Policy Competition in a Spatial Economy

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Abstract

This paper provides a new framework to measure the interactions between strategic governments and their impacts on economic outcomes in a spatial general equilibrium economy. This framework is used to quantify the welfare implications of strategic tax decisions. The degree of tax competition is quantified by deriving an endogenous *Policy Network Matrix* which generalizes the exogenous postulated weight matrix postulated in prior literature. We develop a spatial general equilibrium model with endogenous commodity tax competition. We apply our model to U.S. county sales taxes which allows us (1) to measure the interjurisdictional price incidence of local taxes, (2) to quantify the different components of local governments' tax rules, and (3) to investigate the welfare effects of various tax reforms like the introduction of a minimum tax or the imposition of tax harmonization. At the observed equilibrium, the Policy Network Matrix suggests an average tax competition effect or tax reaction slope of 9% which can be decomposed into a positive reaction of 10.2% to 22% of a county's neighbors, a small negative reaction of −1.2% to 78% of its neighbors. The overall tax exposition of U.S. counties to tax competition is similar. However, their policy impacts on other counties is strikingly heterogenous with only a few large counties facing small competitors having a significant impact. We also measure that a minimum tax reform generates an average positive welfare effects of which is reduced by 5% due to tax competition.

Keywords: Tax competition; Tax havens; Trade; Commodity taxes; Public goods; Tax administration
JEL: H71; H72; R50; R51

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1. Introduction

What are the welfare effects of tax competition? Although the prior literature has demonstrated that tax competition exists, it has generally struggled to assess the welfare implications of this policy competition (see Agrawal et al., 2020, for a review). To assess empirically the degree of tax competition among jurisdictions, due to its partial equilibrium nature, the existing reduced-form literature ignores the endogenous economic network structure in which local governments operate. Each jurisdiction is assumed to compete against an "average neighbor" constructed by arbitrarily specified weights among usually nearby jurisdictions. In practice, jurisdictions compete in a spatial general equilibrium context in which a jurisdictions' neighbors and the intensity of tax competition it faces are endogenously determined and heterogeneous over space. While spatial general equilibrium models have become a popular way to determine the welfare effects of policy changes (Suárez Serrato and Zidar 2016; Fajgelbaum et al. 2019), these models take the existing policies as exogenous—thus ignoring that policies are an equilibrium in a policy competition game.

We study policy competition in a spatial general equilibrium economy by allowing for policies to be determined endogenously. In such a setting, we are able to quantify the intensity of the policy reaction functions in a highly heterogeneous, endogenous and nonlinear context. To make progress on this question, we focus on the specific example of commodity taxes in the United States where jurisdictions have substantial autonomy over their tax policies, spatial linkages are critical, and taxes are set strategically to attract shoppers and firms.

The present paper develops a new framework to measure tax competition in a spatial general equilibrium economy and to assess the welfare implications of strategic tax setting. The fundamentals of the model are in line with Krugman (1980) and recent structural gravity trade models (Allen et al., 2020). Consumers have differentiated tastes for local varieties of goods provided by mobile firms. This standard trade economy is completed by the inclusion of local and state public policies (Suárez Serrato and Zidar, 2016; Fajgelbaum et al., 2019) with the addition of endogenous policy decision making (Ossa, 2014; Ferrari and Ossa, 2023).

In this context, the degree of tax competition is quantified by deriving an endogenous *Policy Network Matrix* that determines the underlying network of competitor jurisdictions when the data do not contain the information. This generalizes the exogenous ad hoc weight matrix postulated in prior literature. The Policy Network Matrix, where rows represent each jurisdiction and columns represent each possible competitor, unveils two fundamental county-specific statistics measuring strategic interactions among governments. The sum of each row of the Policy Network Matrix is the a county's Policy Responsiveness (PR). It measures the effects of a coordinated tax rate increase in all the competitors of a county on its chosen tax rate. The PR generalizes the scalar tax reaction slope coefficient estimated in prior literature. The sum of each columns of the Policy Network Matrix is a new measure, the Policy Impact (PI). It measures the aggregate effect of an increase in the tax rate of a specific county on all the the other county's tax choices in the economy. Overall, the novelty of the Policy Network Matrix is that it quantifies competition among heterogeneous jurisdictions that interact in rich and realistic spatial general equilibrium economies in ways that are unknown to the econometrician. Compared to previous reduced-form assessment of tax competition, it allows us to determine jurisdiction-specific tax reactions and their spatial distribution for a given tax reform. Not surprisingly, the PI vector varies considerably across U.S. counties, unlike their PRs which are quite similar. We show that larger jurisdictions and those with smaller neighbors have larger policy impacts. By estimating a single parameter, the prior literature masks the heterogeneity of responses across cities/suburbs and large/small jurisdictions, etc. Our approach captures this heterogeneity that is critical for understanding the welfare effects of decentralized policymaking.

Moreover, we show that the Policy Network Matrix can be used as a central tool for counterfactual evaluation by allowing for fast and precise simulations of tax reforms. By allowing to easily incorporate strategic governments in local counterfactual evaluation, the Policy Network Matrix extends extensively used approaches assuming exogenous government policy (Allen et al., 2020). We provide evidence that predictions of the general equilibrium effects of minimum tax reforms and tax harmonisation using the Policy Network Matrix gives results that are quantitatively similar to simulating the full general equilibrium counteractual. This strong predictive ability of the Policy Network Matrix is not surprising. First, the components of the Policy Network Matrix include all general equilibrium effects, which allows the Policy Network Matrix to capture tax incidence, firm mobility and all other economic changes induced by a reform. Moreover, although the Policy Network Matrix is a marginal measure that assumes small tax changes, even large tax reforms still represents small tax changes from a general equilibrium viewpoint.

Allowing for strategic interactions of governments requires us to derive their policy decision rule. To this aim, we derive and quantify all the terms in a new open-economy Ramsey rule. We show that two components of this taxation rule are quantitatively important: the standard inverse elasticity rule and the tax export motive. Casual observed data also confirms the tax export motive actually is a key driver of the levels of the observed tax rates.

In addition to the behavioral rules of the strategic governments, one also need to measure their impact on the economy. To our knowledge, the paper is the first contribution to assess the full $n \times n$ matrix of tax incidence of cross-jurisdiction tax incidence. This matrix allows us to quantify the impact of the tax change of each jurisdiction on any other jurisdiction's price, wage, tax base, or any economic variable in the model. Capturing the full matrix is critical because it is well known that, for example, a large city with many retail agglomerations will respond differently than a smaller and more remote suburb.

Then, we apply our spatial general equilibrium model to investigate U.S. county sales tax competition as follows. First, we measure the interjurisdictional price incidence of local taxes. Second, we quantify the different components of local governments' tax rules. We find a PR of 9% which can be decomposed into a positive reaction of 10.2% to 22.37% of a county's neighbors and a small negative reaction of -1.2% to 77.63% of its neighbors. Direct neighbors usually engage play a game of strategic complements, while further away neighbors are more likely to play a game where taxes are strategic substitutes or not react to tax changes. Consistent with intuition on the mobility of cross-border shoppers, we show that a sufficiently flexible polynomial of inverse-distance weights performs well at predicting the structural weights.

Lastly, we use our quantitative model to investigate the welfare effects of various tax reforms like the introduction of a minimum tax or the imposition of tax harmonization. We characterize the overall welfare effects of different levels of the minimum tax as well as the share of the population who would benefit from such a tax. We show that if a minimum tax of 2% is imposed, 79% of the population benefits from a welfare gain which represents $46 per individual. This number raises to $68 in treated counties in which 82% of the population benefits from welfare gains. In contrast, only 75% of the residents of non-treated counties positively benefit from the reform with a small loss of $3 per person. Strategic governments play a significant role in these welfare results, as tax competition reduces the welfare of an individual by 4.7% on average. This welfare loss is in line with the predictions of the tax competition literature surveyed in Agrawal et al. (2020). This global average masks a stark heterogeneity as tax competition induces an average welfare loss of 9.7% for 67% of the population and an average gain of 5.6% for the remaining 33% of the population. These results prove the importance of accounting for strategic governments responses when assessing the welfare effects of policies.

The paper makes several contributions to various strands of the literature. Our paper brings new insights into exisiting measures of tax competition. Several studies quantified tax competition using spatial econometrics methods (Brueckner and Saavedra, 2001; Agrawal, 2016) or quasi-natural experiments (Agrawal, 2015; Eugster and Parchet, 2019; Parchet, 2019). Our paper finds similar average estimates of the PR as found in these work. However, it shows that the PR is heterogeneous for a given policy experiment and that it directly follows from the fundamentals of the economy, like the alternative sources of fiscal revenues available to the localities, the commuting costs, elasticity of substitution. Our work is in line with recent work contributions which determine endogenous weight matrix of tax competition (De Paula et al., 2019; Agrawal et al., 2020).

