalize these approaches by building a structural model of endogenous policy competition—applicable to tax, spending, regulatory or tariff policies and trade wars—featuring thousands of heterogeneous local jurisdictions, allowing us to quantify the welfare effects of strategic policymaking and to fully characterize the endogenous network of potentially millions of bilateral strategic policy linkages.

We focus on local policy competition—where many jurisdictions have substantial autonomy over their tax policies, spatial linkages are critical, and taxes are set strategically to attract individuals and firms. Our quantitative spatial model combines elements of the recent trade (Allen et al., 2020) and public finance literature (Suárez Serrato and Zidar, 2016) with the major modification that local government policies are endogenous (Ferrari and Ossa, 2023). Residents decide where and how much to buy of differentiated products that are produced in each jurisdiction. Firms decide where and how much to produce depending on aggregate demand. Local governments use tax and non-tax revenue to provide public services to their residents. They set their tax rates game-theoretically, maximizing the welfare of their residents, accounting for the decisions of firms and households, anticipating the changes in after-tax prices, and strategically reacting to other jurisdictions. Solving each government's optimization problem yields an elegant Ramsey rule that characterizes the equilibrium level of the tax rate and how governments adjust their tax policy following changes in the rest of the economy. We are the first to provide an overall picture of the magnitudes and distributions of all the elements of a Ramsey rule for commodity taxes in an open-economy. This fills the gap in the literature noted in Caliendo and Parro (2022) that optimal policy needs to better match observed policy changes.

We bring the model to the data to match sales tax rates for all U.S. counties, including

those with zero tax rates. Although capital and high-income households are often regarded as being more footloose than consumption, consumption tax competition is economically important and theoretically important (Kanbur and Keen, 1993).[1] Using our Ramsey rule, we compute counterfactual general equilibrium effects of tax coordination policies, allowing local governments to strategically respond to these centralized interventions—an aspect absent in prior structural models. To assess the significance of relaxing this usually invoked assumption, we compare the welfare effects of centralized interventions with and without these responses, and find that they are economically important and highly heterogeneous across space.

Focusing on our baseline counterfactual that imposes a minimum sales tax rate of 2 percentage points, aggregate welfare increases by $21 per capita or 5% of the initial local sales tax burden. This effect is driven mainly by treated counties (counties with an initial rate lower than the minimum) that experience a welfare increase of $30 per capita (8% of their initial local tax burden) arising from both the direct effects of the intervention and any feedback from tax competition—one of the most common forms of endogenous policy setting. On the other hand, non-treated counties, affected only indirectly through economic and policy linkages, gain on average $3 per capita (0.5% of their initial local tax burden). The welfare effects are also heterogeneous across places, with 20% of the population losing from the minimum tax.

Endogenizing local policy setting plays a significant role in the welfare results: 6% of the welfare effects (in absolute value) of the minimum tax are due to endogenous tax setting. This mean effect masks substantial heterogeneity. For jurisdictions in the 95th percentile of the distribution (in absolute value), 29% of the welfare effects are due to endogenous tax setting. The extent to which strategic responses matter varies across jurisdictions, also leading to detrimental effects for some jurisdictions as prices and taxes change simultaneously everywhere. We find that 55% of the population benefit from endogenous policy setting (8% higher welfare) and 45% lose from it (5% lower welfare) on average. At the 95th percentiles of winners and loser, endogenous policy setting contributes to 33% and 19% of the welfare effects, respectively. These results show the importance of accounting for strategic government responses when assessing the welfare effects of interventions. In the context of other types of policy competition—such as the current trade war where strategic responses to a large country tariff can be one-for-one—endogenous policy may play an even larger role than our setting.

[1] A meta study indicates that the taxable elasticity of cross-border retail sales is -1.79 (Huynh et al., 2022). Our data indicates that the mean share of consumption occurring outside of the home county is 33%. This tax base mobility has led to reduced-form evidence that jurisdictions set their taxes strategically to attract shoppers and firms (Agrawal, 2015). Part of the reason for the prominent role of tax competition over consumption is that jurisdictions have market power in retail markets as they often directly affect the tax base of only a small number of jurisdictions, though they can affect many more via price effects.

What would be the optimal intervention to mitigate policy competition? To advance this discussion, we focus on the essence of policy competition: the interdependence of tax setting among a network of local jurisdictions. To do this, we introduce a new concept: the *Policy Network Matrix* (PNM), along with two measures that rank jurisdictions based on the degree of tax competition: Policy Responsiveness and Policy Impact. The PNM elegantly follows from our Ramsey rule, yielding all (endogenous) bilateral tax linkages at the general equilibrium of the economy. It quantifies strategic interactions (best responses) among heterogeneous jurisdictions that set policy under rich and realistic spatial/economic relationships that are not directly observed to the researcher. The bilateral relationships are heterogeneous, with some jurisdictions raising their tax rates and others lowering their tax rates in response to a tax change elsewhere. In our setting, the Policy Network Matrix contains 9 million elements, which are then summarized into two measures: impact and responsiveness.

Drawing inspiration from the network literature, the sum of each row of the PNM measures a county's Policy Responsiveness (PR), capturing the effect of how that county responds to a coordinated tax rate increase of all its competitors. PR generalizes the scalar tax reaction slope coefficient estimated in prior empirical literature (Agrawal et al., 2022). In contrast, the sum of each column of the PNM, Policy Impact (PI), is our preferred measure of competition, characterizing the intensity of linkages among jurisdictions, and has not previously been defined or used in the literature on policy determination.[2] It measures the effect of an increase in the tax rate of that specific county on all the other counties' tax rates—therefore identifying the key players in the tax competition game. These two measures are equal on average, but differ in their distribution: a county might not be influenced by neighboring counties but may trigger large responses in others. We also find that larger jurisdictions have larger policy impact while policy responsiveness is not correlated with size because all individual local jurisdictions are small relative to the entire economy.

Taxes are likely too low as a result of policy competition. Thus, we compare several counterfactual exercises targeting different sub-groups of jurisdictions based on the level of their tax rate and on their PI rank. We show that a federal intervention targeting high-policy impact jurisdictions leads to higher—six times larger—welfare effects than targeting low-tax jurisdictions. Our results suggest that optimal interventions should be designed to focus on key jurisdictions that have the largest effect on the economy as a whole rather than the cur-

[2] Our Policy Impact [Policy Responsiveness] measure relates to out-degrees [in-degrees] in a network as in de Paula et al. (2024), to which we add an intensity measure of the strategic responses. We discuss the relationship between our Policy Impact and different measures of network centrality developed in the literature such as eigenvector centrality, Katz-Bonacich centrality and intercentrality (Ballester et al., 2006).

rent approach of focusing on tax rates (through standard interventions such as minimum taxes and partial harmonization). Contrary to the conventional wisdom that tax havens cause tax competition, high policy impact jurisdictions are the dominant factor influencing the equilibrium. Intuitively, targeting high-policy impact jurisdictions forces many other jurisdictions to change their tax rates, delivering the largest external welfare effects. While policy impact is a complex and endogenous metric, as a practical matter, we show that it is highly correlated with jurisdiction size. As a result, even simple rules that force larger jurisdictions to raise their tax rates relative to smaller jurisdictions improves welfare substantially.

Our paper blends two strands of the literature focusing on public policies: tax competition and quantitative spatial models (Redding and Rossi-Hansberg, 2017). Although recent papers have use quantitative spatial models to determine the welfare effects of decentralization (Suárez Serrato and Zidar, 2016; Fajgelbaum et al., 2019), these models abstract from the fact that policies are chosen strategically in the first place by competing for mobile tax bases. While Ossa (2014), Bagwell et al. (2021), Bordeu (2024) and Ferrari and Ossa (2023) make progress at endogenizing policies for a small number of competing jurisdictions (trade tariffs and subsidies), we advance the literature by developing a tractable approach that allows researchers to study thousands of competing governments. We achieve this by borrowing tools from standard tax competition models that exploit governments' first order conditions and thus optimal policy rules (Zodrow and Mieszkowski, 1986; Wilson, 1986). In addition, our approach allows us to match the observed policy competition equilibrium, facilitating counterfactual analysis when local policies may endogenously respond to the counterfactual intervention. We do so by adding non-tax revenues (public finance amenities) that play an analogous role to urban amenities in quantitative urban economics models (Ahlfedlt et al., 2015).

To bring clarity on endogenous policy determination, it is essential to know the bilateral linkages among jurisdictions that determine the network of competitors. These linkages are highly asymmetric depending on both exogenous fundamentals as well as endogenous outcomes such as prices. Unlike standard quantitative spatial models, we provide the first explicit characterization and quantification of these linkages, introducing a novel method to rank jurisdictions based on their responses and impact along the network. We achieve this by leveraging the optimal policy rule for each jurisdiction as a first-order approximation of the nonlinear general equilibrium of the economy. This offers a structural identification of the network of competitors across thousands of jurisdictions that complements the more reduced-form approach pioneered in de Paula et al. (2024), while adding a measure of the linkage intensity among competitors. Moreover, our endogenous determination of the network advances reduced-form empirical work on policy competition which relies on exogenous and sometimes ad hoc linkages

across jurisdictions (Agrawal et al., 2022).

Unlike the literature characterizing the welfare effects of decentralization that compares the deviation between the observed competitive equilibrium and the allocation by a social planner (Fajgelbaum and Gaubert, 2020 and Gaubert et al., 2024), our approach is relevant for considering small (marginal) changes in decentralization. Policies such as minimum tax rates, partial harmonization and other forms of policy coordination—including tariff treaties and environmental regulations—are widely used in practice. These interventions are most relevant for studying optimal policy design by a federal government or international agencies. Although there exists an analytical literature on the effects of marginal policy interventions (Kanbur and Keen 1993; Hines 2024; Hebous and Keen 2023), we can observationally identify the winners and losers of these interventions.

The existing tax competition literature has extensively studied the effect of the level of the tax rate elsewhere in the economy on the tax setting of a given jurisdiction (Brueckner, 2003). We challenge the conventional wisdom in this literature, including our own work (Agrawal, 2016; Parchet, 2019), that this metric quantifies the intensity of tax competition. Rather, our metric of Policy Impact is the relevant measure to determine the welfare effects of endogenous policies. We document how this metric can be practically implemented by targeting key players in the policy competition game and provide a tractable approach to do so.

Although our application focuses on tax competition, our modeling approach and findings have broader applications. Many public policy settings, among which tariff-setting and trade wars, regulatory competition, bidding for firms (Slattery, 2024), or environmental standards, exhibit similar strategic interactions where focusing on high-impact players can enhance welfare more effectively than uniform rules based on observed policy choices. For instance, in setting minimum wages, targeting low-wage sectors (or local labor markets) might be less effective than focusing on sectors (local markets) whose wage policy exerts large external effects on others. Similarly, in industrial organization or environmental policy, regulations targeting firms that can most influence efficient technology adoption of other firms rather than those firms that simply pollute the most may be more effective. Our model can thus easily be applied or extended to any such policy setting.

Last, beyond public policy, we provide a general approach to quantifying non-linear best-responses in large-scale quantitative game theoretic models with multiple players (Caplin and Nalebuff, 1991), as common in industrial organization, network economics and information economics.

2. Model

Our purpose is to evaluate the welfare effects of interjurisdictional competition in spatial general equilibrium. To this aim, we build a spatial general equilibrium model using the example of commodity tax competition for cross-border shoppers across counties. To appropriately model these forces, we blend tools from trade and public finance. Our model features monopolistic competition and differentiated products as in Krugman (1980), pair-wise commodity flows that are disciplined by trade gravity models as in Allen et al. (2020), public goods and tax rates as in Suárez Serrato and Zidar (2016); Fajgelbaum et al. (2019), and the endogenous determination of those policies as in Ossa (2014); Ferrari and Ossa (2023). A key contribution is to combine these forces to realistically derive a specific optimal tax rule for subnational governments where there are thousands of jurisdictions who set policy in a game theoretic manner while accounting for all of the general equilibrium forces in the prior literature.

2.1. Economy

The economy is composed of J jurisdictions (e.g., counties) indexed by j, and inhabited by a fixed number of n_j identical households with net-of-tax income e_j.[3] The immobility of households facilitates the government maximization problem without specifying whether governments care about only current or future residents and is also inspired by the tax competition literature. Immobility will allow us to characterize policy reactions and welfare effects as a function of jurisdiction size—the most common exogenous factor used to explain tax rates in the prior tax competition literature **?**: bigger jurisdictions set higher tax rates because they perceive lower elasticities. Endogenizing population would require backing it up by an exogenous amenity, which is then harder to link to tax rates for policymakers.

In each county j, there is an endogenous number of m_j identical firms, indexed by $\omega \in \Lambda_j$, each producing a differentiated variety of a taxable commodity q under monopolistic competition.[4] We assume that the only way for a resident of a county j to consume a variety

[3] Extending the framework to include a mobile population is straightforward as, in our case, workers are homogeneous and there is no commuting. In that case, the Ramsey rule can be adapted to account for local governments' anticipation of changes in the number of residents. With heterogeneous workers or commuting, residents within the same jurisdiction benefit differently from the local tax and public services depending on their wages. One must then specify the local government's (redistributive) objective or introduce a voting mechanism, as in Epple and Romer (1991). This can be implemented, for instance, by modeling a sequence of decisions involving (i) tax setting by local governments, (ii) production, consumption, and location choices by the private economy, and (iii) voting (ratification) on tax rates (see Eugster and Parchet, 2019). We do not believe the assumption of immobile populations is critical, given the model features two other sources of heterogeneity: firms can enter and exit and because consumers are mobile in terms of where they buy goods.

[4] Firms are identical unlike in Melitz (2003)-type models, where firm heterogeneity drives market selection

produced in another county i is to do cross-border shopping. A consumer can possibly consume in any county of the federation.[5]

County j levies a commodity tax rate t_j on the variety of good q produced in j. This tax rate might be positive or zero. We consider a sequential game. In stage 1, the counties set their tax rates accounting for the mobility of the tax base, and thus engaging in strategic competition with each other. In stage 2, the private economy operates: nationally mobile investments determine the endogenous creation of local firms, and consumers choose their bundles of goods consumed in possibly all counties. We solve the game backwards.

2.2. Consumers

The representative resident of county j derives utility from consumption of the taxable varieties of good q and the public services provided in their county, $\mathbb{G}_j$, according to:

$$U_j = \left(\sum_i \int_{\Lambda_i} q_{ij}(\omega)^{\frac{\sigma-1}{\sigma}} \mathrm{d}\omega \right)^{\frac{\sigma}{\sigma-1}} \mathbb{G}_j^{\nu}, \tag{1}$$

where $q_{ij}(\omega)$ is the quantity of variety $\omega \in \Lambda_i$ produced in county i consumed by the representative resident of county j. The parameter $\sigma > 1$ is the elasticity of substitution among varieties. Parameter ν governs the marginal willingness to pay for public services.

Each worker inelastically supplies one unit of labor in her county of residence, receiving a wage w_j. She also owns an exogenous endowment, κ_j, of capital that she supplies in the county that provides the highest return.[6] Capital mobility equates the return to capital across counties. As capital will be considered as the numéraire of the economy, the capital return is treated as exogenous and normalized to unity, and the capital market is ignored as it will automatically be clearing at equilibrium due to Walras' Law. Moreover, in line with standard assumptions in models with monopolistic competition and entry (Krugman, 1980), residents are entrepreneurs who establish firms and receive income in return. This income enters the firm's profit function as a fixed cost ρ_j akin to an entry barrier. Thus, the total entrepreneur

based on productivity. As our focus is on governments' strategic interactions rather than firm-level sorting, introducing firm heterogeneity would not change our core insights.

[5] The model does not require cross-border shopping to be the only trade channel. The framework remains fully consistent with a setting where goods are shipped between counties without consumers physically crossing borders. However, due to data limitations, our empirical implementation focuses on cross-border shopping.