A novelty of our paper is that it derives this weight matrix from economic principles. Specifically, using the implicit function theorem, we show that the weight matrix is a first-order approximation of the nonlinear general equilibrium of the economy. This allows us to use the Policy Network Matrix to directly evaluates the impacts of policy reforms like the imposition of a minimum tax or tax harmonization. Critically, our analysis reveals we cannot extract an exogenous structure out of a network out, and then use it to evaluate tax competition in the standard reduced form way. However, if a researcher is interested in a given tax reform reform they can just plug the exogenous tax rates of the reform into our derived network matrix and get the causal effects of the reform on other tax rates, prices, wages, quantities, etc.

As noted in Agrawal et al. (2020), the empirical tax competition literature has focused on estimating the existence of strategic interactions and tax-induced mobility, but cannot quantify the welfare effects of this competition. Thus, quantifying the welfare effects of tax competition requires the literature moving from reduced form to structural model. Yet, structural approaches are rare in the study of local fiscal competition as most structural approaches take policy as given. Our paper fills this void.

A second branch of the literature that our paper extends is that on place-based policies (Brülhart et al., 2019; Lichter et al., 2021; Couture et al., 2024). This literature examines the welfare effects of tax differentials across sub-federal jurisdictions. Fajgelbaum et al. (2019) develop a quantitative spatial general-equilibrium model that considers how variations in state taxes influence the distribution of workers, firms, and trade flows across states, reflecting on overall economic efficiency and welfare. We complement their approach by considering the effects of tax reforms like (partial) tax harmonization or the imposition a minimum tax in the presence of governments' strategic responses. Suárez Serrato and Zidar (2016) examine the tax incidence of U.S. taxes. Our paper extends those findings by quantifying cross-jurisdictions tax incidence. As noted in Agrawal et al. (2023), very few papers quantify capitalization of local policies outside the border of the jurisdiction implementing the policy (Simon, 2021).

Thirdly, we contribute to the recently emerging literature using quantitative models to assess to study endogenous local and state policy setting (Ossa, 2014; Ferrari and Ossa, 2023; Borck et al., 2022; Bordeu, 2023). This literature follows from Epple et al. (2001) which investigates the effects endogenous local public services provision financed by property taxes on spatial income sorting. This framework has then been developed and used by many subsequent papers (Schmidheiny, 2006; Simon, 2021). Unlike our paper, this literature is mostly focused on the spending side of governments decisions and spatial aspects are mostly overlooked. But the key difference with our paper is that in Epple-type models governments' are not strategic. Indeed, households choose their location first, and then, governments choose their policy. Thus, governments sees themselves as having no impact on their economic environment, so their is no tax competition among them.

More recently, policy competition has been introduced in spatial quantitive general equilibrium models in Ossa (2014) for trade tariffs in a trade model, and extended to subsidy competition in Ferrari and Ossa (2023). Borck et al. (2022) developed a property tax competition model in an urban economic model à la Ahlfedlt et al. (2015). These papers are the closest existing work to ours as they feature competing governments in spatial general equilibrium economies. In particular, our paper can be regarded as directly extending Ossa (2014) which is also a spatial trade model in which governments play a strategic Nash game in their fiscal instruments. Three essential aspects distinguishes the present paper.

Firstly, and most importantly, beyond endogenizing local policy, we quantity tax competition. This is made via the quantification of the Policy Network Matrix, which gathers all bilateral tax reaction slopes in the economy. To our knowledge, no other previous paper derived a structural quatitative weight matrix of tax competition.

Secondly, in Ossa (2014) and Ferrari and Ossa (2023) and in the other cited work, endogenous policy modeling is not used to predict the governments' policy setting observed in the data. The Nash equilibrium taxes/tariffs are different from the observed ones. In contrast, we calibrate our model so the strategic tax rates predicted by the model match observed tax rates. We do so by allowing governments to have access to non-sales tax revenues that we recover as local fundamentals of the model. We view these as public finance amenities that play an analogous role to urban amenities in quantitative urban economics modesl (Ahlfedlt et al., 2015; Tsivanidis, 2022). Matching observed tax rates is essential for public policy evaluation because this allows us to perform counterfactual policy exercises that are comparable to the observed policy settings. Thus, our Policy Network Matrix represents the predicted tax reactions of U.S. counties that would actually occur if their neighbors changed their tax rates. Similarly, our quantification of tax reforms like minimum taxes makes sense only because in the absence of implementation of the reform, our model predicts correctly the observed tax rates.

Thirdly, our work entends Ossa (2014); Ferrari and Ossa (2023) by quantifying tax incidence, which plays a pivotal role in a study of tax competition for two reasons. First, tax competition is a two-stage game in which governments choose their policy in the first stage, anticipating that the economy will return to equilibrium in the second stage (Zodrow and Mieszkowski, 1986; Wilson, 1986; Wildasin, 1989). Formally, this anticipation of the moves second-stage moves of the economy can be reduced to anticipation of price capitalization. This explains that in our model these price responses are derived and measured precisely.[1] The second reason why tax incidence is essential to study tax competition is that price changes are fundamental spillovers across jurisdictions which explain that one jurisdiction responds to tax changes in another jurisdiction. Our analysis even shows that at the equilibrium price capitalization are the only statistics needed to calculate the Policy Network Matrix and thus assess tax competition.

Finally, as our analysis of tax competition is applied to local sales taxes, our paper also contributes to the commodity tax literature is several ways. First, to evaluate tax competition quantitatively, we need to assess the elasticity of the sales tax base with respect to taxes. Our measures are in line with recent estimates of this elasticity (Baker et al., 2020, 2021). We use similar consumer cross-border sales data as these studies and our approach consisting in estimating a gravity regression is in line with Davis et al. (2016). Second, our paper also contributes to better empirical understanding of U.S. sales tax competition as analyzed in Agrawal (2015), among others. Last, by studying tax setting in the presence of mobile consumers when consumers face multiple choices over what and where to buy goods. Existing contributions are usually two-jurisdiction models (Kanbur and Keen, 1993; Lockwood, 2001; Keen and Konrad, 2013) that substantially restrict the consumption choices of individuals.

2. Model

The purpose of this paper 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

[1] In Ossa (2014); Ferrari and Ossa (2023) the tax competition game played between the governments and the private economy is solved simultaneously and not sequentially. Specifically, Ossa solves the game by assuming that each government maximizes its objective subject to all economic equilibrium conditions, taking as given the policy instruments of the other governments. This differs from the two-stage approach followed in our paper which is more in line with traditional tax competition.

endogenous determination of those policies as in (Ossa, 2014; Ferrari and Ossa, 2023). A key contribution is to combine all of these forces to realistically derive a specific optimal tax rule for subnational governments 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 counties indexed by j, and inhabited by a fixed number of n_j identical households with net-of-tax income e_j. 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. We assume that the only way for a resident of a county j to consume a variety produced in another county i is to do cross-border shopping. A consumer can possibly consume in any county of the federation. 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 the following 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 of the federation. 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. 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. Moreover, in line with standard assumptions in models with monopolistic competition and entry (Krugman, 1980), each resident owns part of the firms in her county. The total income of 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 income.

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 $e_j = (1 - \tau_j)(w_j + \kappa_j + m_j \rho_j / n_j)$, 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. Intuitively, higher tax rates in other counties raises 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.

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. [2]

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. Further, firms must incur a cost equal to $\rho_i \equiv c_i f_i$ in order to enter the market, where f_i is the exogenous component of this cost. This fixed cost is equally returned to the owners of the firm (residents of the jurisdiction). 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 located 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 of 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.

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.

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

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, may reflect other resources such as property taxes and 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 the following 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. [3]

In many countries, local governments provides services and raise taxes in the context of a federalist system. Given multiple levels of government tax commodities and earnings in the U.S., our model account for state-level taxes and the services they finance. 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 in which e_i is the gross individual income defined previously in (2). Similarly to the county's public services, the state's public service G_i is fully congestible. Each resident of county i's state receives G_i units of public services. The expenditure on state public services in county i is $p_i n_i G_i$. Further, because income taxes are progressive, the state's income tax rate τ_k varies at the county level 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, $\varphi/(1-\varphi)$: 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

[3] Assuming that counties are endowed with public services (exogenous Δ_i) rather than with nominal revenues (exogenous R_i) has two advantages. First, there is no need to make 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 for formal details.

put on county public services.

2.5. Equilibrium Relation between the Local Economic Variables

Before we turn to the general equilibrium of the economy, let us describe the relations between the 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:[4]

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

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), we can express the number of firms as 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:

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

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

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

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:

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

Equation (15) states that the value of total production, Y_i, is equal to the value of the total demand, itself composed of three elements: the local demand for private consumption, X_i, the demand for public services by the local government, $t_i X_i$, and the 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 $i = 1, \ldots, J$:

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

recalling that m_i, E_i and Y_i are one-to-one mapping with respect to p_i (see 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, $(\mathcal{E}_i)_{i=1,\ldots,I}$, will be called the private economy *general equilibrium system*. 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 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 $(\mathcal{E}_i)_{i=1,\ldots,J}$.