[6] Unlike traditional trade models (Allen et al., 2020), our model includes capital which provides three benefits. First, it aligns the model's outcomes with observed *income* distributions. Second, because capital is mobile across jurisdictions, discrepancies between production value and expenditure arise naturally, eliminating the need for ad hoc assumptions to explain trade imbalances (Head and Mayer, 2014) Third, capital acts as an agglomeration force playing the same role as endogenous total factor productivity.

income generated by the m_j identical local firms is $\int_{\Lambda_j} \rho_j(\omega)\mathrm{d}\omega = m_j\rho_j$. The n_j residents of county j equally share this ownership income.[7]

It follows that the budget constraint of a resident of county j is:

$$\sum_i \int_{\Lambda_i} (1 + t_i + T_i)p_i(\omega)\mu_{ij}q_{ij}(\omega)\mathrm{d}\omega = e_j, \tag{2}$$

where $e_j = (1 - \tau_j)\left(w_j + \kappa_j + m_j\rho_j/n_j\right)$, is individual after-tax income, p_i is the factory gate price of variety i, t_i is county i's sales county tax rate. T_i is the exogenous sales tax rate of the state in which county i is located, τ_j is the exogenous income tax rate of county i's state. Parameter μ_{ij} is an iceberg transportation cost incurred by a resident of j shopping in i. Thus, to consume 1 unit of a good purchased in i, a resident of j needs to buy $\mu_{ij} > 1$ units of goods there. Then, the aggregate income of the residents of county j is:

$$E_j = n_j(1 - \tau_j)\left(w_j + \kappa_j + \frac{m_j\rho_j}{n_j}\right) \tag{3}$$

The expenditure on variety ω purchased by a resident of j in county i is $x_{ij}(\omega) = p_i(\omega)\mu_{ij}q_{ij}(\omega)$. Maximizing utility subject to the constraint yields the Marshallian demand $x_{ij} = (1 + t_i + T_i)^{-\sigma}[p_i(\omega)\mu_{ij}]^{1-\sigma}P_j^{\sigma-1}e_j$, which is inclusive of the transportation cost and where P_j is the Dixit-Stiglitz price index defined below. Aggregating, we obtain the total value of the consumption of the n_j residents of county j purchasing in county i:

$$X_{ij} = m_i(1 + t_i + T_i)^{-\sigma}(p_i\mu_{ij})^{1-\sigma}P_j^{\sigma-1}E_j, \tag{4}$$

where the Dixit-Stiglitz price index is:

$$P_j = \left(\sum_i m_i[(1 + t_i + T_i)p_i\mu_{ij}]^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{5}$$

which is, as usual, increasing with respect to all local variety prices and to transportation costs, but includes both the local and state sales tax rates. Higher tax rates in other counties raise the living cost in j and act as an "inward multilateral resistance" (Anderson and Van Wincoop, 2003), making j more remote by reducing its access to their varieties.

[7] Unlike trade models that redistribute entrepreneurial payments proportionally to production costs (Krugman, 1980; Fajgelbaum et al., 2019), our model assumes that residents, who supply the entrepreneurial idea, directly receive the compensation. While we assume purely local entrepreneurs, our approach could be expanded to a richer spatial distributions of entrepreneurial income in which households in i receive $\sum_j \theta_{ij}m_j\rho_j$ where θ_{ij} is the share of entrepreneurial income received from firms in j. This modeling parallels the way fixed factors and profit income is redistributed in most public finance literature (Agrawal et al., 2023).

2.3. Production

In county i, each firm $\omega \in \Lambda_i$ produces its own local variety, which is consumed by (possibly) all the residents of the economy. This variety is produced by combining labor, $\ell_i(\omega)$, and mobile capital, $k_i(\omega)$ using the following constant returns to scale technology:

$$q_i(\omega) = \left(\frac{\ell_i(\omega)}{\alpha}\right)^{\alpha} \left(\frac{k_i(\omega)}{1-\alpha}\right)^{1-\alpha} \tag{6}$$

where $\alpha \in (0,1)$ is the labor income share parameter.[8]

In county i, each firm ω chooses its price, $p_i(\omega)$, to maximize profit:

$$\pi_i(\omega) = p_i(\omega)q_i(\omega) - c_i q_i(\omega) - \rho_i$$

where $q_i(\omega) = \sum_j \mu_{ij} q_{ij}(\omega)$ is the aggregate demand for its variety, $c_i \equiv w_i^{\alpha}$ is the unit cost function, recalling that capital is the numéraire. Further, as discussed above, firms must incur an entry cost ρ_i as a payment to entrepreneurs. Following Krugman (1980) and Fajgelbaum et al. (2019), we allow this cost to vary endogenously by assuming that $\rho_i \equiv c_i f_i$, where f_i is the exogenous component of this cost.

Profit maximization pins down the price of the local variety according to the usual optimal pricing rule $p_i = w_i^{\alpha}\sigma/(\sigma-1)$, which is identical for all firms in i, as the firms are ex ante identical themselves. The price charged by a firm increases with respect to the input prices.

Using the above pricing rule, the total demand for labor in i is:

$$L_i = \frac{\sigma-1}{\sigma}\frac{\alpha Y_i}{w_i} \tag{7}$$

where $Y_i = p_i m_i q_i$ denotes the value of the aggregate output of the m_i firms operating in county i. Free entry of firms implies zero profit which in turn implies that the output of each firm in i is exogenously determined as $q_i^{\mathrm{s}} = (\sigma-1)f_i$ which determines the firm's output (Fujita et al., 2001). The number of firms, m_i, operating in i is endogenously determined by this zero-profit condition. To see it, we can multiply both sides of this condition by $p_i m_i$ to obtain the following intuitive condition:

$$m_i = \frac{Y_i}{(\sigma-1)p_i f_i} \tag{8}$$

Intuitively, more aggregate output, lower price of the variety (that is, more demand) and lower entry cost imply a larger number of firms operating in i.

[8] Note that in general equilibrium, a county with a higher demand for its variety will attract more capital and have more productive workers.

2.4. Local and State Government Budget

County i uses its local sales tax revenues $t_i X_i$ with $X_i = \sum_j X_{ij}$ being the total tax base of the county to finance per capita public services, g_i, provided at the endogenous unit cost of p_i. Total public expenditures are therefore $p_i n_i g_i$ for which we assume, without loss of generality as population is fixed, full congestion. Although the focus of the paper is on tax competition in local sales tax rates, t_i, it is also quantitatively important to account for other possible sources of revenues accessible to counties. These sources of revenues are denoted R_i. Thus, the local government i's budget constraint is:

$$t_i X_i + R_i = p_i n_i g_i \,. \tag{9}$$

The alternative sources of revenue, R_i, reflect other resources such as property taxes or federal grants that allow sales tax rates to be higher or lower. Modeling the endogenous determination of all the alternative sources of revenue is beyond the scope of this paper. Hence, we consider a parsimonious specification $R_i \equiv p_i n_i \Delta_i$ in which $n_i \Delta_i$ denotes an initial exogenous aggregate endowment of alternative sources of revenue in units of private goods.[9]

Local governments provide services and endogenously raise taxes in the context of a federalist system. Given that states and counties tax commodities in the U.S., our model accounts for state-level taxes and the services they finance, although state-level policies will be treated as exogenous. The budget constraint of county i's state is:

$$\sum_{k \in \mathcal{S}_i} T_k X_k + \sum_{k \in \mathcal{S}_i} n_k \tau_k y_k = \sum_{k \in \mathcal{S}_i} n_k p_k G_k \tag{10}$$

where $\mathcal{S}_i$ is the set of counties in county i's state, and $y_i \equiv e_i/(1-\tau_i)$ is the the individual net-of-tax income, where e_i is the income defined previously in (2). Similarly to the county-level public services, the state-level public service G_i is fully congestible. Each resident of county i's state receives the same amount of G_i, meaning $G_k = G_i$, $\forall k \in \mathcal{S}_i$. The expenditure on state public services in county i is $p_i n_i G_i$. As income taxes are progressive, the state's income tax rate τ_k varies across counties depending on its average income.

Having defined public services at the state and local level, $\mathbb{G}_j \equiv \varphi g_j + (1-\varphi) G_j$ is the aggregator of public services provided in j that enters into the utility function. The parameter $\varphi < 1$ governs the marginal rate of substitution between local and state public services,

[9] Assuming that counties are endowed with public services (exogenous Δ_i) rather than with nominal revenues (exogenous R_i) has two advantages. First, there we do not need assumptions about the location of the residents who finance these other resources. Thus, Δ_i is a utility shifter. Second, if all prices in the economy vary proportionately, private consumption and public services are both unchanged. See Subsection 2.5.

$\varphi/(1-\varphi)$: it measures the amount of state public services that an individual is willing to trade to obtain one unit of local public services. Higher values of φ mean more relative value put on county public services.

Having now introduced the model, it is important to note that our model features several sources of heterogeneity including population (exogenous), other local sources of revenue (exogenous) income (backed up by κ_i, state tax rates on sales and income (exogenous) and the number of firms (backed up by f_i). As a result policy choices across space will depend on these factors.

2.5. Equilibrium Relation between the Local Economic Variables

This section shows that the central economic variable in the model is the price of the local variety, which unambiguously determines the levels of most of the local economic variables.

First, the local wage w_i is an increasing function of the price of the local variety p_i as per the optimal pricing rule that can be rewritten as:[10]

$$w_i = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{1}{\alpha}} p_i^{\frac{1}{\alpha}} \tag{11}$$

Thus, higher prices allow the firms to pay higher wages.

Second, inserting the expression of the labor demand (7) into the local labor market clearing condition, $L_i = n_i$, we can express the value of i's total production Y_i as:

$$Y_i = \frac{n_i}{\alpha}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{1-\alpha}{\alpha}} p_i^{\frac{1}{\alpha}} \tag{12}$$

which is an increasing function of the price, p_i. Higher prices increase both the value of total production and incentivize firms to produce more.

Third, inserting (12) into (8), the number of firms is an increasing function of p_i:

$$m_i = \frac{n_i(\sigma-1)^{\frac{1-2\alpha}{\alpha}}}{\alpha f_i \sigma^{\frac{1-\alpha}{\alpha}}} p_i^{\frac{1-\alpha}{\alpha}} . \tag{13}$$

Higher prices attract firms into the jurisdiction.

Last, the aggregate payment of $m_i\rho_i$ to the owners can be expressed as an increasing function of the local price. Inserting $m_i\rho_i$ into the local income E_i defined in (3) gives:

$$E_i = \frac{n_i[(\sigma-1)\alpha+1](\sigma-1)^{\frac{1-\alpha}{\alpha}}}{\alpha\sigma^{\frac{1}{\alpha}}} p_i^{\frac{1}{\alpha}} + n_i\kappa_i . \tag{14}$$

[10] See the Appendix A for the derivation of these equilibrium relations.

Higher prices increase total income through both higher wages and owners' payment.

2.6. General Equilibrium of the Private Economy

This section describes the general equilibrium of the private economy, taking as given local taxes as in Suárez Serrato and Zidar (2016) and Fajgelbaum et al. (2019).

As established in Subsection 2.5, all the local variables in the private economy are functions of the local price p_i. Therefore, the general equilibrium consists of solving for a vector of all equilibrium commodity prices in all jurisdictions. These prices are jointly determined by the J local commodity market clearing conditions:

$$Y_i = X_i + t_i X_i + n_i p_i G_i \,. \tag{15}$$

This equation states that the value of total production, Y_i, is equal to the value of total demand, composed of three elements: local demand for private consumption, X_i, demand for public services by the local government, $t_i X_i$, and demand for the state public services, $n_i p_i G_i$.

More specifically, to obtain the general equilibrium of the private economy, we solve the system of market clearing conditions (15) for equilibrium prices p_i using the price indices P_i defined in (5) and the value of state public services G_i defined in (10). Formally, we solve for three sets of equations for all $i = 1, \ldots, J$:

$$(\mathcal{E}_i)\begin{cases} Y_i - (1+t_i)\displaystyle\sum_j m_i (1+t_i+T_i)^{-\sigma} p_i^{1-\sigma} \mu_{ij}^{1-\sigma} P_j^{\sigma-1} E_j - n_i p_i G_i = 0, & (16) \\ P_i^{1-\sigma} - \displaystyle\sum_k m_k (1+t_k+T_k)^{1-\sigma} p_k^{1-\sigma} \mu_{ki}^{1-\sigma} = 0, & (17) \\ \displaystyle\sum_{k\in\mathcal{S}_i} n_k p_k G_i - \sum_{k\in\mathcal{S}_i} \frac{\tau_k}{1-\tau_k} E_k - T_i \sum_{k\in\mathcal{S}_k} \sum_j m_k (1+t_k+T_k)^{-\sigma} p_k^{1-\sigma} \mu_{kj}^{1-\sigma} P_j^{\sigma-1} E_j = 0, & (18) \end{cases}$$

recalling that m_j, E_j and Y_j are endogenous variables reducing to one-to-one mapping with respect to p_j for each jurisdiction j as discussed in Subsection 2.5.

The 3-equation system $(\mathcal{E}_i)$ will be referred to as the private economy *partial equilibrium system* in county i, while the $3J$-equation system, $(\mathcal{E}_i)_{i=1,\ldots,J}$, will be called the private economy *general equilibrium system*.[11] Note that the general equilibrium system determines the equilibrium levels of prices, $\{p_i(\mathbf{t})\}_{i=1,\ldots,J}$, for all counties, with each jurisdiction's price being a function of the tax rates of all counties $\mathbf{t} \equiv (t_1, \ldots, t_J)$. Thus, if any jurisdiction k changes its tax rate, the price, and therefore all other endogenous variables in all other jurisdictions

[11] Because G_i is the same for all towns in a state, the number of equations is $2J$ plus the number of states.

will be affected. For later reference, we denote the *general equilibrium responses*:

$$\frac{\partial p_i}{\partial t_k}, \qquad \frac{\partial P_i}{\partial t_k}, \qquad \frac{\partial G_i}{\partial t_k}, \tag{19}$$

which are obtained by implicitly differentiating the entire general equilibrium system $(\mathcal{E}_i)_{i=1,\dots,J}$.

2.7. Local Taxation Choice

Let us now turn to the optimal tax choice of the counties in the first stage of the tax competition game. The government of county i chooses its tax rate t_i taking as given and fixed the tax rates in other jurisdictions, and anticipating the responses of the private economy. Formally, it maximizes the aggregate welfare (indirect utility) of its residents:

$$n_i V_i = \frac{E_i \mathbb{G}_i^{\nu}}{P_i}, \tag{20}$$

subject to the equilibrium system of prices (16)–(18) and to its budget constraint (9). Using the commodity market clearing condition (15), as derived in Appendix A, the government budget constraint (9) is:

$$g_i = \frac{t_i}{1+t_i}\left(\frac{1}{\alpha}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{1-\alpha}{\alpha}} p_i^{\frac{1-\alpha}{\alpha}} - G_i\right) + \Delta_i, \tag{21}$$

which indicates that the direct effect of the tax rate t_i and the price p_i on the local public service g_i is positive, while the effect of G_i is negative. The price of the variety increases the value of production by local firms, which increases the size of the tax base and allows the county to provide more public services. Taking as given the value of local production, an increase in the state's public services crowds out local public services by the market clearing condition (15). This equation also makes it clear that Δ_i will act as a residual, that is, an exogenous shifter of local public services.

For tractability purposes, and consistent with practical local tax-setting behavior, we assume that local governments account for how their tax changes influence their own prices but view the prices elsewhere as given. This assumption is weaker than countless studies of tax competition that assume atomistic jurisdictions (Zodrow and Mieszkowski, 1986; Wilson, 1986; Hoyt, 1991), which implies that jurisdictions do not even affect price changes in their own jurisdiction. This is also a weaker assumption than used in many structural models of (exogenous) state and local tax policy that also rely on atomistic governments (Suárez Serrato and Zidar, 2016; Fajgelbaum et al., 2019). Our governments have some market power and thus change prices elsewhere, but simply do not account for these general equilibrium effects. One can view the counties as behaving myopically—analogous to voters not accounting for price

changes in Epple and Romer (1991) and Epple et al. (2001)—so they are not able to predict the change in the prices of nearby jurisdictions.

Formally, we assume that as county i changes its tax rate, t_i, it only accounts for the *partial equilibrium* in i, $(\mathcal{E}_i)$, and ignores the changes on the equilibrium in other counties, $(\mathcal{E}_j)_{j\neq i}$. Implicitly differentiating the partial equilibrium in i defines the *partial equilibrium responses*:

$$\frac{\partial p_i}{\partial t_i}, \qquad \frac{\partial P_i}{\partial t_i}, \qquad \frac{\partial G_i}{\partial t_i}, \tag{22}$$

in which the "vertical bar" distinguishes these partial equilibrium responses from the general equilibrium responses in (19). For later reference, we summarize this assumption as:

Assumption 1. *When county i changes t_i, it only accounts for the partial equilibrium in i, $(\mathcal{E}_i)$, and ignores its effect on the equilibrium in other counties, $(\mathcal{E}_j)_{j\neq i}$.*

Assumption 1 implies that the first-order condition of government i only includes the local economic responses $\partial p_i/\partial t_i$, $\partial P_i/\partial t_i$ and $\partial G_i/\partial t_i$ with respect to the own-jurisdiction tax rate and ignores all cross-economic responses $\partial p_j/\partial t_i = 0$, $\partial P_j/\partial t_i = 0$ and $\partial G_j/\partial t_i = 0$. This assumption is not strictly necessary for our counterfactual analysis, but it allows us to derive a tractable expression for the Policy Network Matrix by simplifying cross-effects and expressing the tax rate of county i solely as a function of its own variables.

We will show that Assumption 1 has minimal impact on our baseline results, but invoking it will enable us to further investigate the mechanisms underlying the welfare effects. Notice that although the local government ignores the full *impact* of its policy on economic variables, it always observes correctly the *level* of theses variables. Critically, governments still anticipate that markets in their own jurisdiction will clear. And Assumption 1 places no assumption on the magnitude of the jurisdiction's strategic responses.

Having delineated the fundamentals of the government's problems, we now derive the expressions for the Nash tax rates. The first-order condition for a county i can be expressed according to the following open economy Ramsey rule (see Appendix A.2 for the derivation):

$$\frac{t_i}{1+t_i+T_i} = \frac{1 - \overbrace{\frac{\chi_i\lambda_i}{\nu}}^{A} - \overbrace{\frac{\eta_i\phi_i}{\nu}}^{C}}{\varepsilon_i + \underbrace{\frac{\theta_i}{\nu}}_{B}}, \tag{23}$$

where $\varepsilon_i \equiv -[(1+t_i+T_i)/X_i]\partial X_i/\partial t_i > 0$ is the absolute value of the elasticity of the tax base with respect to the county (gross) sales tax rate, $\chi_i \equiv X_{ii}/X_i$ is the share of county i's tax base (total sales) raised from its residents, $\lambda_i \equiv (R_i + (1-\varphi)n_i p_i G_i/\varphi)/E_i$ is the ratio of non-sales

tax revenues to income, and $\theta_i \equiv (1+t_i+T_i)X_{ii}/E_i$ is the after-tax local expenditure share of a resident of county i on the goods produced in i. In addition, our Ramsey rule accounts for the effect of taxes on welfare through prices via the term $\eta_i\phi_i$.[12]

If $\theta_i = 1$ (fully local consumption), $\lambda_i = 0$ (no alternative sources of revenue) and $\phi_i = 0$ (no general equilibrium effects) our Ramsey rule boils down to the standard inverse elasticity rule for optimal commodity taxation.[13] If $\theta_i = 0$ (negligible local consumption), $\lambda_i = 0$ and $\phi_i = 0$, it reduces to the standard inverse elasticity rule for an optimal tariff in a small open economy (Caliendo and Parro, 2022). To interpret Term A, when χ_i is large, sales tax revenue in i is mainly raised from residents; when λ_i is large, jurisdictions raise a large amount of total revenue from non-sales tax sources. As more tax revenue is raised from residents, there is less ability to export the tax burden to non-residents, which puts downward pressure on the sales tax rate. As non-sales tax revenue sources become larger, the sales tax become less important and there are more instruments to raise revenue from, allowing the jurisdiction to lower the sales tax rate. Thus, there is a substitution effect among sales and non-sales revenue.

When $\theta_i > 0$, Term B is increasing when a resident of i consumes a higher share of their income in their own county. Again, as residents like low taxes on their own consumption to increase disposable income, an increase in θ_i puts downward pressure on tax rates.

Term C captures the effects of taxes on prices. When η_i is large, public services provided relative to the size of the local tax base are more significant. This places downward pressure on tax rates because households are willing to pay less for abundant public services due to diminishing marginal utility. When ϕ_i is large, aggregate income, public services and the price index are very sensitive to changes in taxes. This puts downward pressure on taxes if the elasticity on income and public services is larger that the elasticity on the price index.[14]

Fourth, the parameter ν which governs the marginal willingness to pay for public services has a positive impact on t_i. Further, the share of local public services in total public services, φ, enters the expression for λ_i. A high φ indicates a low marginal rate of substitution between state and local public services ($\mathrm{d}g/\mathrm{d}G = (1-\varphi)/\varphi$), implying a higher tax rate.

In sum, our Ramsey rule (23) highlights four main possible causes of heterogeneity in the

[12] The term $\eta_i \equiv n_i p_i(\mathbb{G}_i/\varphi)/X_i$ is the ratio of the public services provision relative to the tax base and $\phi_i \equiv -\left(\varepsilon^i_{E,p} - \varepsilon^i_{P,p} + \nu\varepsilon^i_{G,p}\right)\epsilon^i_{p,t} - \nu\varepsilon^i_{\mathbb{G},G}\,\epsilon^i_{G,t}$ captures the effects of taxes on the local price and the state public service provision where $\varepsilon^i_{y,x}$ [$\epsilon^i_{y,x}$] is the partial equilibrium [semi-]elasticity of y_i with respect to x_i. Our model allows us to sign unambiguously: $\varepsilon^i_{E,p} > 0$ as higher prices increase the local income, and $\varepsilon^i_{P,p} > 0$ and $\varepsilon^i_{\mathbb{G},G} > 0$ which are two mechanical effects. On the contrary, the model does not allow us to predict unambiguously the signs of the partial equilibrium semi-elasticities, $\epsilon^i_{p,t}$ and $\epsilon^i_{G,t}$. However, our quantitative analysis will be able to sign negatively these two elasticities, and sign positively the overall price effect ϕ_i.

[13] In this case, $t_i/(1+t_i+T_i) = 1/(\varepsilon_i + 1/\nu)$ in which $1/\nu$ is the marginal cost of public funds.

[14] In our empirical implementation, ϕ_i will be positive.

levels of local commodity tax rates. Its richness makes it one of the most comprehensive open-economy optimal tax rules in the literature. Moreover, our empirical analysis in 3.7 will quantify the relative importance of these four motives.

2.8. General Equilibrium: Private Economy and Local Taxation Choice

Even though counties take prices in other counties as given by Assumption 1, all equilibrium prices are determined simultaneously. Therefore, solving for the complete equilibrium of the economy requires computing the prices and taxes in all jurisdictions simultaneously.

First, using Assumption 1 and starting from $(\mathcal{E}_i)$, we analytically derive the partial equilibrium responses that each county i anticipates by changing its tax rate: $\partial p_i/\partial t_i$, $\partial P_i/\partial t_i$ and $\partial G_i/\partial t_i$. To do so, we apply the implicit function theorem to $(\mathcal{E}_i)$ by differentiating it with respect to t_i, obtaining $(\mathrm{d}\mathcal{E}_i)$. This allows us to express each county's optimal tax rule (23), as functions of the levels of the key endogenous variables of the model (p_i, P_i and G_i).

Second, we solve for the complete equilibrium of the economy by solving numerically the $7J$-general-equilibrium equation system (5), (10), (15) and (23) for the Nash equilibrium tax rates $\{t_i^\star\}_{i=1}^J$, price $\{p_i^\star\}_{i=1}^J$, the price indices $\{P_i^\star\}_{i=1}^J$ and state public services, $\{G_i^\star\}_{i=1}^J$.We prove existence and uniqueness of the general equilibrium, following the approach of Allen et al. (2024), for a simplified version of the model—i.e. no state government and simplified Ramsey rule—can be found in Appendix A.3.

Comparing our approach to Ossa (2014) and Ferrari and Ossa (2023), we explicitly derive the government's first order condition rather than numerically maximize the objective function of governments. Thus, we exploit an additional equilibrium condition for optimal policies, such that the model can then be computationally applied to a much larger number of jurisdictions (e.g., counties vs. states or countries) in a very efficient manner.

3. From Theory to Empirics

3.1. Data and Summary Statistics

We next bring our general equilibrium model of commodity taxation to the data. Commodity taxation in the United States is highly decentralized, with sales taxes being set at the state, county and local level. In this paper, we focus on county governments because there is a sufficiently large number to provide ample variation and to allow for cross-border consumption of goods. Ignoring Alaska and Hawaii, our sample includes 3,109 counties. In the continental U.S., 13 states (with 488 counties) do not allow municipal or county sales taxation. As we are interested in local tax setting decisions, our welfare analysis focuses on the 2,621 counties

located in the 36 states allowing for local taxation. The 488 institutionally constrained counties without local tax authority are however always included as a shopping destination to account for cross-border shopping opportunities.

We use data on sales tax rates for all states, counties and cities for 2011, assuming the data represent the governments' choices in equilibrium. To account for the multi-tiered federal structure, the effective county sales tax rate is the sum of its observed county rate plus the average tax rate of the municipalities it includes. State-level tax rates are always included in our quantitative analysis but are taken as exogenous. Among the 2,621 counties that are free to choose their tax rates by state law, 2,219 choose to set a positive county tax rate and 402 (around 15%) choose to set a zero tax rate.

Table 1 reports the list of observed endogenous (Panel A) and exogenous (Panel B) variables we use in the analysis and provides descriptive statistics for taxing counties.[15] Figure C.1 illustrates the spatial variation in counties' sales tax rates.

Table 1. Descriptive statistics for taxing counties.

	Var	Mean	SD	Min	Max
A. Endogenous model variables					
County + avg. municipal sales tax rate (%)	t_i	1.754	1.202	0.007	6.
Number of retail firms	m_i	553	1838	2	47704
Average household after-tax income (in $1,000)	e_i	60.299	14.173	31.432	152
Earnings (in $1,000)	w_i	44.587	12.76	17.209	126
Non-sales tax revenue relative to expenditure (%)	$R_i/(p_i n_i g_i)$	89.602	12.261	5.341	100
B. Exogenous model variables					
Population (in 1,000 households)	n_i	37.542	124	0.243	3219
State sales tax rate (%)	T_i	5.191	1.14	0	7.25
State income tax rate (%)	τ_i	2.619	1.664	0	5.835

NOTE— Summary statistics are shown for taxing counties. Data sources: Agrawal (2015) for sales tax rates, U.S. Census for demographic and income data, County Business Patterns for retail firm counts, NielsenIQ Consumer Panel for cross-border expenditures, and the Annual Survey of State and Local Government Finances for fiscal data. Income tax rates are average tax rates and are calculated for a representative taxpayer in each state using NBER TAXSIM.

[15] Other socioeconomic variables used in the paper from U.S. census data are reported in Table C.1.

3.2. Model Inversion

We invert the model in the following manner.[16] First, we obtain the iceberg transportation costs using data on interjurisdictional shopping patterns. Second, we solve (15) for p_i using data on t_i, m_i, e_i from Table 1 for different incremental values of σ. Using (11), we then obtain σ by minimizing the variance in log wages predicted by the model versus those in the data. Third, using this value of σ and the implied equilibrium private economy endogenous variables, along with the estimated iceberg transportation costs, we obtain the pairwise commodity flows between all jurisdictions, X_{ij}, allowing us to construct local tax bases. In addition, we derive all the partial equilibrium responses at the observed tax rates, (22). Fourth, we calibrate κ_i using data on e_i and f_i using data on m_i. Fifth, ν and φ are estimated to match moments of non-sales tax revenues $R_i/p_i n_i g_i$ in Table 1. Finally, armed with all inputs to our optimal tax rule except for residual non-sales tax revenues per capita, Δ_i, we solve (23) for Δ_i to match observed local sales tax rates, t_i.

3.3. Estimation of the Transportation Costs: μ_{ij}

Cross-border shopping costs, μ_{ij}, are unobserved and therefore we use a gravity model to predict these transportation costs. Taking logs of the aggregate purchases from residents of j to stores in i, (4), we obtain the standard fixed-effect gravity equation, $\log X_{ij} = \varkappa_i + \vartheta_j - (\sigma - 1)\log \mu_{ij} + \varsigma_{ij}$, where $\varkappa_i$ is a fixed effect that absorbs the sales tax rate and price in the shopping destination, ϑ_j is an origin fixed effect that controls for disposable income, and ς_{ij} is an error term (Head and Mayer, 2014). Following the literature (Yotov et al., 2016), we assume that the shopping costs take the following functional form: $\mu_{ij} = \exp\left(\sum_k \beta_k z_{ij}^k/(1-\sigma)\right)$, where z_{ij}^k includes the straight-line distance between the county population centroids and other relevant covariates such as an indicator for purchases at home, in a contiguous county, or within different driving times.[17] We therefore estimate the following gravity equation

$$\log X_{ij} = \varkappa_i + \vartheta_j + \sum_k \beta_k z_{ij}^k + \varsigma_{ij} \tag{24}$$

[16] This section focuses on intuition, all technical details are provided in Appendix D. This includes proofs of existence and uniqueness of this inversion procedure. Additionally, Table D.1 summarizes the nature of the main variables of the model and their degree of matching with data.

[17] In our setting, it is natural to think of shopping costs being related to the distance between jurisdictions. But, in other contexts, such as globally mobile factors, distance can be replaced by other bilateral frictions such as tariff, certifications or migration restrictions, etc. Note that in 2011, e-commerce represented 4.5% of total retail sales. We expect the growth of online shopping to reduce, though not eliminate the influence of physical distance on shopping costs. Indeed, the recent Supreme Court decision requiring taxes to be paid on online sales has resulted in a new wave of cross-border shopping (Bruce et al., 2023).

where X_{ij} is county-to-county aggregate expenditure in i of residents of j constructed using the 2010 NielsenIQ Consumer Panel and the Retail Scanner Panel (Kilts Center for Marketing, 2010a,b). See Appendix C for how we match consumer locations and purchase locations to determine bilateral consumption patters between jurisdictions. Estimating (24) using a Poisson pseudo-maximum-likelihood approach, we obtain the results reported in Table 2.

A 1% increase in distance between counties i and j lowers purchases in i by a resident of j by 1.34%. The subsequent indicators for purchases in the home county, in adjacent or within 60 minutes driving time counties are positive indicating a preference for consumption in nearby counties rather than those that are far away. In Appendix E.1, we use different specifications of Table 2 to predict the local expenditure share of each county (θ_i). They all lead to very similar results and to be highly correlated with the observed expenditure share in the NielsenIQ data (Table E.1 and Table E.2). We therefore use the most flexible specification.

Table 2. Gravity regression results.

	(1)	(2)	(3)	(4)	(5)	(6)
Log(distance)	−1.341***	−1.231***	−1.183***	−1.332***	−1.216***	−1.169***
	(0.0974)	(0.0969)	(0.0965)	(0.0967)	(0.0962)	(0.0955)
Home	4.254***	5.123***	5.523***	4.309***	5.212***	5.605***
	(0.568)	(0.583)	(0.590)	(0.565)	(0.580)	(0.586)
Adjacent	5.447***	5.958***	6.203***	5.473***	6.000***	6.239***
	(0.248)	(0.269)	(0.280)	(0.248)	(0.269)	(0.280)
Neighbor60	3.371***	3.822***	4.041***	5.336***	6.073***	6.376***
	(0.193)	(0.215)	(0.226)	(1.129)	(1.149)	(1.159)
Neighbor90		2.145***	2.346***		8.726***	8.973***
		(0.212)	(0.223)		(3.383)	(3.421)
Neighbor120			1.409***			−12.76**
			(0.261)			(5.580)
Neighbor60 × Log(distance)				−0.529*	−0.602*	−0.627**
				(0.305)	(0.309)	(0.312)
Neighbor90 × Log(distance)					−1.599*	−1.611*
					(0.826)	(0.833)
Neighbor120 × Log(distance)						3.174**
						(1.247)
Observations	5,272,737	5,272,737	5,272,737	5,272,737	5,272,737	5,272,737

NOTE— * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The dependent variable is the logarithm of expenditures of a resident of county j in county i. Home: $i = j$; Adjacent: i is adjacent but is not home; Neighbor60: i is within 60 minutes of driving time from j but not adjacent to j; Neighbor90: i is between 60 and 90 minutes of driving time from j; Neighbor120: i is between 90 and 120 minutes of driving time from j. Standard errors are two-way clustered at the i and j levels.