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 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), the latter can be expressed as:

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

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 makes it also clear that $\mathit{\Delta}_i$ 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 government 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*:

$$\left.\frac{\partial p_i}{\partial t_i}\right|, \qquad \left.\frac{\partial P_i}{\partial t_i}\right|, \qquad \left.\frac{\partial G_i}{\partial t_i}\right|, \tag{22}$$

in which the "vertical bar" aside the derivative 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 change on the equilibrium in other counties, $(\mathcal{E}_j)_{j\neq i}$.(19).*

We will show that Assumption 1 has minimal impact on our baseline results, but evoking 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.

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.1 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 $\eta_i\phi_i$.[5]

Note that if $\theta_i = 1$, $\lambda_i = 0$ and $\phi_i = 0$, our Ramsey rule boils down to the standard

[5] 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 z_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.

inverse elasticity rule for optimal commodity taxation (Salanie, 2011). If $\theta_i = 0$, $\lambda_i = 0$ 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). In order to interpret Term A, note that 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 local 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 consume 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.[6]

Fourth, the parameter ν which governs the level of the marginal willingness to pay for public services has a straightforward 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 local tax rate.

In sum, our Ramsey rule (23) highlights four main possible causes of heterogeneity in the levels of local commodity tax rates. It is one of the most comprehensive of the trade 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. We

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

proceed in two steps.

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 (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 $4I$-general-equilibrium equation system (5), (10), (15) and (23) for the Nash equilibrium tax rates $\{t_i^\star\}_{i=1}^J$, wage $\{p_i^\star\}_{i=1}^J$, the price indices $\{P_i^\star\}_{i=1}^J$ and state public services, $\{G_i^\star\}_{i=1}^J$.

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

We next bring our general equilibrium model of commodity taxation to the data.

3.1. Data and Summary Statistics

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 they are large enough in geographic size to have shopping opportunities. Ignoring Alaska and Hawaii, our sample includes 3,108 counties. In the continental U.S., 13 states (with 706 counties) do not allow municipal or county sales taxation. As we are interested in local tax setting decisions, our analysis focuses on the 2,402 counties located in the 35 states allowing for local taxation. The 706 institutionally constrained counties without local tax authority are always included 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.[7] 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 2,402 counties that are free

[7] These data are cleaned in a similar manner as Agrawal (2015).

to choose their tax rates by state law, 2,146 choose to set a positive county tax rate and 257 (around 11%) 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.[8]

Table 1. Descriptive statistics for taxing counties.

	Var	Mean	SD	Min	Max	Obs
A. Endogenous model variables						
County + avg. municipal sales tax rate (%)	t_i	1.767	1.204	0.007	5.622	2146
Number of firms	m_i	564	1865	2	47704	2146
Average household after-tax income (in $1,000)	e_i	60.307	14.267	31.432	152	2146
Earnings (in $1,000)	w_i	44.517	12.847	17.209	126	2146
Non-sales tax revenue relative to expenditure (%)	$R_i/(p_i n_i g_i)$	89.253	12.317	5.341	100	2146
B. Exogenous model variables						
Population (in 1,000 households)	n_i	38.453	125	0.243	3219	2146
State sales tax rate (%)	T_i	5.239	1.095	2.9	7.25	2146
State income tax rate (%)	τ_i	2.696	1.626	0	5.835	2146

Figure A.1 illustrates the spatial variation in counties' sales tax rates. Figure A.2 shows the spatial distribution of tax types levied at the county and state levels.

3.2. Model Inversion

We invert the model in the following manner.[9] 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 value of σ. Using (11), we then obtain *sigma* 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, novel to our paper, armed with all inputs to our optimal tax rule except for residual non-sales tax revenues per capita, $\mathit{\Delta}_i$, we solve (23)

[8] Other socioeconomic variables used in the paper from U.S. census data are reported in Table A.2.
[9] This section focuses on intuition, all technical details are provided in Appendix C.

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, $\log X_{ij} = \varkappa_i + \delta_j - (\sigma - 1)\log \mu_{ij} + \varsigma_{ij}$, where λ_i is a fixed effect that absorbs the sales tax rate and price in the shopping destination, δ_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, we assume that the shopping costs take the following functional form: $\mu_{ij} = \exp\left(\sum_k \beta_k z^k ij/(1-\sigma)\right)$, 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.[10] We therefore estimate the following gravity equation

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

where X_{ij} is county-to-county aggregate expenditure in i of residents of j constructed using the Nielsen Consumer Panel data matched with the Retail Scanner Panel. Estimating (24) using a Poisson pseudo-maximum-likelihood approach, we obtain the results reported in Table 2.

[10] 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 (`https://www.census.gov/retail/index.html`). We expect the growth of online shopping to reduce, though not eliminating the influence of physical distance on shopping costs.

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— The dependent variable is the logarithm of expenditure of a resident of county j in county i. Home: county j itself; 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.

A one percent 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 D.1, we use the different specifications of Table 2 to predict the local expenditure share of each county (θ_i). They all prove to lead very similar results and to be highly correlated with the observed expenditure share in the Nielsen data (see Table A.3 and Table A.4). We therefore use the most flexible specification (6) in Table 2.

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. An 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 the 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.

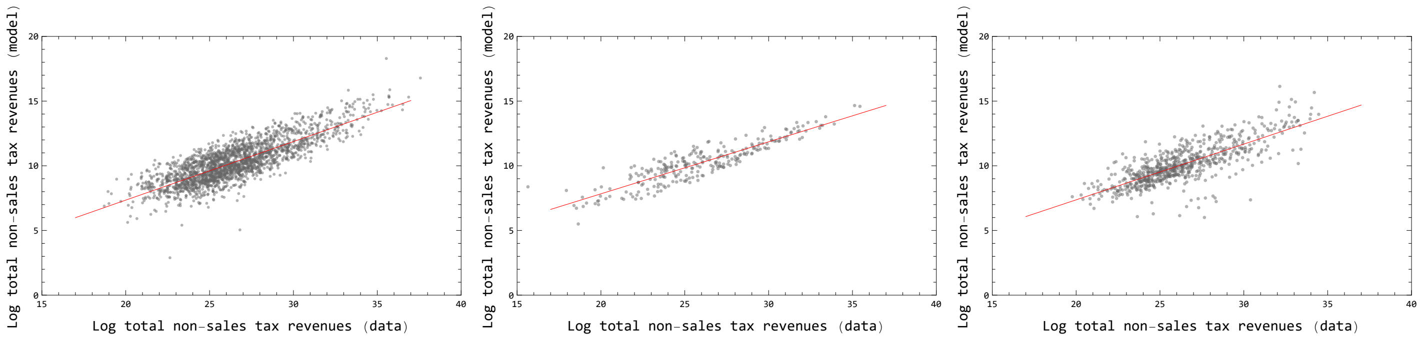
Next, we need to determine the non-alternative resources R_i of non-taxing counties. This is challenging as these counties' observed zero tax rates as we do not observe their unconstrained optimal (possibly negative) tax rate. To recover the R_i for these counties, we estimate the relationship $R_i = \sum_k \beta_k s_i^k + \epsilon_i$ in taxing counties where s_i^k are a set of socio-economic variables described in Table A.2.

We need to distinguish between the 257 counties which voluntarily choose a zero tax—indicating that their optimal tax rate is negative—and the 706 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 aim, 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 our approach 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 predicts accurately 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 actually match the data.

3.6. Overidentification Checks

We now examine the model's predictions for variables not used in the calibration and for the relationships between variables not directly imposed by the model. Figure 1 shows that counties' alternative sources of revenue 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 with their observed counterparts.



(a) Taxing counties

(b) Non-taxing counties (states allow)

(c) Non-taxing counties (states not allow)

Figure 1. Overidentification check: counties' non-sales tax revenues. The red line is the linear model fit.

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 shocking the tax rate in counties currently setting a zero tax rate.

Our quantitative model perfectly matches observed household income, e_i, by calibrating capital income as described. 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.

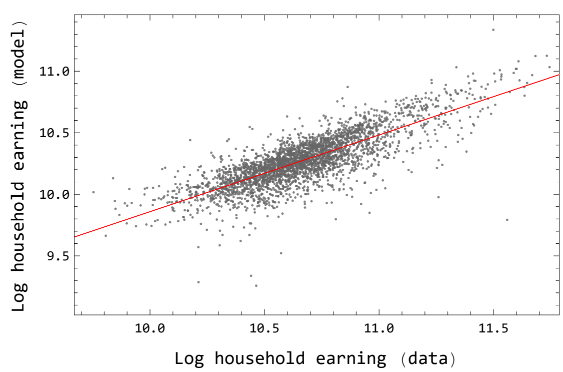


Figure 2. Overidentification check: household earning per county. The sample includes all 3,109 counties. The red line is the linear model fit.

Further, in Appendix D, we show that own-jurisdiction consumption shares in the model match those in the Nielsen 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 Nielsen data.