3.4. Parameter Calibration: α, σ, ν and φ

First, we follow standard practice and parametrize the labor income share α to 2/3. Second, we follow Ahlfedlt et al. (2015) and calibrate the elasticity of substitution σ so as to minimize the square of the difference between the variance of the wages (w_i) predicted by the model and the variance of the observed wages (see Table 1). We perform a grid search of potential values of σ between 1 to 10 with a step size of 0.01 and obtain a value of σ of 4.96 which is close to central estimates in the trade literature (Head and Mayer, 2014). This parameter governs the degree of substitution among of the varieties produced in the different counties. A higher value of σ implies a greater elasticity of the tax base with respect to local sales tax rates and hence a smaller optimal tax rate in equilibrium.

Third, parameter ν which characterizes the level of the marginal willingness to pay for public services and the parameter φ which determines the marginal rate of substitution between state and local public services are estimated jointly. We use the method of moments to estimate these parameters so that the share of non-sales tax revenues in total government revenues (expenditures) in the model, $R_i/p_i n_i g_i$ (see Table 1) matches both the sample mean and the variance of data from the Census of Governments for our sample of taxing counties. Intuitively, our estimation of ν and φ guarantees that the Ramsey rule predicts a correct share of sales tax revenues in total revenues. Our method of estimating these parameters differs from Suárez Serrato and Zidar (2016) or Fajgelbaum et al. (2019) because they do not model tax decisions and therefore do not have an optimal tax rule, thus necessitating that they rely on workers' mobility to reveal their preference for public services.

We obtain a value of $\nu = 0.495$ which means that a resident's desired expenditure share on public services is $\nu/(\nu+1) = 0.332$ which is larger than the value of 0.23 in Fajgelbaum et al. (2019). Our larger estimates are consistent with incumbent voters being more likely to vote for higher taxes than newly settled, hence marginal, residents.

Our method of moments estimation yields $\varphi = 0.276$, so that the marginal rate of substitution between state and local public services is $(1-\varphi)/\varphi = 2.623$. That is, a household is willing to trade one unit of state public services for 2.623 units of local public services. While such a high value is large, it is consistent with local residents seeking to finance local public services (e.g., education) using state rather than local funds. Because state and local services are substitutable, a high value of the MRS, $(1-\varphi)/\varphi$, means that if the residents of county i had to choose both state and local funding for education, g_i and G_i, they would select a higher amount from the state than the local government. This is because residents of i do not fully pay for state funding for education, as it is mostly financed by residents outside of the county.

3.5. Local Fundamentals: Δ_i, κ_i and f_i

Capital Income κ_i and firm's entry cost f_i. We compute the household capital income κ_i by solving (14) using data on individual net income, e_i and we recover the firms' entry cost f_i by solving (13) using data on the number of firms m_i (see Table 1).

Alternative Sources of Revenue R_i. Alternative sources of revenue are $R_i = p_i n_i \Delta_i$, which are governed by the per capita non-sales tax revenue (measured in goods) Δ_i. For each taxing county, given the equilibrium quantities implied by model inversion, we compute Δ_i so that each jurisdiction's Ramsey rule is satisfied. Thus, we can recover R_i for taxing counties.

Next, we determine the non-tax resources R_i of non-taxing counties. This is challenging because counties with zero tax rates have unconstrained optimal tax rates that are unobserved—and possibly negative. To recover the R_i for these counties, we estimate the relationship $R_i = \sum_k \beta_k s_i^k + \epsilon_i$ in taxing counties where s_i^k are socioeconomic variables in Table C.1.

We need to distinguish between the 402 counties which voluntarily choose a zero tax—indicating that their optimal tax rate is negative—and the 488 counties that are forced to set zero due to state restrictions. For the latter counties, we simply set $R_i = \widehat{R}_i = \sum_k \widehat{\beta}_k s_i^k$. However, for the former, we need to choose a sufficiently high R_i such that the optimal tax rate is non-positive. To this end, we use a conditional bootstrap procedure based on the distribution of $\widehat{\beta}_k s_i^k$ and then assign $R_i = \mathbb{E}[\widehat{R}_i | \partial V_i / \partial t_i \leqslant 0]$, as this condition guarantees that their optimal tax rate is non-positive.

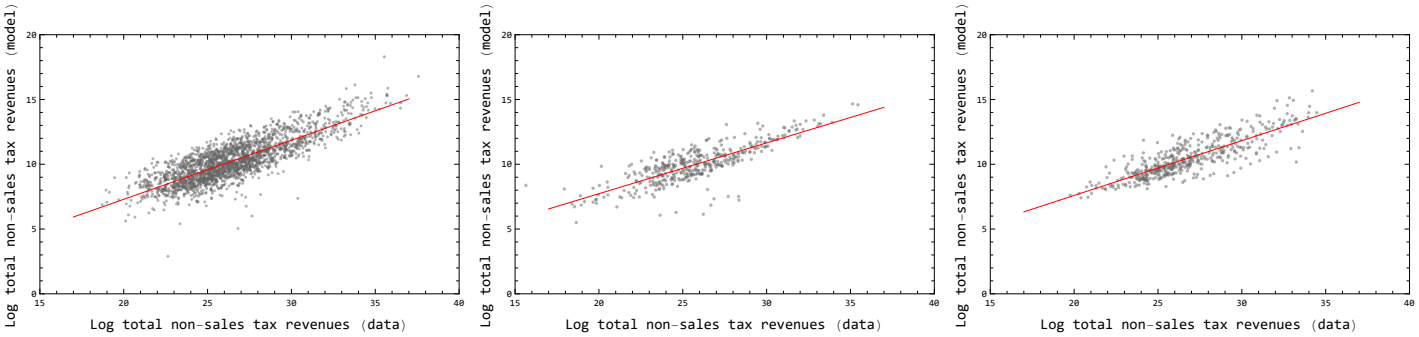
Our procedure distinguishes us from prior studies incorporating endogenous government (Ossa, 2014; Ferrari and Ossa, 2023) where the model's predictions of governments' policy do not match with observed data. As our paper is interested in quantifying welfare effects of tax reforms, it is essential that the model accurately predicts observed endogenous tax rates, highlighting yet again the advantage of exploiting the government's first order condition. A further advantage of our approach is that the counties' alternative sources of revenue are directly observable in the data, allowing us to test the ability of our model to match the data.

3.6. Overidentification Checks

We examine the model's predictions for variables not used in the calibration and the relationships between variables not directly imposed by the model. Figure 1 shows that counties' alternative revenues R_i, our main structural residual, is highly correlated with observed data. As R_i is computed so that predicted tax rates coincide with observed ones, non-sales tax revenues predicted by the model are not guaranteed to match their observed counterparts.

Using data on non-sales tax revenues from the Census of Governments, Figure 1a shows

a strong positive correlation with the non-sales tax revenues predicted by our model for the taxing counties. This suggests that our open-economy Ramsey rules accurately represents the policy decision of these counties. An even more striking result, shown in Figure 1b and Figure 1c, is that our taxation rule allows us to predict well the non-sales tax revenues of the non-taxing counties that were not used in the calibration of ν and σ. This suggests that our model should perform well in counterfactual scenarios that shock the tax rate in counties currently setting a zero tax rate.



(a) Taxing counties

(b) Non-taxing counties (with tax authority)

(c) Non-taxing counties (without tax authority)

Figure 1. Overidentification check: counties' non-sales tax revenues. This figure shows the correlation between our model's main structural residual—alternative sources of revenue for the county R_i—on the vertical axis with data on observed non-sales tax revenue from the Census of Governments on the horizontal axis. We depict this correlation for three different sub-groups of counties: those that levy local sales taxes (Panel a), non-taxing counties that have the ability to levy sales taxes (Panel b), and non-taxing counties in states that ban local taxes (Panel c). While the residuals in Panel a directly follow from our structural estimation, the residuals for both Panel b and Panel c are recovered using the procedure in Subsection 3.5 that relies on predictions from exogenous observables.

Our quantitative model perfectly matches observed household income, e_i, by calibrating capital income. However, it does not enforce a perfect match between wages, w_i, and observed earnings; instead, it only ensures that their variances coincide. Figure 2 shows that, although not imposed, household wages in the model are positively correlated with those in the data.

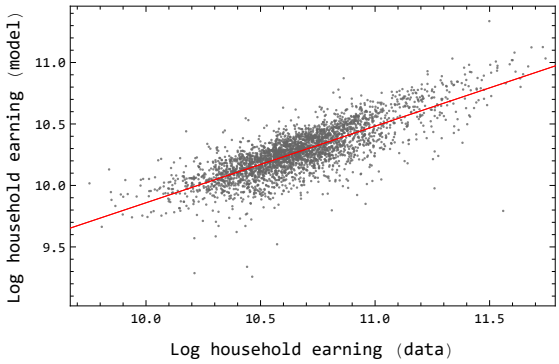


Figure 2. Overidentification check: household earning per county. The sample includes all 3,109 counties. The red line is the linear model fit.

Further, in Appendix E, we show that own-jurisdiction consumption shares in the model match those in the NielsenIQ data. In addition, to demonstrate how well we match the policy choices of local governments, we show that observed tax rates are strongly correlated with various components of the Ramsey rule. In addition, we show that own-jurisdiction consumption shares in the model match those in the NielsenIQ data.

3.7. Results: Tax Decision and Tax Incidence

Table 3 provides our quantification of the different components of the open economy Ramsey rule (23).[18] To the best of our knowledge, this is the first overall picture of the magnitudes and distributions of all the elements of a Ramsey rule for commodity taxes in an open-economy.[19]

Table 3. Components of the open economy Ramsey rule (23): $\frac{t}{1+t+T} = \frac{1-\frac{\chi\lambda}{\nu}-\frac{\eta\phi}{\nu}}{\varepsilon+\frac{\theta}{\nu}}$.

Index	Description	Mean	SD	Min	Max
ε	Elasticity of demand w.r.t. tax (absolute value)	2.135	0.13	1.292	2.336
θ	Local expenditure share	0.738	0.138	0.076	0.992
χ	Share of total sales from own residents	0.776	0.107	0.057	0.985
λ	Non-sales tax revenue to expenditures ratio	0.350	0.019	0.300	0.440
η	Public services to tax base ratio	0.475	0.110	0.163	1.324
ϕ	Equilibrium price effect	0.418	0.058	0.256	0.940

NOTE— The table reports the values of the components of open-economy Ramsey rule (23), evaluated at the general equilibrium of the economy, for the 2,219 taxing counties.

[18] Table F.1 quantifies the terms of the government's first-order condition in an alternative yet equivalent form.
[19] Several prior contributions used reduced-form approach to estimate components of open-economy Ramsey rule for tariffs and tariff equivalents (Goldberg and Maggi, 1999).

Table 3 indicates that the tax elasticity of demand plays a critical role. Even in a rich spatial open economy, optimal tax rates are still significantly influenced by the elasticity of demand. Our structural estimate of the elasticity with respect to local sales tax rates (2.136) is very close to similar estimates in the reduced-form literature (see, e.g., Baker et al. (2021)'s 2.20). This elasticity has a low standard deviation, suggesting that the elasticities do not vary much across counties. With respect to the role of ϕ_i, as acknowledged in the trade literature (Mayer, 1984; Grossman and Helpman, 1994; Mitra, 1999; Bagwell and Staiger, 1999, 2004), the expected sign and magnitude of it is theoretically ambiguous. This ambiguity arises because a tax cut raises the prices, which in turn have the following direct effects: increased wages, increased public spending, and decreased private consumption. In our setting, this term is always positive, suggesting the first two effects dominate, raising utility.

Table 4. General equilibrium local and external tax incidence.

	(1)	(2)	(3)	(4)	(5)	(6)
	All counties			20% largest counties j		
	Mean	SD	Obs	Mean	SD	Obs
A. Local incidence $\frac{1}{p_i}\frac{\partial p_i}{\partial t_i}$	−0.6415	0.1043	3,109	−0.5324	0.1366	524
B. External incidence $\frac{1}{p_i}\frac{\partial p_i}{\partial t_j}$						
Adjacent neighbors	0.0428	0.0512	18,474	0.0993	0.0803	3,136
Non-adjacent neighbors within 60 miles	0.0143	0.0216	14,026	0.0332	0.0342	3,042
Non-adjacent neighbors between 60 and 90 miles	0.0058	0.0127	29,279	0.0121	0.024	5,434
Non-adjacent neighbors between 90 and 120 miles	0.0012	0.0097	40,414	0.0005	0.0195	7,155

NOTE— The table reports the pairwise tax incidence. Columns 1 and 2 include all 3,109 counties, while columns 4 to 6 focus on price responses across all counties resulting from a tax change in the top 20% of counties with the largest number of households. Recall that p_i is the producer price, so these incidence estimates are on firms.

Table 4 presents our estimates for the elasticity of prices with respect to local sales tax rates.[20] We compute those price elasticities by implicitly differentiating the general equilibrium system $(\mathcal{E}_i)_{i=1,\dots,J}$. This yields a matrix of all prices changes $\partial p_i/\partial t_j$ in the economy for a 1 percentage point increase in the tax rate of any jurisdiction. Although Assumption 1 means these terms are unnecessary to calculate the first-order conditions of the governments, calculating the cross-jurisdiction price effects is easy using the implicit function theorem.

[20] Figure F.1 compares the partial and general equilibrium tax incidence on prices.

We find that, on average, producer prices decrease by 0.642% after a one percentage point increase of the local sales tax rate. Because $1 + t_i$ is close to one, the semi-elasticity in the table can be interpreted (approximately) as a classic elasticity of -0.642 corresponding to a one percent change in $1+t_i$. This contrasts with the full pass-through on consumers estimated in older reduced-form sales tax studies (Poterba, 1996), but is more in line with recent VAT estimates (Benzarti et al., 2020). In the presence of tax base mobility, some of the incidence of the tax should be born by consumers/producers in other jurisdictions. The reduced-form estimates of multi-market estimates are nearly nonexistent in the literature. One exception is the work by Harding et al. (2012) who show that the incidence of a state tax increase depends on the distance to the nearest low-tax state border. We find a similar pattern: a one percentage point increase in the sales tax rate of a county increases producer prices in the adjacent county by 0.04%, which declines with distance from the taxed county. The semi-elasticity amounts to 0.001% for counties between 90 and 120 minutes driving time. Columns 4 to 6 report tax incidence generated by the largest counties. As expected, their effects on the price of other counties are much more significant, as illustrated by the larger means and standard deviations.[21] Also note that local price tax incidence is smaller in these large counties (columns 1 to 3) suggesting that the demand there is more elastic.

4. The Welfare Effects of Tax Competition

We now use our structural estimates to investigate the welfare effects of tax competition. To do that, we investigate two counterfactual policies: a minimum local tax of 2% that would be uniformly imposed in all states that allow for local sales taxes (Subsection 4.1) and a partial tax harmonization imposing both a minimum and a maximum tax rate of 1% and 2.5%, respectively (Subsection 4.2). If tax competition is harmful, we expect overall welfare to increase with these centralized interventions. We then check that the mechanism at play works indeed through the strategic tax setting of local government and compare the welfare effects of both reforms under two scenarios: (i) without tax competition, that is, without allowing counties to further change their tax rates; (ii) with tax competition, that is allowing counties to re-optimize their tax rates afterwards.

To measure the welfare effects of these two tax reforms, we use equivalent variations, that is the amount of income that should be transferred to a representative resident prior to the reform so that her utility increases/decreases up to her after-reform utility level. The higher

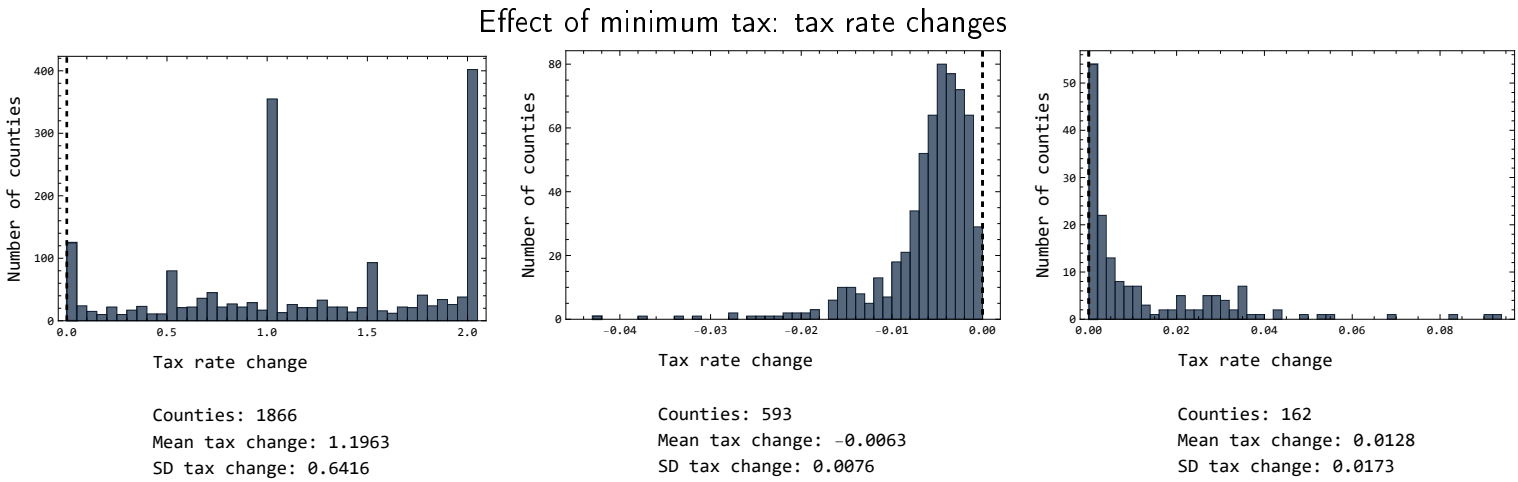
[21] The exceptions are the most remote neighborhoods between 90 and 120 miles which have a slightly positive average tax incidence resulting from the balance between positive and negative incidence.

the equivalent variation the "better" the policy. Given that preferences are homothetic, the general formula of the equivalent variation is $EV_i = (V_i' - V_i)/V_i e_i$. where V_i $[V_i']$ is the pre[post]-reform indirect utility of the resident of i. Note that all welfare effects that we present should be interpreted in the context of changes in the neighborhood of the existing equilibrium, and not as deviations from the social optimum where a planner chooses the local tax rates for each jurisdiction. While our model can technically solve for the social optimum, we do not do this, as it has little policy relevance.

4.1. The Welfare Effects of a Minimum Tax

We consider a baseline minimum sales tax rate of 2%. As the average county-level sales tax rate is low (around 1.75%, see Table C.1), this would directly constrain the tax setting policy of 69% of the counties leading to a mechanical increase of 1.1 percentage point on average.[22]

Figure 3 represents the effects of the minimum tax on the tax rate chosen by counties in the new general equilibrium (that is, allowing all counties to change their tax rates afterwards). Figure 3a presents the change in tax rate imposed on counties that are directly affected by the minimum tax rate (treated counties). We find that the maximum tax increase to be of 2 percentage points, indicating that no treated counties over-react to the minimum tax by setting a tax rate above 2%.



(a) Treated counties.

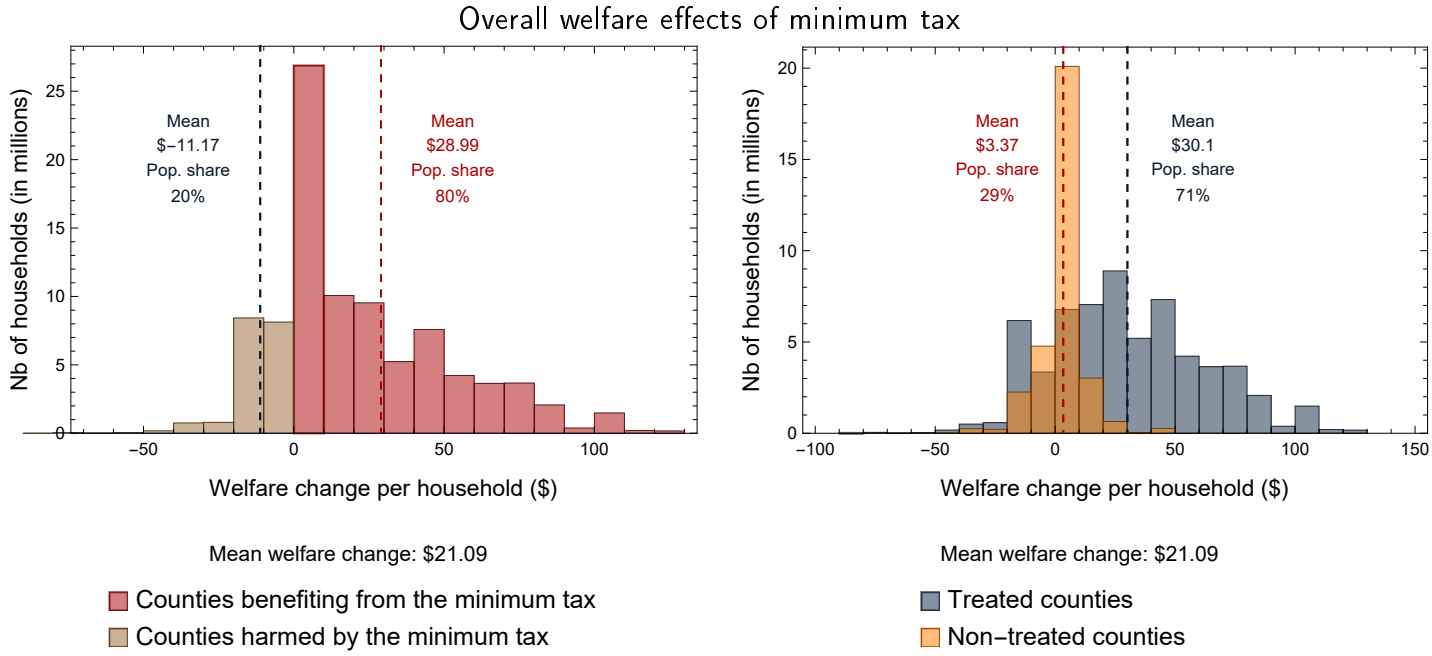
(b) Non-treated counties with negative tax reactions.

(c) Non-treated counties with positive tax reactions.

Figure 3. Change in tax rate in response to a 2% minimum tax. The figure represents the change in tax rate: $100 \times (t^{after} - t^{before})$.

[22] Figure G.1 reports for the share of counties constrained by different levels of minimum tax rates and the resulting mechanical tax rate change.

The strategic responses of counties with an initial tax rate above 2% (non-treated counties) are represented in Figure 3b and Figure 3c. A significant mass of counties decrease their tax rate (Figure 3b) while fewer counties increase their tax rate in the new equilibrium (Figure 3c). The range of positive reactions is larger than that of negative reactions. For this particular reform, a large mass of weakly strategic substitute neighbors dominates the scarcer strategic complement ones, so the average tax response is slightly negative. In absolute value, the tax adjustments of non-treated counties are small compared to treated counties. This reflects the fact that each county has a few treated neighbors changing their tax rates.



(a) Separating by winning and losing counties.

(b) Separating by treated and non-treated counties.

Figure 4. Total welfare effects of a minimum tax of 2%. The welfare effects are calculated in our full general equilibrium, allowing treated and non-treated counties to respond strategically. The horizontal axis represents the equivalent variation of the counties weighted by their populations, shown separately for different groups of counties with tax authority. The vertical axes are number of households. Table G.1 in Appendix G provides more details on welfare effects.

Figure 4 presents the welfare effects of the minimum tax, measured by the equivalent variation. We find that residents of treated counties are the winners of the policy, while the outcome is mixed in non-treated counties. On average, an individual values the benefits of the policy at $21. This number increases to $30.1 in treated counties but is only $3.4 in non-treated counties. With respect to the magnitude of the welfare changes, it is important to keep in mind that local sales tax rates in the U.S. are low. Therefore, it is useful to benchmark these numbers with respect to the local sales tax burden faced by households. In this respect,

the overall increase in welfare amounts to 5.3% of the per capita local sales tax burden. For treated and non-treated counties, the increase amounts to 8% and 0.5%, respectively.

The rationale of this welfare increase is that the minimum tax rate forces treated counties to increase significantly their tax rates so their population benefit from more public services overcoming the cost of paying higher taxes.[23] This is consistent with the finding that tax competition leads counties to set too low tax rates in the first place (Zodrow and Mieszkowski, 1986; Wilson, 1986). The small welfare effects on non-treated counties are not surprising as these counties are only indirectly affected by the minimum tax. Note also that the welfare effects are more dispersed among treated counties, reflecting the fact that these counties experience the largest change in their tax rates.

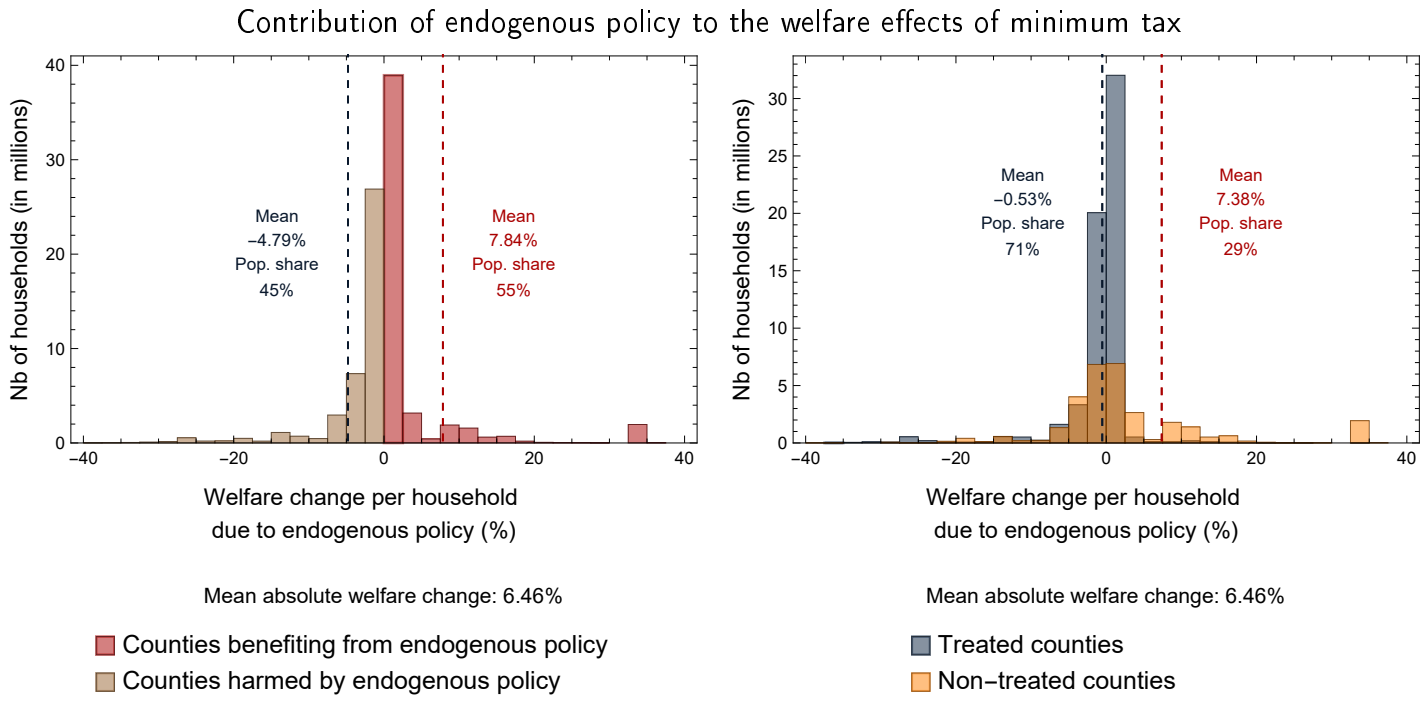
How much of these welfare effects are due to endogenous policy responses? We answer this question by comparing the above welfare effects with a counterfactual world in which counties are not allowed to autonomously set their tax rates. For each county we first calculate the equivalent variation with endogenous policy responses EV^{endo} and then the equivalent variation without endogenous responses EV^{exo}. The percent change is then relative to the scenario with endogenous policy responses, $100 \times (EV^{endo} - EV^{exo})/|EV^{endo}|$. As this can be positive or negative, the average effect is reported as the mean of the absolute deviation.

Figure 5 presents the distribution of the difference in equivalent variations due to endogenous tax setting. The (absolute value of the) welfare effect of allowing governments to strategically respond amounts to around 6.4%. As a result, not counting for endogenous policy in a quantitative model would lead to substantial biases in the welfare effects. This mean contribution masks a substantial heterogeneity with endogenous policy contributing to 29% of the welfare effect at the 95th percentile of the (absolute value of the) distribution. Figure 5 also shows the extent of heterogeneity among winners and losers from endogenous tax setting: 55% of the population benefit from endogenous tax setting with an increase in welfare due to tax competition of 7.8% on average (33% at the 95th percentile of winners) while 45% of the population lose from endogenous tax setting with an average loss due to it of 4.8% (19% at the 95th percentile of losers). Among non-treated counties, endogenous policy making accounts for 7.4% of their welfare gains. For treated counties, the effect is slightly negative -0.5%, meaning that endogenous tax setting dampens the welfare gains for these counties.[24] The non-treated counties drive the welfare differences with endogenous policy, as these are the

[23] Figures G.2 and G.3 in Appendix G further decompose the welfare effects of the minimum tax into public and private gains.

[24] Figure G.4 in the Appendix G correlates the change in tax rate and the change in welfare. Results indicate that counties increasing their tax rates are more likely to benefit from endogenous policy responses than counties reducing their tax rates.

jurisdictions who react strategically to the treated jurisdictions.



(a) Separating by winning and losing counties.

(b) Separating by treated and non-treated counties.

Figure 5. This graph represents the percent change in equivalent variations of a minimum tax of 2% with strategic interactions relative to without strategic interactions. Percent change are defined as $100 \times (EV^{endo} - EV^{exo})/|EV^{endo}|$. The average welfare effect of endogenous policy is computed as the mean absolute value of the welfare change. The sample includes all counties with taxing authority.

4.2. The Welfare Effects of Tax Harmonization

Appendix H studies the welfare effects of (partial) tax harmonization (Fajgelbaum et al., 2019; Hines, 2023) imposing both a minimum and a maximum tax rate of 1% and 2.5%, respectively. This corresponds to a policy in which all states allowing for a local sales tax would require their counties to choose a tax rate within a bandwidth of 0.7 percentage points around the mean tax rate of all counties in those states (around 1.75%). We can therefore investigate whether the welfare effects differ between counties treated from above ("top-treated") or from below ("bottom-treated").

In our baseline scenario of a bandwidth of 0.7 percentage points, partial tax harmonization leads to an overall welfare decrease of −$9 driven by top-treated counties that are forced to decrease their tax rate (see Table H.1 and Figure H.2). These results extend those observed for the introduction of a minimum tax: counties that have to increase (decrease) their tax rate experience a welfare gain (loss), suggesting that observed tax rates are loo low. Comparing

our welfare effects with and without endogenous tax setting also leads to a similar conclusion as for minimum taxes: endogenous policy responses amount on average to 5.6% of the welfare effects with 56% of the population benefiting from endogenous tax setting and 44% of the population losing from it (Figure H.3)

What would be the optimal minimum tax rate? Is partial harmonization preferable to a minimum tax, or could another policy result in higher aggregate welfare? Answering these questions is inherently challenging, as it requires comparing a broad spectrum of policies. Moreover, since such policies inevitably create both winners and losers, it is necessary to adopt a clear stance on the objective function of a social planner. To advance this discussion, we focus instead on the essence of tax competition: the interdependence of tax setting among a network of local jurisdictions. In Section 5, we introduce a new concept—the Policy Network Matrix (PNM)—along with two associated measures of the degree of tax competition: Policy Responsiveness and Policy Impact. In Section 6, we show that Policy Impact is a key determinant of the welfare effects of tax competition and provide evidence that any optimal policy should incorporate this measure into its design.

5. The Policy Network of Tax Reforms

The Policy Network Matrix (PNM) is the extension to a general spatial equilibrium economy of the well-known spatial weight matrix and its coefficients estimated in many prior tax competition papers (see Agrawal et al., 2022, for a review). It is defined as follows.

Definition 1. *The Policy Network Matrix (PNM), denoted* $\boldsymbol{\Omega}$*, is an* $J \times J$ *matrix including all bilateral interjursidiction tax reaction functions evaluated at the general equilibrium of the economy. The element of the* i^{th} *row and* j^{th} *column of the PNM,* ω_{ij} *is the tax response of jurisdiction* i *to a marginal change in jurisdiction* j*'s tax rate, taking as fixed the tax rates in all other counties:* $\omega_{ij} = \partial t_i / \partial t_j$.