3.7. *Results: Tax Incidence and Tax Decision*

Table 3 provides our quantification of the different components of the open economy Ramsey rule (23). 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.[11]

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	Obs
ε	Elasticity of demand w.r.t. tax (absolute value)	2.136	0.131	1.292	2.336	2146
θ	Local expenditure share	0.737	0.139	0.076	0.992	2146
χ	Share of total sales from own residents	0.775	0.108	0.057	0.985	2146
λ	Non-sales tax revenue to income ratio	0.349	0.018	0.3	0.44	2146
η	Public services to tax base ratio	0.478	0.109	0.176	1.324	2146
ϕ	Equilibrium price effect	0.417	0.058	0.256	0.939	2146

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. (2020)'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 terms is always positive, suggesting the first two effects dominate, raising utility.

[11] 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 4. General equilibrium local and external tax incidence.

	Mean	SD	Obs
A. Local incidence $\frac{1}{p_i}\frac{\partial p_i}{\partial t_i}$			
	-0.6417	0.1044	3,109
B. External incidence $\frac{1}{p_i}\frac{\partial p_i}{\partial t_j}$			
Adjacent neighbors	0.0428	0.0512	18,474
Neighbors within 60 miles	0.0142	0.0216	14,026
Neighbors within 90 miles	0.0058	0.0127	29,279
Neighbors within 120 miles	0.0012	0.0097	40,414
All neigbors	0.00006	0.0038	9,662,772

NOTE— Each neighborhood group excludes the other ones. For example, neighbors witin 90 miles are counties that are neither adjacent nor within 60 miles of county i.

Table 4 presents our estimates for the elasticity of prices with respect to local sales tax rates. We compute those price elasticities by implicitly differentiating the general equilibrium system $(\mathcal{E}_i)_{i=1,\ldots,I}$. This yields a matrix of all prices changes $\partial p_i/\partial t_j$ in the economy given a 1 percentage point increase in the tax rate of any jurisdiction. We find that, on average, prices decrease by $exp^{-0.642} - 1 = 47\%$ after a one percentage point increase of the local sales tax rate, leading to an incidence on the producers of approximately 82%(0.47/0.57) . 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 inexistent 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 the prices in the adjacent county of 4%, which quickly decreases when considering counties further away. The semi-elasticity amounts to 0.10% for counties between 90 and 120 minutes driving time.

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). We study the role of strategic tax setting by local governments by comparing the welfare effects of both reforms under two: (i) without tax competition, that is, without allowing counties to further changes their tax rates; (ii) with tax competition, that is allowing counties to re-optimize their tax rates afterwards.

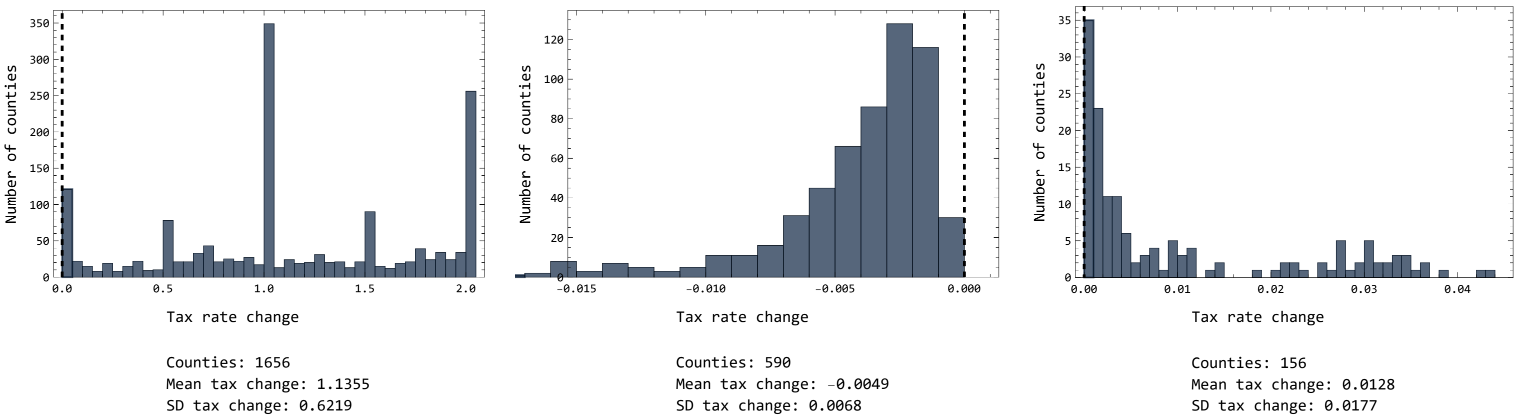
To measure the welfare effects of these two tax reforms, we use equivalent variations, that is the amount of income that should be transferred to a representative resident prior to the reform so that her utility increases/decreases up to her after-reform utility level. The higher the equivalent variations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

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 1.77%, see Table A.2), 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.[12]

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 county over-react to the minimum tax by setting a tax rate above 2%.

[12] Figure A.5 reports for the share of counties constrained by different levels of minimum tax rates and the resulting mechanical tax rate change.



(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: $100 \times (t^{after} - t^{before})$.

The strategic responses of the counties with an initial tax rate above 2% (non-treated counties) are represented in Figure 3b and Figure 3c. We find that 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 (-0.0036%). In absolute value, the tax adjustments of non-treated counties are small compared to treated counties. This reflects the fact that each county has only a few treated neighbors changing their tax rates.

Figure 4 presents the welfare effects of the minimum tax. We find that residents of treated counties are the actual winners of the reform, while the outcome is mixed in non-treated counties. On average, an individual in the population values the benefits of the reform at \$37. This number raises to \$55 in treated counties and is only \$3 in non-treated counties. The rationale of this result 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.[13] This is consistent with tax competition leading counties to set too low tax rates in the first place (Zodrow and Mieszkowski, 1986; Wilson, 1986; Wildasin, 1989). Note also that the dispersion of the welfare effects is more dispersed among treated counties. This is not surprising as these counties experience the largest change in their tax

[13] Figures A.6 and A.7 in Appendix F further decomposes the welfare effects of the minimum tax into public and private gains.

rates.

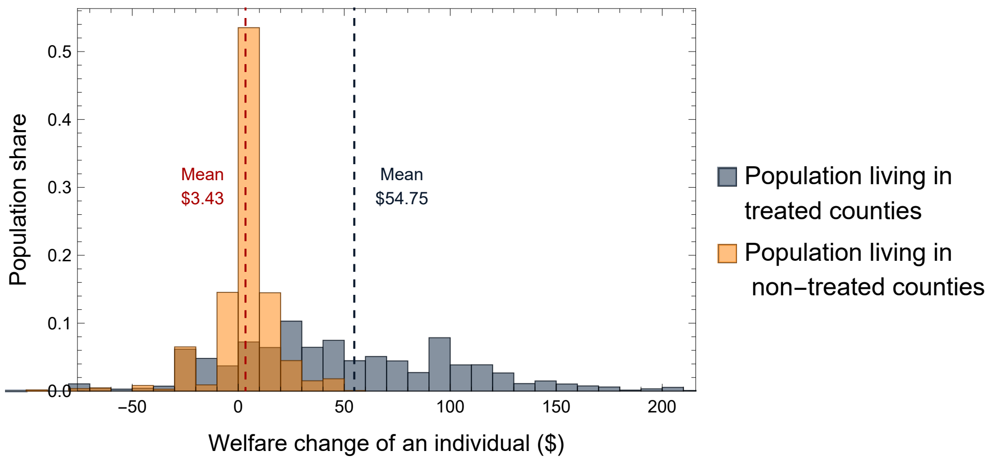


Figure 4. Welfare effects of a minimum tax of 2%. The graph represents the equivalent variations of the different shares of people leaving in treated and non-treated counties, respectively. The population shares are computed within these two groups of counties. The mean welfare change in the entire population is \$37 as can be seen in Table A.9 in Appendix F which provides more details on welfare effects.

How much of these welfare effects are actually due to tax competition? 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 compute the percentage difference in equivalent variations under the two scenarios (with and without tax competition). We focus only on non-treated counties as we find that treated counties do not further change their tax rates in the general equilibrium after the introduction of the minimum tax.

Figure 5 presents the distribution of the difference in equivalent variations due to tax competition. On average, the welfare change is low, around 2% among the 746 non-treated counties and one would be tempted to conclude that tax competition is not important (the difference in the average welfare effects between endogenous taxation (panel A) and exogenous taxation (panel B) in Table A.9 is hard to see at first sight). This masks however a large heterogeneity among winners and losers from tax competition that is revealed in Figure 5. 55% of the population in non-treated counties benefit from tax competition with an increase in welfare of 14% on average while 45% of the population lose from tax competition with an average loss of 5%.footnoteFigure A.8 in the Appendix F correlates the change in tax rate and the change in welfare. Results indicates that counties increasing their tax rates are more likely to benefit from tax competition than counties reducing their tax rates. The (absolute value of the) welfare effect of tax competition amounts therefore to around 10%.