Intuitively, the PNM is the first-order tax change of any county to a tax change in any other county (or set of counties) through spatial general equilibrium linkages. It is a matrix with J^2 entries resulting from possibly highly nonlinear tax functions. It differs from the general equilibrium tax changes in our counterfactual exercises as it is derived taking as fixed the tax rates of all other counties.

Using network terminology, the PNM is a proper *adjacency matrix* describing the network consisting of the set of the jurisdictions (*nodes*) connected by their pairwise best policy responses, ω_{ij} (*links*)—see Jackson (2008) for a survey. As policy responses are non-binary links that vary in intensity, the network is *weighted*; and as policy responses are asymmetric,

$\omega_{ij} \neq \omega_{ji}$, the network is *directed*. Another network property of the PNM is that it represents a *strongly connected* network because the general equilibrium implies that each jurisdiction's tax change can affect the tax setting of every other jurisdiction by a direct path.

5.1. Computation of the Policy Network Matrix

The PNM includes all the tax reaction functions evaluated at the general equilibrium. Its computation requires differentiating the first-order conditions of the local governments introduced in Subsection 2.7, subject to the general equilibrium of the private economy defined in Subsection 2.6. This section derives in four steps the closed-form expression of the PNM using the implicit function theorem. Importantly, although the following derivation of the PNM is motivated by our particular quantitative model, the resulting formula of the PNM is general and does not assume any particular structure; it applies to any quantitative model.

Step 1: General Equilibrium of the Economy

As the PNM is evaluated at the equilibrium, we first need to compute the general equilibrium of the economy as described in Subsection 2.8. In particular, this step computes the levels of the three key endogenous variables—the prices, p_i, the price indices, P_i, and the state public services, G_i—and their partial equilibrium responses to taxation—$\partial p_i/\partial t_i$, $\partial P_i/\partial t_i$ and $\partial G_i/\partial t_i$ evaluated at their general equilibrium levels $\{t_i^\star\}_{i=1}^J$, $\{p_i^\star\}_{i=1}^J$, $\{P_i^\star\}_{i=1}^J$ and $\{G_i^\star\}_{i=1}^J$.

Step 2: General Equilibrium Economic Responses to Taxes: Tax Incidence

How do economic variables, p_j, P_j an G_j vary in all counties as some (not necessarily all) taxes change exogenously? To answer this question, we need to compute the actual general equilibrium responses to a tax change. We therefore totally differentiate the general equilibrium system $(\mathcal{E}_i)_{i=1...,J}$ which gives $\mathbf{A}\,\mathbf{dZ} = \mathbf{B}\,\mathbf{dt}$, where $\mathbf{dt}' = (\mathrm{d}t_1 \dots \mathrm{d}t_J)$ is the aggregate tax response vector, $\mathbf{dZ}' = (\mathbf{dZ}_1' \dots \mathbf{dZ}_J')$ with $\mathbf{dZ}_i' \equiv (\mathrm{d}p_i \quad \mathrm{d}P_i \quad \mathrm{d}G_i)$ is the aggregate vector of economic changes, $\mathbf{A}$ is a $3J \times 3J$ matrix and $\mathbf{B}$ is a $3J \times J$ matrix which can both be fully computed from the step 1 (their explicit expressions are derived in Appendix I). Inverting this system, we obtain the economic responses to exogenous tax changes:

$$\mathbf{dZ} = \boldsymbol{\Pi}\,\mathbf{dt} \tag{25}$$

where $\boldsymbol{\Pi} \equiv \mathbf{A}^{-1}\,\mathbf{B}$ is a $3J \times J$ matrix which represents the Jacobian of the economic prices with respect to exogenous tax changes. Hereafter, we call this matrix the *price response matrix*. It is important as it allows us to infer, for any vector of small exogenous tax changes, the

resulting incidence on all the prices of the economy.

Step 3: Behavioral Tax Responses to Economic Changes

The next step is to determine the responses of taxes, $\mathrm{d}t_i$, to changes in the economic variables, $\mathrm{d}p_j$, $\mathrm{d}P_j$ and $\mathrm{d}G_j$. To do so, we need to totally differentiate the governments' first-order conditions based on two important preliminary observations.

First, immediate inspection of the expression of county i's first-order condition (23) indicates that it only includes county i's variables. This property is due to Assumption 1, which means that (16)-(18) so all derivatives of p_j, P_j, and G_j in this system with respect to $t_i, \forall j \neq i$ are zero. This is computationally particularly useful because it will allow us to compute the tax responses to economic variables for each county separately.[25] Second, a property of the government's decision rule compared to other economic agents (households and firms) is that this rule depends on (anticipated) price responses ($\partial p_i/\partial t_i$, $\partial P_i/\partial t_i$ and $\partial G_i/\partial t_i$).[26] Hence, differentiation of the government's first-order condition generates second-order terms: the differential of these price derivatives, $\mathrm{d}(\partial p_i/\partial t_i)$, $\mathrm{d}(\partial P_i/\partial t_i)$, and $\mathrm{d}(\partial G_i/\partial t_i)$. Intuitively, these terms capture the fact that, as a government observes a change in the economy, it re-evaluates the responses of economic variables to its policy in order to choose the appropriate tax rate.

In sum, the above two observations imply that we need to totally differentiate county i's first-order condition together with the three-equation first-order partial equilibrium system ($\mathrm{d}\mathcal{E}_i$). From the implicit function theorem, total differentiation of this $4J$-equation system can be written in matrix form as $\mathbf{K}_i \mathbf{dV}_i = \mathbf{L}_i \mathbf{dZ}_i$, where $\mathbf{dV}_i' \equiv (\mathrm{d}t_i \quad \mathrm{d}(\partial p_i/\partial t_i) \quad \mathrm{d}(\partial P_i/\partial t_i) \quad \mathrm{d}(\partial G_i/\partial t_i))$ is the vector of local tax and second-order responses, $\mathbf{dZ}_i'$ is the vector of changes in economic variables already introduced, and $\mathbf{K}_i$ is a 4×4 matrix and $\mathbf{L}_i$ is a 4×3 matrix which can both be fully computed from the step 1 (see Appendix I for their explicit expressions). Inverting this system allows us to compute the tax and second order responses as $\mathbf{dV}_i = \mathbf{K}_i^{-1} \mathbf{L}_i \mathbf{dZ}_i$, from which we can extract:

$$\mathbf{dt} = \mathbf{H}\,\mathbf{dZ} \tag{26}$$

where $\mathbf{H}$ is a $I \times 3J$ block diagonal matrix. Relation (26) represents the tax response to changes in any economic variables treating changes in prices as exogenous. Importantly, the price changes can result from any possible cause. They may be the result of a tax reform as analyzed in this paper, but they can also be caused by any other policy (such as. e.g., a

[25] Let us reiterate that Assumption 1 has minimal impacts on our estimates of the welfare effects of endogenous policy setting. The gain in tractability allows us to study the mechanisms underlying these welfare effects.

[26] Immediate derivation of the government's objective function (20) yields: $\frac{1}{E_i}\frac{\partial E_i}{\partial t_i} - \frac{1}{P_i}\frac{\partial P_i}{\partial t_i} + \frac{\nu}{\mathbb{G}_i}\frac{\partial \mathbb{G}_i}{\partial t_i}$

transportation infrastructure). Here we consider these economic responses to result from a tax change itself. These are the tax incidence effects as described in step 3 below.

Step 4: Policy Network Matrix

Combining steps 2 and 3 allow to compute the tax responses of any jurisdiction to changes in the tax rates by any other jurisdictions. Formally, inserting the price responses (25) into the tax responses (26), we obtain $\mathbf{dt} = \mathbf{O}\,\mathbf{dt}$, where $\mathbf{O} \equiv \mathbf{H}\boldsymbol{\Pi}$. Notice that as a jurisdiction's tax rate appears on both sides of the equation, we need to zero-out the diagonal. After trivial matrix manipulation, we get:

$$\mathbf{dt} = \boldsymbol{\Omega}\,\mathbf{dt}, \qquad \text{or equivalently,} \qquad \mathrm{d}t_i = \sum_j \omega_{ij}\mathrm{d}t_j, \tag{27}$$

where $\boldsymbol{\Omega} \equiv (\mathbf{I} - \mathbf{O}^d)^{-1}(\mathbf{O} - \mathbf{O}^d)$. $\mathbf{I}$ is the identity matrix and $\mathbf{O}^d$ is the diagonal matrix whose diagonal elements are the diagonal elements of $\mathbf{O}$, and off-diagonal elements are zero. $\boldsymbol{\Omega}$ is a $J \times J$ non-symmetric matrix in which all the diagonal elements are zeros. It collects the set of endogenous weights composing the Policy Network Matrix.[27]

5.2. Properties of the Policy Network Matrix

The Policy Network Matrix is a spatial general equilibrium measure with three important properties: nonlinearity, endogeneity, and heterogeneity. We discuss each in turn.

In a spatial general equilibrium economy, tax response functions, $t_i = f_i(t_1, ..., t_J)$, are implicitly defined by highly nonlinear first-order conditions. This implies that the slope of these function depend on the levels of the tax rates. The slope of these functions represents the strategic response of i to a small tax change of competitor(s) tax rate(s) in $j \neq i$. Consequently, the PNM will measure the marginal effect around the initial equilibrium.

Observation 1 (**Nonlinearity**). *The tax response function is nonlinear. Consequently, the PNM measures marginal tax responses around the initial equilibrium and cannot be used to determine the level of the tax rate.*

Nonlinear tax functions mean that strategic responses may vary widely across jurisdiction pairs. There are two sources of heterogeneity in the policy responses of jurisdictions. First, the tax response function, $t_i = f_i(t_1, \ldots, t_{i-1}, t_{i+1}, \ldots, t_J)$, can be jurisdiction specific—even

[27] Equation (27) makes clear that the PNM $\boldsymbol{\Omega}$ can be used to analyze the local stability of any tax reform $\mathbf{dt}_0$ by examining its eigenvalues. Our quantification in Appendix J shows that all eigenvalues have an absolute value less than 1, indicating that any tax reform is locally stable.

if jurisdiction have the same tax rates, they can respond differently to a unit change in taxes. Second, even if the function was not jurisdiction-specific, $t_i = f(t_1, \ldots, t_{i-1}, t_{i+1}, \ldots, t_J)$, the slope of the response function near the equilibrium may differ because the equilibrium levels of tax rates are different in the first place.

Typically, for a sample of size J jurisdictions, we need to estimate the J^2 entries of the PNM. This contrasts with the prior reduced-form literature that estimates a single parameter rather than J^2 pairwise responses. Estimating a single response forces all jurisdictions' tax rates to be either strategic substitutes or strategic complements. Yet, both cases could coexist. In other words, strategic responses differ not only in magnitudes, but may also differ in sign depending on the characteristics of the competitor jurisdiction. Only a structural approach like ours can recover this key heterogeneity. See Appendix J for a discussion that compares our approach with the reduced-form literature.

This leads to Observation 2:

Observation 2 (**Heterogeneity**). *The Policy Network Matrix's components are heterogeneous:*

(i) The Policy Network Matrix is not symmetric.

(ii) The Policy Network Matrix may include positive, negative and zero terms.

One reason why policy responses are heterogeneous is because endogenous price changes and fiscal externalities differ dramatically across space. The PNM is a function of all of these endogenous linkages. Therefore, by definition, it is itself endogenous:

Observation 3 (**Endogeneity**). *The Policy Network Matrix is endogenous.*

An important implication of the endogeneity of the Policy Network Matrix is that in addition to the standard simultaneity of tax rates, the individual elements of the PNM are endogenous. Thus, any reduced-form approach would require both instruments for tax rates and instruments for the elements of the weight matrix.

The PNM is a powerful tool for two reasons: first, it allows us to recover the linkages and the extent of competition between jurisdictions. While the prior literature has resorted to ad hoc proxies (e.g., contiguity) the PNM places no a priori constraints on who/where the competitors are. Second, the PNM can be used to approximate, still accurately, the effects of different counterfactual policy scenarios near the equilibrium without the need to solve for complex and computationally intensive general equilibrium effects in the case of a large number of jurisdictions.[28] This is stated in Observation 4 and formally derived in Appendix J.2.

[28] As the PNM is a local approximation of the tax responses near the observed equilibrium, we assess in

Observation 4 (**Counterfactual**). *Evaluation of local counterfactual policy scenarios accounting for strategic responses of governments can be assessed using the PNM and the general equilibrium price response matrix. Formally, for any counterfactual exercise that exogenously changes the tax rates in a set of jurisdictions,*

(i) compute the change in the tax rates of all other jurisdictions using the PNM,

(ii) compute the change in the general equilibrium prices due to changes in the tax rates in all jurisdictions using (25)*,*

(iii) the impacts on economic variables can then be measured by differentiation of conditions (11)–(14)*.*

Observation 4 extends the *network effects of trade shocks* characterized in Allen et al. (2020) and Baqaee and Farhi (2024) (steps *ii* and *iii*) by accounting for the extra network effects of strategic governments' decisions (step *i*). Existence and uniqueness of the local policy counterfactual is guaranteed by the implicit function theorem (Allen et al., 2020). The usefulness of step *i* of Observation 4 will be shown in Section 6.

5.3. Summarizing the PNM: Policy Responsiveness and Policy Impacts

While the PNM yields all pairwise relationships in the economy, when studying thousands of local governments, it is useful to construct economically-meaningful summary measures of this matrix. We propose two such measures—policy responsiveness and policy impact—the first of which is consistent with prior reduced-form studies, while the latter is novel to the literature and will be the relevant measure that drives the welfare effects of tax competition.

Policy responsiveness is obtained by row-standardizing the Policy Network Matrix, making it comparable to reduced-form spatial weight matrices that are usually standardized so each row sums to unity. Denote each element of the PNM, where i indexes rows and j indexes columns, as $\omega_{ij} = \partial t_i / \partial t_j$. Then, the row-sum of these elements yields policy responsiveness β_i for each jurisdiction i. It measures how jurisdiction i's tax rate responds to a simultaneous 1 unit change in the tax rates of all other jurisdictions.

Definition 2 (**Policy Responsiveness**). *The policy responsiveness (PR) of jurisdiction i is:*

$$\beta_i \equiv \sum_j \omega_{ij} = \sum_j \frac{\partial t_i}{\partial t_j}. \tag{28}$$

Appendix J.3 the accuracy of this approximation by comparing the tax change predicted by the PNM with the tax change obtained by solving for the general equilibrium; they are highly correlated.

To link to prior reduced form work, policy responsiveness is analogous to coefficient b from a regression of $t_i = a + b\bar{t}_i + e_i$ where $\bar{t}_i$ is the spatial lag of competitor tax rates (Brueckner, 2003). However, relative to this literature which estimates a single slope parameter b, note that our policy responsiveness is allowed to vary across jurisdictions, thus allowing us to quantify the extent of heterogeneous responses in Subsection 6.1.

If, instead, the PNM is column-standardized rather than row-standardized, a new important measure emerges: policy impact. It measures the aggregate impact of a one unit increases in jurisdiction j's tax rate on all other jurisdictions tax rates. While policy responsiveness yields the effect of the economy on a single jurisdiction, policy impact yields the effect of a singe jurisdiction on the economy.

Definition 3 (**Policy Impact**). *The policy impact (PI) of jurisdiction j is:*

$$\gamma_j \equiv \sum_i \omega_{ij} = \sum_i \frac{\partial t_i}{\partial t_j}. \tag{29}$$

Policy impact is novel to the tax competition literature because estimating the effect of a single (small) jurisdiction on the rest of the economy is challenging. This stems from the premise that reduced-form researchers do not have enough degrees of freedom to estimate all pairwise responses in the economy. As shown in Subsection 6.2, policy impact will be more heterogeneous across jurisdictions than policy responsiveness.

While novel to strategic policy setting, β_i and γ_i represent standard centrality statistics of a network. The network literature calls $\beta_i = \sum_j \omega_{ij}$ the *in-degree* of node i—the extent to which node i is influenced by others—and $\gamma_i = \sum_j \omega_{ji}$ the *out-degree* of node i—the influence exerted by node i on others. In Appendix J, we quantitatively compare our measure of Policy Impact with other measures of centrality: eigenvector centrality, Katz-Bonacich centrality and intercentrality, as well as multilateral resistances in the trade literature.

In practice, β_i and γ_i for a given county need not be similar. For example, a large county may be little influenced by other counties but have a significant impact on them. We will quantify and compare both both measures and their heterogeneity across all U.S. counties. While we have defined each of these terms by summing over the entire row or column, they can easily be extended to summations over a smaller set (e.g., neighboring) jurisdictions.

Although the PR and the PI will in general differ for a particular county, an important property is that, on average, both are equal. This is summarized in the following proposition:

Observation 5 (**Average Policy Competition Effect**). *The average policy responsiveness is equal to the average policy impact:*

$$\overline{\beta} = \overline{\gamma},$$

where $\overline{\beta} \equiv \sum_i \beta_i/J$ *is the mean of the PRs and* $\overline{\gamma} \equiv \sum_j \gamma_j/J$ *is the mean of the PIs.*

Proof. The proof mechanically follows from Definitions 2 and 3. Indeed, $\overline{\beta} = \sum_i \beta_i/J = \sum_i \sum_j \omega_{ij}/J = \sum_j \gamma_j/J = \overline{\gamma}$. □

Observation 5 is important for quantitatively analyzing policy competition. It guarantees that the policy responsiveness, β_i, and the policy impacts, γ_i, are comparable measures on average.[29] In the extreme case in which all jurisdictions have the same responsiveness to tax competition, and in which they all trigger the same aggregate impacts on their neighbors, Observation 5 implies that a jurisdiction's exposure and impact are equal, i.e. $\forall i, \beta_i = \gamma_i$.

6. Policy Network Matrix and Welfare Effects

We now quantify the PNM and its summary measures in the context of sales tax competition.

6.1. Policy Network Matrix

Figure 6.a plots the elements of the Policy Network Matrix, $\partial t_i/\partial t_j$, for the counties allowed to set local tax rates where the vertical axis represents county i and the horizontal axis represents county j. Counties are sorted by straight-line distance from the most northwest county.[30]

A first striking feature of Figure 6.a is that the PNM is not symmetric. A county i might react to a change in the tax rate of county j differently than county j reacts to county i. Moreover, as acknowledged in models of oligopolistic competition (Bulow et al., 1985), tax rates can be either strategic complements (red color scale) or strategic substitutes (blue color scale), depending on two possible offsetting economic forces:

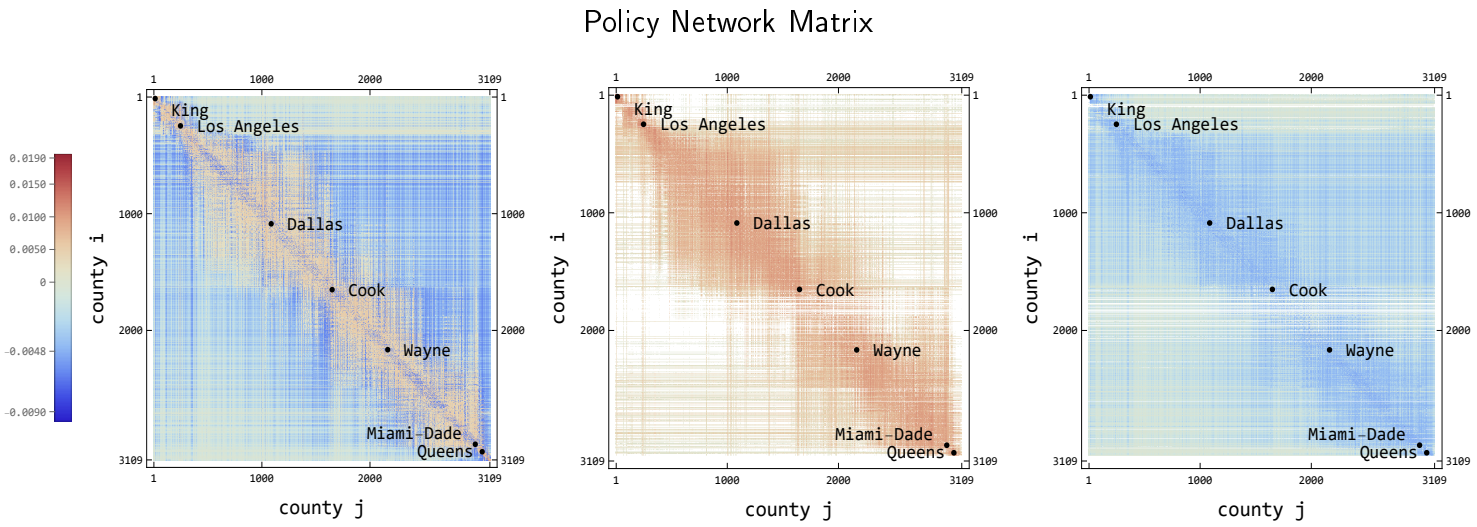
1. *tax base effects*: a tax increase in j expands the tax base of competitor jurisdictions i, creating incentives for the i jurisdictions to raise their tax rate because of the larger base and the desire to engage in tax exporting,

2. *price effects*: a tax increase in j increases the price of that variety paid by residents of i, which jurisdiction i seeks to compensate by lowering its tax rate.

Figure 6.b and Figure 6.c further decompose the PNM into positive and negative values. Comparing panels b and c reveals that strategic complementarity in tax rates is more

[29] An implicit assumption for Observation 5 to hold is that the PNM is a square matrix. If policy impact and policy responsiveness are calculated by summing over a subset of jurisdictions, this property will not hold.
[30] Note that in Figure 6 two geographically nearby counties will be represented as adjacent cells, but not all adjacent cells represent nearby counties.

likely to arise among geographically close neighbors (around the diagonal), while tax rates as strategic substitutes are more likely among more distant (away from the diagonal) neighbors. Furthermore, positive tax reactions are larger than negative reactions which are very small in absolute value. This result is intuitive: tax base effects are likely to be strongest among proximate neighbors and price effects to slightly dominate for more remote jurisdictions.



(a) All elements of the PNM $\partial t_i/\partial t_j$.

(b) Positive elements of the PNM ($\partial t_i/\partial t_j > 0$).

(c) Negative elements of the PNM ($\partial t_i/\partial t_j < 0$).

Figure 6. Policy Network Matrix. The figure represents the elements of the PNM for the 3,109 counties. Counties are sorted by straight-line distance from the most northwest county. A cell of the matrix has element $\partial t_i/\partial t_j$ where i represents a row and j a column.

Last, policy reactions are stronger in absolute value (darker color) when jurisdictions are closer to each other, while more distant jurisdictions are less likely to engage in strategic competition. This is confirmed by Table 5 that breaks down the average tax reactions (separately for positive and negative values) according to the distance of the neighbors.

Table 5. Spatial gradient of the components of the PNM.

	$\partial t_i/\partial t_j > 0$		$\partial t_i/\partial t_j < 0$	
	Mean	SD	Mean	SD
Adjacent neighbors	0.0022	0.0047	−0.0023	0.0052
Non-adjacent neighbors within 60 miles	0.0016	0.0036	−0.0007	0.0016
Non-adjacent neighbors between 60 and 90 miles	0.0012	0.0032	−0.0003	0.001
Non-adjacent neighbors between 90 and 120 miles	0.001	0.0028	−0.0002	0.0005

Although distance is a powerful force in determining the heterogeneity of responses, it is

not the only force—this can be seen by the dark long lines for some counties in Figure 6. In our model, strategic reactions to depend on other location fundamental such as size, socio-economic variables, and political characteristics, which we will explore subsequently. The fact that elements of the PNM can be heterogeneous across multiple dimensions adds substantial flexibility relative to prior models that only allow contiguity or distance to matter. Finally, while the numbers in the table may appear small, they are the pair-wise responses and not the aggregate responses estimated in studies of tax reaction functions. This leads us to our summary measures of policy responsiveness and policy impact.

6.2. Policy Responsiveness and Policy Impact

First focusing on policy responsiveness, Panel A of Table 6 indicates that if all other counties in the economy increase their tax rate by one percentage point, the average county response is to increase its tax rate by 0.09 percentage points. This aggregate effect masks some of the heterogeneity by summing both positive and negative pairwise responses. The second row of this panel show that on average, 20% of a given jurisdiction's responses are positive and thus 80% of these pairwise responses are negative. Yet, as the aggregate effect is positive, this shows that despite being less frequent, complementary responses are much larger in magnitude.

The tax responses are in the lower range of those in prior tax competition work, perhaps because we focus on all bilateral competition. That literature estimates that if its average neighbors' tax rate increase by one percentage point a sales tax jurisdiction increases its tax rate by 0.10 and 0.35 percentage points (Devereux et al., 2007; Agrawal, 2016). These estimates, using ad hoc assumptions on who competitors are, provide the link from the reduced-form literature to our measure of policy responsiveness.

Table 6. Policy Responsiveness, Policy Impact, strategic complementarity and strategic substitutability of the 2,621 counties with tax authorities.

	Mean	SD	Min	Max	Obs
A. Policy Responsiveness					
Policy responsiveness (β_i)	0.085	0.033	−0.188	0.212	2621
Share of positive reactions in β_i (%)	20.04	23.86	2.9	97.46	2621
B. Policy Impact					
Policy impact (γ_i)	0.085	0.274	−0.395	5.55	2621
Share of positive reactions in γ_i (%)	21.06	8.52	8.91	89.48	2621

NOTE— β_i and γ_i are sums over the 3,019 counties in the sample. The standard deviations of the positive and negative shares are equal because two vectors with a constant component-wise sum have equal standard deviations.

Next, focusing on policy impact, Panel B of Table 6 indicates—consistent with Observation 5—the mean policy impact is very similar to the mean policy policy responsiveness.[31] In words, on average, a one unit change in a given county's tax rate raises the tax rate of all other counties by 0.085 percentage points.

Importantly, while the average policy responsiveness and policy impact are similar, the standard deviation of policy impact is 8.3 times larger than policy responsiveness. Policy impact is much more heterogeneous across jurisdictions than policy responsiveness. We next turn to why one of the metrics is more heterogeneous than the other and what characteristics of jurisdictions drive this heterogeneity.

Further evidence of this difference between PR and PI are reported in Figure 7 which represents these two indicators with respect to population quantiles—Appendix J.4 reports the specific cases of the states of New York and California.

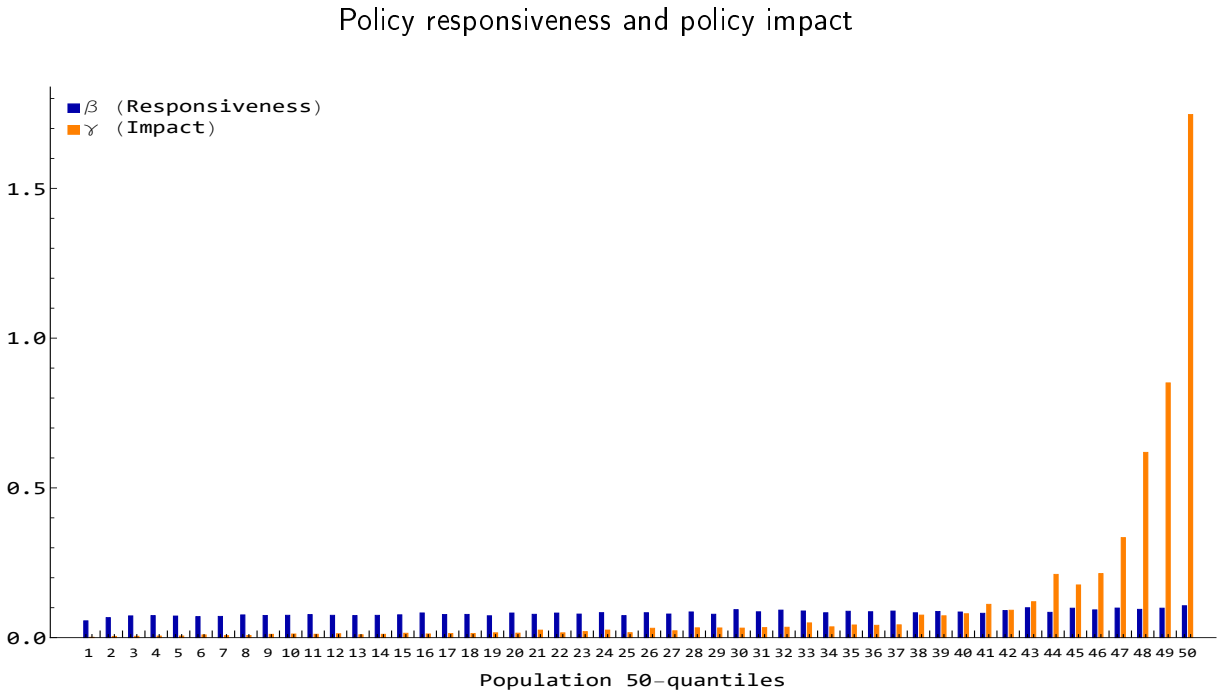


Figure 7. Policy responsiveness and policy impact with respect to the county population.

Figure 7 confirms that the policy responsiveness of all counties are essentially similar even though several larger counties like New York and Los Angeles are in the lower range. It also confirms that the policy impact is strongly heterogeneous with only a few large counties having

[31] In theory, both means should be identical, but in this table we only report the averages over the 2,403 counties with taxation authority. The average over all counties is indeed the same for PI and PR.

an impact being non-negligible. Among them, the largest counties have strikingly high PIs.

Table 7 reports the results of the regressions of the PR and the PI of the counties on several exogenous variables, focusing on the effects of size of the jurisdiction and the size of nearby competitor jurisdictions. Our model features several sources of heterogeneity including population, income, state taxes, and the number of firms. Despite the multiple sources of heterogeneity in the model we find that own-jurisdiction and neighboring jurisdictions populations explains most of the variation in our new metric, policy impact. In particular a regression of policy impact on population variables yields an R^2 of 0.59, while adding other variables only increases this to 0.65. This contrasts with policy responsiveness where these variables do not explain much of the variation ($R^2 = 0.04$).

In addition to explaining little of the variation of policy responsiveness, own-jurisdiction population has no significant correlation with policy responsiveness. At best, policy responsiveness has a slight correlation with neighboring jurisdiction population. Population is not able to explain much of policy responsiveness because, by definition, it captures the effects from changes in the rest of the economy.

Turning to policy impact, relative population sizes are the key explanatory variables. With respect to own-jurisdiction population, bigger jurisdictions have a higher impact on the rest of the economy. The negative relationship with neighboring population further indicates that it is relative size that matters, though the relationship with own-population is almost three times larger than neighboring population.

Panel B indicates that, as expected, opposite effects are observed for the policy impact. A county's tax rate responds more to a joint increase in its neighbors' tax rates the larger these neighbors. This effect is intuitive, as bigger neighbors are expected to generate larger tax base spillovers. In sum, these results show that in order to understand the policy responses of a county one needs to consider not only its size, but also the size of the other counties with which it directly interacts.

6.3. Policy Impact and Welfare Effects

The Policy Network Matrix provides useful information for designing potential tax reforms. It may help policymakers to target subgroups of jurisdictions according to their policy impact or, as shown in Table 7, by using a close proxy to it such as population.

Table 7. Policy responsiveness, policy impact and covariates.

	(1)	(2)	(3)	(4)
	Responsiveness β		Impact γ	
Population n_i	−0.002	0.015	1.722***	2.753***
	(0.006)	(0.012)	(0.526)	(0.552)
Population squared n_i^2		−0.009		−0.524***
		(0.007)		(0.140)
Population of an average neighbor within 120 miles n_i^{neigh}	−0.031	−0.139***	−0.806**	−0.938***
	(0.023)	(0.022)	(0.302)	(0.343)
Population squared of an average neighbor within 120 miles $n_i^{neigh\,2}$		0.137***		−0.006
		(0.019)		(0.320)
N	2621	2621	2621	2621
Adjusted R squared	0.685	0.694	0.594	0.647
Adjusted R squared (no control and no state FE)	0.034	0.036	0.519	0.589
Marginal effect of n_i		0.014		2.716***
		(0.012)		(0.543)
Marginal effect of n_i^{neigh}		−0.129***		−0.938***
		(0.021)		(0.328)

NOTE— * $p < 0.10$, ** $p < 0.5$, *** $p < 0.1$. Standard errors in parentheses are clustered at the state level. The sample includes all counties with tax authority. All population variables are in millions for readability. All the regressions include state fixed effects and the county control variables reported in Table C.1.