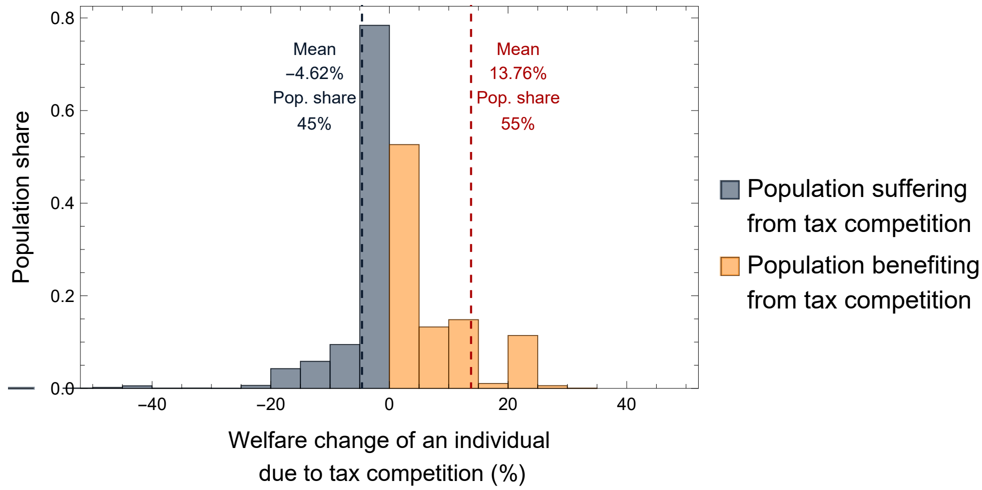


Figure 5. Welfare effects due to tax competition for a minimum tax of 2%. The graph represents the percentage change in equivalent variations for non-treated counties between two scenarios: with and without endogenous taxation. Counties benefiting (losing) from tax competition are shown in orange (gray). Population shares are computed within these two groups. The mean welfare change due to tax competition in the entire population is −2.08%.

4.2. The Welfare Effects of Tax Harmonization

Appendix G studies the welfare effects of (partial) tax harmonization (Fajgelbaum et al., 2019; Hines Jr, 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 1.77%). We can therefore investigate whether the welfare effects differ between counties treated from above ("top-treated", herafter) or from below ("bottom-treated" county, herafter).

Figure A.12 shows that tax competition lead to an increase in welfare of 15% on average for 26% of the population in non-treated counties and a welfare loss of 12% for 74% of the population. In absolute values, the welfare effect of tax competition amounts to 12%, a number very similar to the one obtained in the minimum tax exercise.

5. The Policy Network of Tax Shocks

To decompose the welfare effects of tax competition, we now introduce a new measure of the degree of tax competition: the Policy Network Matrix (PNM). The PNM is the extension to a general spatial equilibrium economy of the well-known spatial weight matrix and its coefficient estimated in many prior tax competition papers (see Agrawal et al., 2020, for a review). It is defined as follows.

Definition 1. *The Policy Network Matrix (PNM), denoted $\boldsymbol{\Omega}$, is an $I \times I$ matrix including all bilateral interjursidiction tax reaction slopes measured 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: $\omega_{ij} = \partial t_i / \partial t_j$.*

Intuitively, the PNM is a spatial general equilibrium weight matrix with I^2 endogenous entries, and resulting from possibly highly nonlinear tax functions.

Subsection 5.1 describes how to compute the PNM. 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. The derivations of the explicit components of the PNM is provided in **??**. Subsection 5.2 establishes general properties of this matrix with respect to usual tax competition weight matrices. Subsection 5.3 describes how the PNM can be used to evaluates the effects of counterfactual tax reforms. The PNM will be quantified empirically in the context of the U.S. sales taxes in Section 6.

5.1. Computation of the Policy Network Matrix

The PNM includes all the tax reaction slopes measured at the general equilibrium. Hence, its computation essentially requires to differentiate 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.

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 endgenous 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: 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 (E.1) indicates that it only includes county i's variables (p_i, P_i, G_i, $\partial p_i/\partial t_i|$, $\partial P_i/\partial t_i|$ and $\partial G_i/\partial t_i|$). This property is due to our assumption of the local tax setting. This is computationally particularly useful because it allows to compute the tax responses to economic variables for each county separately.

Second, a specificity of a government's decision rule like (E.1) 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 $\partial G_i/\partial t_i|$). Hence, differentiation of the government's first-order condition generate 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 an economic change in the economy, it re-evaluates the responses of economic variables to its policy in order to choose the appropriate tax rate. Although these second-order terms may be small in practice, this need not always be the case, so they have to be computed as well.

In sum, the above two observations imply that in order to compute the effects of changes in economic variables on local tax rates in county i, we need to totally differentiate county i's first-order condition together with the first-order partial equilibrium system ($\mathrm{d}\mathcal{E}_i$). 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, $\mathbf{dZ}_i' \equiv (\mathrm{d}p_i \quad \mathrm{d}P_i \quad \mathrm{d}G_i)$ is the vector of economic changes, 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 the Appendix for their explicit expressions). Inverting this system allows 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:

$$\mathbf{dt} = \mathbf{H}\,\mathbf{dZ} \tag{25}$$

where $\mathbf{dt}' = (\mathrm{d}t_1 \ldots \mathrm{d}t_I)$ is the aggregate tax response vector, $\mathbf{dZ}' = (\mathbf{dZ}_1' \ldots \mathbf{dZ}_I')$ is the aggregate vector of economic changes, and $\mathbf{H}$ is a $I \times 3I$ block diagonal matrix.

Relation (25) represents the tax response to economic changes; it is the first intermediate component of the Policy Network Matrix. This relation is a behavioral rule resulting from the government's taxation rule and treating economic prices as exogenously changed. It allows to compute, for any price changes in the economy how the localities change their tax rates.

Importantly, the price changes can result from any possible cause. For example, they may be the result of a tax reform as analyzed in this paper, but they can also be caused by any other exogenous change (e.g. construction of a highway). Here, in order to determine the PNM, we need to consider these economic responses as resulting from tax changes, as described in the step 3 below.

Step 3: General Equilibrium Economic Responses to Taxes: Tax Incidence

The tax response relation derived in the previous step treats economic changes as exogenously given. However, the assessment of tax competition requires to start from exogenous tax changes. These initial exogneous tax changes are the cause of the economic responses in the right-hand side of relation (25). The present step shows how to compute these *tax incidence effects*.

How do all economic variables, p_j, P_j an G_j, $\forall j$, vary as some (not necessarily all) taxes change exogenously? To answer this question, notice that we need to compute the actual general equilibrium responses, not the partial equilibrium responses perceived by localities. Thus, we simply need to totally differentiate the general equilibrium system $(\mathcal{E}_i)_{i=1...,I}$ which gives $\mathbf{A}\,\mathbf{dZ} = \mathbf{B}\,\mathbf{dt}$, where $\mathbf{A}$ is a $3I \times 3I$ matrix and $\mathbf{B}$ is a $3I \times I$ matrix which can both be fully computed from the step 1 (their explicit expressions are derived in the Appendix). Inverting this system, we obtain the economic responses to exogenous tax changes:

$$\mathbf{dZ} = \boldsymbol{\Pi}\,\mathbf{dt} \tag{26}$$

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

Relation (26) is the second key relation to determine the Policy Network Matrix. This is a tax incidence relationship taking governments as exogenous and quantifying price responses to tax changes.

Step 4: Policy Network Matrix and Weight Matrix

The last two steps derived the price responses to exogenous tax changes and the tax responses to exogenous price changes. Combining these two relations allow to compute the tax responses of any jurisdiction to changes in the tax rates by any other jurisdictions. Formally, inserting the price responses (26) into the tax responses relation (25), 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, so that after trivial 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 the Policy Network Matrix is defined as $\boldsymbol{\Omega} \equiv (\mathbf{I}-\mathbf{O}^d)^{-1}(\mathbf{O}-\mathbf{O}^d)$ where $\mathbf{I}$ is the identity matrix and $\mathbf{O}^d$ is the diagonal matrix whose diagonal elements are the diagonal elements of $\mathbf{O}$, and off-diagnoal elements are zero. The PNM is a $I \times I$ non-symmetric matrix in which all the diagonal elements are zeros. where represent the set of endogenous weight composing the PNM.