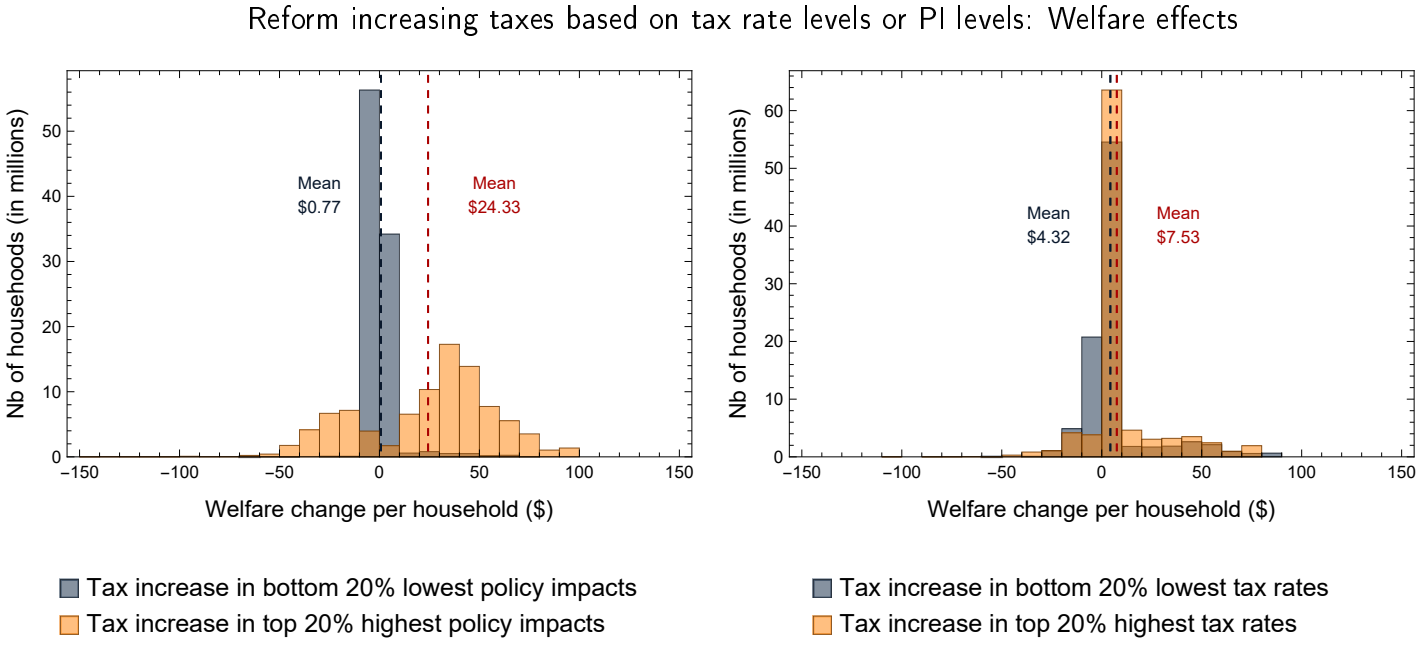
To illustrate this, this section considers several different counterfactual exercises that target different sub-groups of jurisdictions. The first imposes a tax increase of 1 percentage point for the bottom 20% of counties with the lowest policy impact. The second imposes the same tax increase, but now for the top 20% of counties with the highest policy impact. We compare these scenarios with conventional reforms where policy makers target jurisdictions based on the level of the jurisdiction's tax rates (the top/bottom 20% with the highest/lowest tax rate). In all reforms, we impose a 1 percentage point increase, but we allow these jurisdictions to further change their tax rates in response to tax changes in the rest of the economy.[32]

Figure 8 offers intuitive insights on how to target tax coordination policies. A policy targeting jurisdictions with the largest policy impacts generates larger welfare effects than targeting low impact jurisdictions. In addition, comparing interventions that target based on policy impact have larger effects than when targeting based on the level of the tax rate, as is done with

[32] Appendix J.5 provides summary statistics on each of these target groups and supplements the results presents the results presented in this section.

minimum or maximum tax rates. In addition to comparing the overall welfare effects of the reform, we can compare the heterogeneity of how welfare changes across jurisdiction. When targeting based on the level of the tax rate, the distribution for targeting the highest and lowest tax jurisdictions are similar (Figure 8.b). However, with respect to policy impact, targeting high policy impact jurisdiction leads to a more dispersed distribution (higher variance) yet right-shifted (higher mean) distribution than targeting low policy impact jurisdiction.

As shown in Appendix J.5, targeting high policy impact jurisdictions results in a wider range of strategic tax adjustment in addition to a wider range of welfare effects among non-treated counties. Focusing on the initially non-treated counties, most raise their tax rates in response as high policy impact jurisdictions now set higher rates, but still these jurisdictions experience overall welfare losses. This welfare loss arises because residents of non-treated jurisdictions now pay higher taxes that benefit residents of the high policy impact jurisdictions (large jurisdictions). The welfare loss of higher prices by non-treated residents is partially offset by higher taxes and public services at home, but not enough to provide welfare gains because of the small tax bases in low policy impact (small) jurisdictions.



(a) Reform based on policy impact levels

(b) Reform based on tax rate levels

Figure 8. Total welfare effects of a targeted 1 percentage point increase in tax rates. In each case, 20% of the counties are constrained to increase their tax rates by 1 percentage point. All 2,621 counties with tax authority are subsequently allowed to change their taxes endogenously. The welfare effects (equivalent variation) include all counties with tax authority and are weighted by the counties populations.

7. Conclusion

Designing optimal policies when both economic linkages across heterogeneous jurisdictions and their own policy setting are endogenous is notoriously difficult. This paper makes two contributions in this direction. First, it introduces endogenous policies in a quantitative spatial model that features thousands of heterogeneous jurisdictions that compete both at the intensive and the extensive margins. We bring this model to the data to match local tax rates for all US counties, drawing on an elegant open-economy Ramsey rule. We show that various minimum-tax or tax-harmonization policies increase aggregate welfare, providing evidence that tax competition leads to socially suboptimal tax rates and is therefore harmful. Our key result underscores the importance of endogenizing policy responses when conducting counterfactual analyses. We estimate that ignoring endogenous policy responses can bias the estimates of the welfare effect of introducing minimum sales tax rate of 2% among U.S. counties by about 6.5%. This mean contribution basks substantial heterogeneity across place, with endogenous policy contributing to 29% of the welfare change at the 95th percentile.

Second, our Ramsey rule for optimal tax rates allows us to derive and quantify all bilateral policy linkages, thus identifying the key players in a tax competition game. Specifically, jurisdictions can be ranked according to two measures: the effect of each jurisdiction on the broader economy (policy impact) or the effect of the economy on each jurisdiction (policy responsiveness). We show our novel measure of policy impact is more critical for welfare than policy responsiveness. We show that targeted interventions focusing on key jurisdictions with the largest effect on the economy as a whole—that is, high-policy impact jurisdictions—will improve welfare by six times as much as traditional policies targeting low tax rates. However, while such targeted interventions increase welfare overall, the welfare effects are heterogeneous and some households may even lose due to higher prices.

Contrary to the conventional wisdom that the presence of low-tax jurisdictions constrain the tax-setting of high-tax jurisdictions, our results suggest that increasing the tax rates of high-impact jurisdictions (even if they already have relatively high tax rates) can yield larger welfare gains. In practice, measuring policy impact is complex and endogenous, but we find a strong correlation between policy impact and jurisdiction size. As a result, even simple policy rules that force larger jurisdictions to raise their tax rates relative to smaller jurisdictions improves welfare substantially. Intuitively, in a competitive equilibrium, tax rates of large (high-tax) and small (low-tax) jurisdictions may be too low, making public services inefficiently provided everywhere. In other words, the conventional view is that zero(low)-tax jurisdiction are parasitic on revenues in high-tax jurisdictions, but in equilibrium zero(low)-

tax jurisdictions might be the result of lower taxes everywhere else, not the cause. This is consistent with recent empirical work in local public finance showing that spending on local public services (education) is inefficiently low (Bayer et al., 2020)—especially so in urban and suburban jurisdictions.

References

Agrawal, D. R. (2015). The tax gradient: Spatial aspects of fiscal competition. American Economic Journal: Economic Policy 7(2), 1–30.

Agrawal, D. R. (2016). Local fiscal competition: An application to sales taxation with multiple federations. Journal of Urban Economics 91, 122–138.

Agrawal, D. R., W. H. Hoyt, and T. Ly (2023). A new approach to evaluating the welfare effects of decentralized policies. SSRN working paper 4009872.

Agrawal, D. R., W. H. Hoyt, and J. D. Wilson (2022). Local policy choice: Theory and empirics. Journal of Economic Literature 60(4), 1378–1455.

Ahlfedlt, G., D. Sturm, S. Redding, and N. Wolf (2015). The economics of density: Evidence from the Berlin Wall. Econometrica 83(6), 2127–2189.

Allen, T., C. Arkolakis, and X. Li (2024). On the equilibrium properties of spatial models. American Economic Review: Insights 6(4), 472–489.

Allen, T., C. Arkolakis, and Y. Takahashi (2020). Universal gravity. Journal of Political Economy 128(2), 393–433.

Anderson, J. E. and E. Van Wincoop (2003). Gravity with gravitas: A solution to the border puzzle. American Economic Review 93(1), 170–192.

Armington, P. S. (1969). A theory of demand for products distinguished by place of production. IMF Staff Papers 16(1), 159–178.

Bagwell, K. and R. W. Staiger (1999). An economic theory of GATT. American Economic Review 89(1), 215–248.

Bagwell, K. and R. W. Staiger (2004). The economics of the world trading system. MIT press.

Bagwell, K., R. W. Staiger, and A. Yurukoglu (2021). Quantitative analysis of multiparty tariff negotiations. Econometrica 89(4), 1595–1631.

Baker, S. R., S. Johnson, and L. Kueng (2021). Shopping for lower sales tax rates. American Economic Journal: Macroeconomics 13(3), 209–250.

Ballester, C., A. Calvó-Armengol, and Y. Zenou (2006). Who's who in networks. wanted: The key player. Econometrica 74(5), 1403–1417.

Baqaee, D. R. and E. Farhi (2024). Networks, barriers, and trade. Econometrica 92(2), 505–541.

Bayer, P., P. Q. Blair, and K. Whaley (2020). Are we spending enough on teachers in the US? National Bureau of Economic Research WP 28255.

Benzarti, Y., D. Carloni, J. Harju, and T. Kosonen (2020). What goes up may not come down: Asymmetric incidence of value-added taxes. Journal of Political Economy 128(12), 4438–4474.

Bordeu, O. (2024). Commuting infrastructure in fragmented cities. Princeton University.

Bruce, D., W. F. Fox, and A. M. Shute (2023). Wayfair: A step towards the destination, but sales tax competition remains. NBER WP 31074.

Brueckner, J. K. (2003). Strategic interaction among governments: An overview of empirical studies. International Regional Science Review 26(2), 175–188.

Brueckner, J. K. and L. A. Saavedra (2001). Do local governments engage in strategic property—tax competition? National Tax Journal, 203–229.

Bulow, J. I., J. D. Geanakoplos, and P. D. Klemperer (1985). Multimarket oligopoly: Strategic substitutes and complements. Journal of Political Economy 93(3), 488–511.

Caliendo, L. and F. Parro (2022). Trade policy. Handbook of International Economics 5, 219–295.

Caplin, A. and B. Nalebuff (1991). Aggregation and imperfect competition: On the existence of equilibrium. Econometrica 59(1), 25–59.

de Paula, A., I. Rasul, and P. Souza (2024). Identifying network ties from panel data: Theory and an application to tax competition. Review of Economic Studies.

Devereux, M. P., B. Lockwood, and M. Redoano (2007). Horizontal and vertical indirect tax competition: Theory and some evidence from the USA. Journal of Public Economics 91, 451–479.

Epple, D. and T. Romer (1991). Mobility and redistribution. Journal of Political Economy 99(4), 828–858.

Epple, D., T. Romer, and H. Sieg (2001). Interjurisdictional sorting and majority rule: An empirical analysis. Econometrica 69(6), 1437–1465.

Eugster, B. and R. Parchet (2019, August). Culture and taxes. Journal of Political Economy 127(1), 296–337.

Fajgelbaum, P., E. Morales, J. C. Suárez Serrato, and O. Zidar (2019). State taxes and spatial misallocation. Review of Economic Studies 86(1), 333–376.

Fajgelbaum, P. D. and C. Gaubert (2020, 01). Optimal spatial policies, geography, and sorting. The Quarterly Journal of Economics 135(2), 959–1036.

Ferrari, A. and R. Ossa (2023). A quantitative analysis of subsidy competition in the U.S. Journal of Public Economics 224, 104919.

Fujita, M., P. R. Krugman, and A. Venables (2001). The spatial economy: Cities, regions, and international trade. MIT press.

Gaubert, C., P. Kline, D. Vergara, and D. Yagan (2024). Place-based redistribution. NBER Working Paper 28337.

Goldberg, P. K. and G. Maggi (1999). Protection for sale: An empirical investigation. American Economic Review 89(5), 1135–1155.

Grossman, G. M. and E. Helpman (1994). Protection for sale. American Economic Review 84(4), 833–850.

Harding, M., E. Leibtag, and M. F. Lovenheim (2012). The heterogeneous geographic and socioeconomic incidence of cigarette taxes: evidence from Nielsen homescan data. American Economic Journal: Economic Policy 4(4), 169–198.

Head, K. and T. Mayer (2014). Gravity equations: Workhorse, toolkit, and cookbook. In Handbook of International Economics, Volume 4, pp. 131–195. Elsevier.

Hebous, S. and M. Keen (2023). Pareto-improving minimum corporate taxation. Journal of Public Economics 225, 104952.

Hines, Jr, J. R. (2023). Evaluating tax harmonization. National Bureau of Economic Research WP 31900.

Hines, Jr., J. R. (2024). Evaluating minimum taxation. National Bureau of Economic Research WP 33140.

Hoyt, W. H. (1991). Property taxation, Nash equilibrium, and market power. Journal of Urban Economics 30(1), 123–131.

Huynh, D., A. Sokolova, and M. S. Tosun (2022). Tax elasticity of border sales: A meta-analysis. SSRN WP 4203197.

Jackson, M. (2008). Social and Economic Networks. Princeton University Press.

Kanbur, R. and M. Keen (1993). Jeux Sans Frontières: Tax competition and tax coordination when countries differ in size. American Economic Review 83(4), 877–892.

Kilts Center for Marketing (2010a). NielsenIQ datasets consumer panel data. https://www.chicagobooth.edu/research/kilts/research-data/nielseniq.

Kilts Center for Marketing (2010b). NielsenIQ datasets retail scanner data. https://www.chicagobooth.edu/research/kilts/research-data/nielseniq.

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. The American Economic Review 70(5), 950–959.

Mayer, W. (1984). Endogenous tariff formation. The American Economic Review 74(5), 970–985.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate in-

dustry productivity. Econometrica 71(6), 1695–1725.

Mitra, D. (1999). Endogenous lobby formation and endogenous protection: a long-run model of trade policy determination. American Economic Review 89(5), 1116–1134.

Ossa, R. (2014). Trade wars and trade talks with data. American Economic Review 104(12), 4104–4146.

Parchet, R. (2019). Are local tax rates strategic complements or strategic substitutes? American Economic Journal: Economic Policy 11(2), 189–224.

Poterba, J. M. (1996). Retail price reactions to changes in state and local sales taxes. National Tax Journal 49(2), 165–176.

Redding, S. J. and E. Rossi-Hansberg (2017). Quantitative spatial economics. Annual Review of Economics 9(1), 21–58.

Slattery, C. (2024). Bidding for firms: Subsidy competition in the US. Journal of Political Economy.

Suárez Serrato, J. C. and O. Zidar (2016). Who benefits from state corporate tax cuts? A local labor markets approach with heterogeneous firms. American Economic Review 106(9), 2582–2624.

Wilson, J. D. (1986). A theory of interregional tax competition. Journal of Urban Economics 19(3), 296–315.

Yotov, Y. V., R. Piermartini, and M. Larch (2016). An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model. WTO iLibrary.

Zodrow, G. R. and P. Mieszkowski (1986). Pigou, Tiebout, property taxation, and the underprovision of local public goods. Journal of Urban Economics 19(3), 356–370.