As spatial weight matrices in the literature are usually standardized so each row sums to unity, let us row-standardize our PNM to make it more easily comparable with prior work. To this aim, let us define the standardized weights $\mathrm{w}_{ij} \equiv \omega_{ij}/\sum_j \omega_{ij}$ and the multiplier coefficients, $\beta_i \equiv \sum_j \omega_{ij}$ that we call the Policy Responsiveness (PR) measure. Thus, an element of the PNM is equal to $\omega_{ij} = \beta_i \mathrm{w}_{ij}$, and the tax responses (27) can be written as:

$$\mathbf{dt} = \boldsymbol{\beta} \circ \mathbf{W}\,\mathbf{dt}, \qquad \text{or equivalently,} \qquad \mathrm{d}t_i = \beta_i \sum_j \mathrm{w}_{ij}\mathrm{d}t_j, \tag{28}$$

where $\boldsymbol{\beta}' \equiv (\beta_1 \dots \beta_I)$ is the PR vector, and $\mathbf{W} = (\mathrm{w}_{ij})$ is the row-standardized matrix associated with the PNM, i.e. $\boldsymbol{\Omega} = \boldsymbol{\beta} \circ \mathbf{W}$. The operator $\circ$ stands for an Hadamard product of vector and matrix, such that $\boldsymbol{\beta} \circ \mathbf{W} \equiv \mathbf{diag}\,(\boldsymbol{\beta})\,\mathbf{W}$, in which $\mathbf{diag}(\boldsymbol{\beta})$ is the matrix with diagonal $\boldsymbol{\beta}$ and zeros off diagonal. This is summarized in:

Definition 2 (**Policy Responsiveness**). *The Policy Network Matrix, $\boldsymbol{\Omega}$, can be decomposed into a row-standardized weight matrix, $\mathbf{W}$, and a parameter vector, $\boldsymbol{\beta}$, such that $\boldsymbol{\Omega} = \mathbf{diag}(\boldsymbol{\beta})\mathbf{W}$. An element of $\boldsymbol{\beta}$ is defined as:*

$$\beta_i \equiv \sum_j \omega_{ij} = \sum_j \frac{\partial t_i}{\partial t_j}, \tag{29}$$

and called, Policy Responsiveness (PR). It measures how jurisdiction i's tax rate change to a simultaneous change in all the other jurisdictions' tax rates.

The expressions in (28) are reminiscent of the tax reaction functions estimated in the empirical tax competition literature pioneered by (Brueckner and Saavedra, 2001). The PNM plays the same role as standard spatial weight matrices considered in the tax competition literature. However, as the PNM is more general it has a number of properties that critically differ from standard spatial weight matrices. The next section states these differences and establishes the general properties of the PNM.

5.2. *Properties of the Policy Network Matrix*

The Policy Network Matrix and its associated weight matrix are spatial general equilibrium measures that differ from traditional spatial reduced-from weight matrices in three main respects: nonlinearity, endogeneity and heterogeneity. Table 5 and the properties established in this section describe these specificities. Moreover, it establishes that the measure of tax competition require to compute two fundamental vectors: the Policy Response $\boldsymbol{\beta}$, derived in the previous subsection and the Policy Impact (PI) $\boldsymbol{\gamma}$, introduced below.

Table 5. Measuring tax competition: structural approach versus traditional approach.

	(1)	(2)	(3)
	Structural approach		Reduced-form approach
Tax response function	$\mathbf{t} = \mathbf{f}(\mathbf{t}, \mathbf{Z}, \boldsymbol{\varepsilon})$ $t_i = f_i(t_1, \ldots, t_I, Z_{1i}, \ldots, Z_{Ki}, \varepsilon_i)$ nonlinear		$\mathbf{t} = \beta \mathbf{W}\mathbf{t} + \mathbf{Z}\boldsymbol{\theta} + \boldsymbol{\varepsilon}$ $t_i = \beta \sum_j \mathrm{w}_{ij} t_j + \sum_k Z_{ki}\theta + \varepsilon_i$ nonlinear
Marginal tax response function	$\mathbf{dt} = \boldsymbol{\Omega}\mathbf{dt}$ $\mathrm{d}t_i = \sum_j \omega_{ij} \mathrm{d}t_j$ linear	$\mathbf{dt} = \boldsymbol{\beta} \circ \mathbf{W}\mathbf{dt}$ $\mathrm{d}t_i = \beta_i \sum_j \mathrm{w}_{ij} \mathrm{d}t_j$ linear	$\mathbf{dt} = \beta \mathbf{W}\mathbf{dt}$ $\mathrm{d}t_i = \beta \sum_j \mathrm{w}_{ij} \mathrm{d}t_j$ linear
Policy Network Matrix (PNM)	$\boldsymbol{\Omega}$ endogenous	$\boldsymbol{\beta} \circ \mathbf{W}$ endogenous	$\beta \mathbf{W}$ exogenous
Policy responsiveness (PR)		$\boldsymbol{\beta} \in \mathbb{R}^I$ endogenous	$\beta \in \mathbb{R}$ exogenous
Weight matrix		$\mathbf{W}$ endogenous	$\mathbf{W}$ exogenous

Note: Columns (1) and (2) are equivalent, only the notation differ, they represent the approach described in Subsection 5.1. Column (3) represent the traditional reduced-form approach (Brueckner and Saavedra, 2001). $f_i(\cdot)$ is a nonlinear function implicitly defined by the local government's first-order condition. Z_{ki} [ε_i] are control variables [residuals] which are parts of weights ω_{ij}.

In a spatial general equilibrium economy, tax response functions are nonlinear and only implicitly defined by nonlinear first-order conditions like (E.1). Consequently, the weight matrix measures marginal impacts only and cannot be directly inferred from observed levels of the tax rates (row 1 of Table 5). However, the weight matrix can be directly deduced from the marginal tax response function (row 2 in the table). Similarly, control variables and residuals are nonlinearly included in the components of the PNM. This is summarized in Proposition 1.

Proposition 1 (**Nonlinearity**). *The tax response function is in general nonlinear. Consequently,*

(i) The PNM and the weigth matrix measure marginal tax responses only. They are not informative about the levels of the taxes.

(ii) Control variables and residuals are nonlinearly included in the coefficients of the PNM.

Nonlinearity does not invalidate the traditional reduced-form estimation approaches *per se*. Indeed, the traditional approach can be viewed as a Taylor expansion near the equilibrium. However, nonlinearity implies that the Policy Network Matrix is strongly heterogeneous across observations. Typically, for a sample of size I, we need to estimate the I^2 entries of the PNM, instead of a single scalar β. As a workaround, the literature has assumed that the I^2 elements of the weight matrix follow predetermined (most often unidimentional) spatial patterns, like inverse-distance weighting. Although it might be correct approximations in some cases, the traditional approach misses a lot of key heterogeneous interactions among jurisdictions. In particular, it forces all jurisdictions' tax rates to be either strategic substitutes or strategic complement. Yet, both cases could coexist in general. This leads to Proposition 2.

Proposition 2 (**Heterogeneity**). *The Policy Network Matrix and the weight matrix results from the economic interactions in the model. Therefore, their components are highly heterogenous. In general,*

(i) The Policy Network Matrix and the weight matrix are not symmetric.

(ii) The Policy Network Matrix and the weight matrix include positive, negative and zero terms.

(iii) The Policy Responsiveness is a vector, not a scalar.

The immediate implication of Proposition 2 is that the overall weight matrix, $\mathbf{W}$, and Policy Responsiveness measure, $\boldsymbol{\beta}$, are not accurate instruments to measure tax competition. Better description of tax competition can be obtained by decomposing the weight matrix and policy responsiveness into positive and negative tax reactions, such as:

$$\mathbf{dt} = \boldsymbol{\beta}^{+} \circ \mathbf{W}^{+}\mathbf{dt} + \boldsymbol{\beta}^{-} \circ \mathbf{W}^{-}\mathbf{dt} \tag{30}$$

where $\mathbf{W}^{+}$ is a $I \times I$ row-standardized matrix that includes the non-negative terms of $\mathbf{W}$ (and has zero in places of negative elements of $\mathbf{W}$) and is associated with the positive $\boldsymbol{\beta}^{+}$. Similarly, the row-standardized matrix $\mathbf{W}^{-}$ includes the absolute value of the non-positive terms of $\mathbf{W}$

and is associated with the negative $\boldsymbol{\beta}^{-}$. In words, this representation decomposes of the tax reactions depending on whether a complement strategy or a substitute strategy is adopted, as summarized in Corollary 1.

Corollary 1. *The weight matrix can be meaningfully decomposed into two row-standardized weight matrices: one including the non-negative elements of the overall weight matrix, and the other including the non-positive elements of the overall weight matrix. Likewise, the Policy Responsiveness can be decomposed into two vectors associated with these two matrices, respectively.*

Like nonlinearity, heterogeneity in itself does not disqualify the traditional linear reduced-form approach to estimating tax reactions. Indeed, non-modelled heterogeneity would be simply captured by the residuals of the linear regression. However, this heterogeneity implies that the residuals of a linear regression are endogenous variables correlated with the weight matrix and the tax rates, leading to the classical endogeneity or reflection problem famously explained by Manski (1993). This is stated in in Proposition 3

Proposition 3 (**Endogeneity**). *The Policy Network Matrix, the weight matrix and the Policy Responsiveness $\boldsymbol{\beta}$ are endogenous.*

This endogeneity problem concerns all empirical approaches that do not allow for sufficiently flexible heterogeneity of the weight matrix and/or of the Policy Responsiveness $\boldsymbol{\beta}$. This includes not only analysis building on spatial econometrics (Brueckner and Saavedra, 2001; Agrawal, 2012) but also those, more recent, exploiting quasi-natural experiments (Lyytikäinen, 2012; Agrawal, 2015; Parchet, 2019).

Last, the Policy Responsiveness $\boldsymbol{\beta}$ definition results directly from the traditional approach to row-standardize the spatial weight matrix. If, instead, the weight matrix is column-standardized, a new important measure emerges, as stated in Definition 3.

Definition 3 (**Policy Impact**). *The Policy Network Matrix, $\boldsymbol{\Omega}$, can be decomposed into a column-standardized weight matrix, $\mathbf{V}$, and a parameter vector, $\boldsymbol{\gamma}$, such that $\boldsymbol{\Omega} = \mathbf{V}\,\boldsymbol{diag}(\boldsymbol{\gamma})$. An element of $\boldsymbol{\gamma}$ is defined as:*

$$\gamma_j \equiv \sum_i \omega_{ij} = \sum_i \frac{\partial t_i}{\partial t_j}, \tag{31}$$

and called, policy impact (PI). It measures the aggregate impact of jurisdiction j's tax rate change on all other jurisdictions tax choice in the economy.

In practice, the Policy Responsiveness (PR), β_i, and the policy impact (PI), γ_i, of a county i need not be similar. For example, a large county may be little influenced by other counties but have a significant impact on them. Our quantitative analysis will quantify and compare both the PR and PI of all U.S. counties to provide more intuition into this.

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:

Proposition 4 (**Average Tax Competition Effect**). *Suppose that the PNM includes all relevant competitiors. The policy responsiveness and the tax competition are on average equal. That is, the average policy responsiveness (APR) can be equivalently measured as the mean of the PRs, . or as the mean of the PIs. This can be stated as:*

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

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

Proof. The proof mechanically results from the definitions of β_i in Definition 2 and γ_j in Definition 3. Indeed, $\overline{\beta} = \sum_i \beta_i / I = \sum_i \sum_j \omega_{ij} / I = \sum_j \gamma_j / I = \overline{\gamma}$. □

Proposition 4 states that the expected exposure to tax competition of a county is equal to its expected policy impact on others. This property is natural. To see it, notice that naming appropriately the summation indices, we immediately obtain:

$$\overline{\beta} = \overline{\gamma} \iff \frac{\sum_i \frac{\sum_j \partial t_i / \partial t_j}{I}}{I} = \frac{\sum_i \frac{\sum_j \partial t_j / \partial t_i}{I}}{I}$$

Thus, intuitively, Proposition 4 states that for an average jurisdiction i, the average effect of i'tax rate on one of its neighbor j's tax rate —right-hand side of (5.2)— is equal to the average effect of j's tax rate on i's tax rate —left-hand side of (5.2). In other words, if one takes randomly two jurisdictions i and j, the effect of i's tax rate of j's tax rate is expected to be similar to the opposite effect. [CLARIFY]

Proposition 4 is important for analyzing quantiatively tax competition. It guarantees that the policy responsiveness, β_i, and the policy impacts, γ_i, are comparable measures. In the extreme case in which all jurisdictions have the same exposure to tax competition, and in which they all trigger the same aggregate tax responses from their neighbors, Proposition 4 implies that a a jurisdiction's exposure and impact are equal, i.e. $\forall i, \beta_i = \gamma_i$. Of course, in practice, β_i and γ_i may drasctically differ, as showed in our quantitative analysis.

An implicit assumption for Proposition 4 to hold is that the PNM is a square matrix. That is, all jurisdictions considered in the analysis —which are usually dropped in prior reduced-form literature— do need to be accounted for. In particular, zero-tax jurisdictions need to be included as well, especially if the analysis investigates policy reforms like minimum tax constraints (Subsection 5.3). As these jurisdictions are located at corner solutions of their tax rules, they will not respond to marginal policy changes of the other jurisdictions. In practice, this means that the PNM includes rows of zeros for these zero-tax jurisdictions.

To conclude this section on the properties of the PNM, let us mention two other important empirical uses of the PNM. Firstly, the fact that the elements of the PNM can be endogeneously non-significantly different from zero can be used to identify the actual competitors of a jurisdiction. Secondly, the PNM can be directly used to assess the effects of exogenous tax reforms on endogenous tax decsions, by setting appropriated the value of the exogenous tax changes induced by the reform (Subsection 5.3). Beyond tax reforms, if measures of the capitalization effects of any policy experiment are available, our structural approach allows to predict the local governments' tax responses, according to equation (25). Finally, to make sure the vocabulary and notation related to the Policy Network Matrix introduced in this section are transparent, they are summarized in Table A.11 in the Appendix H.1.

5.3. Counterfactual Evaluation

A typical use of quantitive spatial general equilibrium models is the evaluation of counterfactual scenarios. In particular, researchers have been interested in the effects of exogenous changes in tax policies on various outcomes like price capitalization and welfare effects (Suárez Serrato and Zidar, 2016; Fajgelbaum et al., 2019). For sufficiently realistic models, evaluation of a large number of counterfactuals may too large computational time to be practically feasible. For small counterfactual shocks —as is typically the case of tax policies— instead of reevaluating the whole general equilibrium, considerable computational time can be saved by approximating, still accurately, the effects of the counterfactual near the equilibrium. Such an approach is described in Allen et al. (2020) for tariff reforms, assuming exogenous governments.

Government decisions complexify the evaluation as one needs to account for endogenous policy responses whose equilibrium levels already depends on price capitalization, as can be seen in the first-order condition (E.1). However, these policy responses are precisely the components of the the PNM introduced above. This section describes how the PNM can be directly used to evaluate the effects of counterfactual tax reforms in the presence of endogenous governments. We show that the elements of the PNM and the price response matrix are sufficient to recover the effects such a reform on all the economic variables including the policy variables.

First, one needs to decompose the overall differential tax vector $\mathbf{dt}$ into a first part including the non-treated taxing counties, $\mathbf{dt}_1$ and a second part including the treated counties and those which are not free to choose their tax rates, $\mathbf{dt}_2 = \mathbf{dt}_2^c$. The superscript "$c$" indicates the counterfactual level of a variable. We also decompose the PNM accordingly, so that:

$$\boldsymbol{\Omega} \equiv \begin{pmatrix} \boldsymbol{\Omega}_{11} & \boldsymbol{\Omega}_{12} \\ \boldsymbol{\Omega}_{21} & \boldsymbol{\Omega}_{22} \end{pmatrix}, \qquad \mathbf{dt} \equiv \begin{pmatrix} \mathbf{dt}_1 \\ \mathbf{dt}_2 \end{pmatrix},$$

so that, assuming that the non-treated jurisdictions do not further change their tax rates, the tax competition condition (27) implies that:[14]

$$\mathbf{dt}_1^c = (\mathbf{I} - \boldsymbol{\Omega}_{11})^{-1} \boldsymbol{\Omega}_{12} \mathbf{dt}_2^c, \tag{32}$$

which defines the endogenous general equilibrium policy responses of the non-treated jurisdictions, $\mathbf{dt}_1^c$, as a function of the exogenous policy change of the treated jurisdictions $\mathbf{dt}_2^c$. Notice that these general equilibrium policy responses capture the feedback effects of the change in the policy of a non-treated county on the others non-treated counties.

Thus, we can define the equilibrium vector of counterfactual policies as $\mathbf{dt^{c\prime}} \equiv (\mathbf{dt}_1^{c\prime} \quad \mathbf{dt}_2^{c\prime})$. Then, from (26), we can compute the effect of the reform on the equilibrium prices:

$$\mathbf{dZ}^c = \boldsymbol{\Pi}\, \mathbf{dt}^c, \tag{33}$$

where $\mathbf{dZ}^{c\prime} = (\mathbf{dZ}_1^{c\prime} \ldots \mathbf{dZ}_I^{c\prime})$ in which $\mathbf{dZ}_i^{c\prime} \equiv (\mathrm{d}p_i^c \quad \mathrm{d}P_i^c \quad \mathrm{d}G_i^c)$ is the vector of price changes. In sum, condition (32) and (33) prove that for any reform vector, $\mathbf{dt}_2^c$, the PNM, $\boldsymbol{\Omega}$, and the price response matrix, $\boldsymbol{\Pi}$, are sufficient to compute the effect of the reform on all economic variables, as summarized in the following proposition.

Proposition 5. *Evaluation of counterfactual policy senarios accounting for strategic responses of governments can be assessed using the PNM and the general equilibrium response price response matrix. Formally, for an exogenous policy change,* dt_2*,*

(i) the impacts on local governments policy can be measured using condition (32)*,*

(ii) the impacts on equilibrium prices can be measured using condition (33)*,*

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

Proposition 5 extends the *network effects of a trade shocks* characterized Allen et al. (2020) by accounting for the extra network effects of strategic governments' decisions. The accuracy

[14] In this approximation, the tax responses of the non-treated jurisdictions, $\mathbf{dt}_2$, are treated as exogenous. The extent to which this assumption is valid as all jurisdiction can respond endogenously to the initial policy choc will be assessed in Section 6.

of using the PNM for counterfactual analysis versus re-evaluating the whole counterfactual general equilibrium will be assessed in Section 6.

6. Policy Network Matrix and Welfare Effects

Subsection 6.1 quantifies the Policy Network Matrix and the tax reaction slopes. Subsection 6.2 analyses how tax exposure and tax impacts differ in the data. Appendix H.2 discusses the relation between the PNM and the inverse distance matrices used in prior literature.

6.1. Policy Network Matrix

Prior literature struggled with estimating tax reaction functions due to well-known endogeneity issues Gibbons and Overman (2012). In contrast, applying the implicit function theorem to our structural model allows us to quantify heterogeneous general equilibrium tax reaction functions. Table 6 reports the policy responsiveness parameters, β. These tax reaction slopes are the effects of a marginal change in all the other counties' tax rates on a county's tax rate determined by the taxation rule (23), and accounting for the general equilibrium responses of all variables (earnings, number of firms, shopping flows, etc.).

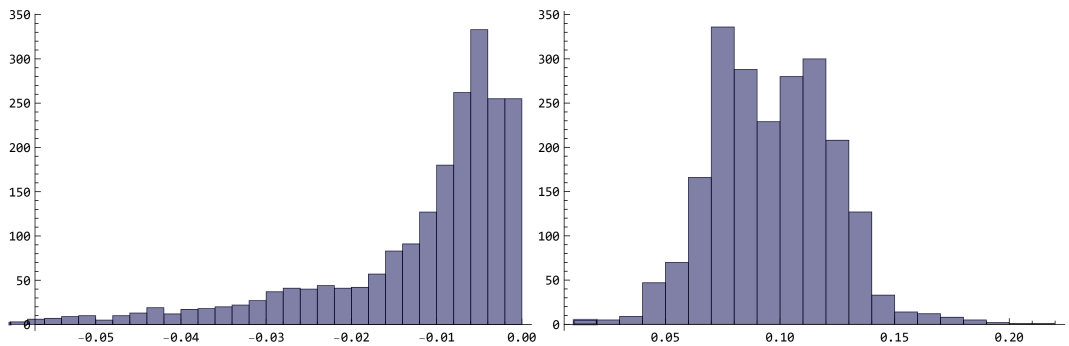
Table 6. Policy Responsiveness, strategic complementarity and strategic substitutability.

	Mean	Median	Min	Max	Obs
A. Policy responsiveness (PR)					
All tax reaction slopes (β)	0.083	0.084	−0.088	0.212	2146
Positive tax reaction slopes (β^+)	0.097	0.096	0.011	0.213	2146
Negative tax reaction slopes (β^-)	−0.014	−0.008	−0.22	−0.0003	2146
B. Types of neighbors: number					
Number of strategic complement neighors	647	372	103	3029	2146
Number of strategic substitute neighbors	2461	2736	79.	3005	2146
C. Types of neighbors: share					
Share of strategic complement neighbors (%)	20.81	11.97	3.31	97.46	2146
Share of strategic substitute neighbors (%)	79.19	88.03	2.54	96.69	2146

NOTE— Panel A includes the tax competition effects. Panels B and C report the number/share of neighbors with respect to which a county has a positive, negative or insignificant tax reaction slope.

Panel A of Table 6 indicates that if all other counties in the economy increase their tax rate by one percentage point on average, a county increases its tax rate by 9 percentage point.

As established in Section 5, this effect represents the aggregate slope of the tax reaction of a county with respect to all its neighbors. Therefore, it gathers positive and negative slopes. The second and third rows of panels A, B and C show that on average, a county's tax change is positive (response of 10.2%) for 22.37% of its neighbors, negative (response of −1.2%) for 77.63 of its neighbors.

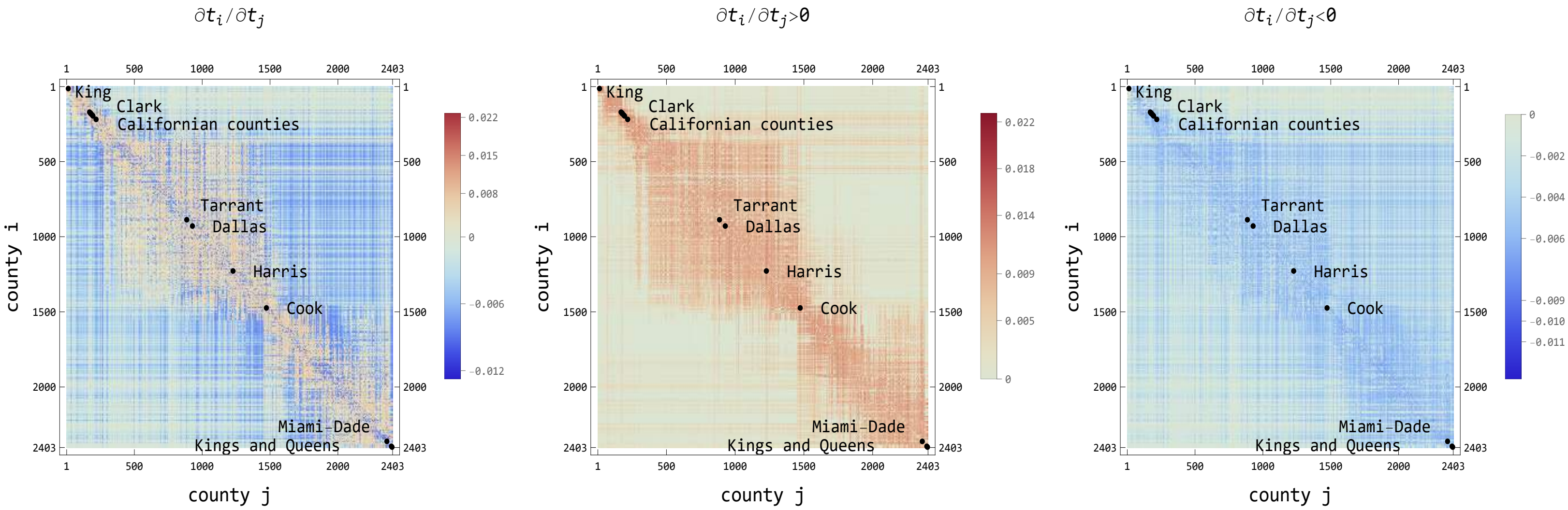


(a) Negative PR (β^-) **(b)** Positive PR (β^+)

Figure 6. Policy Responsiveness (β).

Figure 6 shows that the slope of the tax reaction functions are in the lower range of those in pior tax competition work which estimate that if its average neighbors' tax rate increase by one percentage point a sales tax jurisdiction increases its tax rate by 0.10 and 0.5 percentage point. (Devereux et al., 2007; Jacobs et al., 2010; Agrawal, 2016). This lower reaction is consistent with studies which estimate tax reaction slopes exploiting quasi-natural experiments (Lyytikäinen, 2012).

Importantly, our structural approach allows us to estimate not only positive but also negative and non-significant tax reaction slopes. This contrasts with most previous work which estimated an average response that was either positive or negative for all the sample.



(a) $\boldsymbol{\Omega}$ **(b)** $\boldsymbol{\Omega}^{+}$. **(c)** $\boldsymbol{\Omega}^{-}$

Figure 7. Policy Network Matrix. The figure represents the elements of the PNM for the 2,402 autonomous counties. Counties are ordered by latitudes and longitudes with respect to the furthest north-west point in the country (Drucker et al., 2013). The set "Californian couties" includes (from top to bottom): Los Angeles county, San Bernardino county, Orange county, Riverside county, Sand Diego county, and Maricona county. These county are all slightly below Clark county. A cell of the matrix has element $\partial t_i/\partial t_j$ where i represents a row and j a column.

Figure 7 represents the Policy Network Matrix. The first striking fact is that the impact of (sets of) populated counties are clearly visible. Figure 7b shows that as these counties change their tax rates, the other counties respond substantially, while the reverse is not true. The PNM also reveals that although often concentrated nearby, neighbors need not be contiguous. Moreover, direct neighbors usually engage in complement strategies, while remote neighbors are more likely to slightly use susbstitute strategies or to not react to tax changes. This result is intuitive: as a county increases its tax rate, direct neighbors benefit from the strong tax base spillovers and thus are encouraged to marginally increase their tax rates. On the contrary, indirect neighbors only essentially suffer from the tax increase of the direct neighbors so they are more prone to reduce their tax rates, to compensate their residents.

Appendix D discusses the relation between the policy network matrix and the inverse distance matrices used in prior literature.

6.2. *Policy Responsiveness and Policy Impact*

Subsection 5.2 derives two different measures of tax competition from the viewpoint of a jurisdiction i: its policy responsiveness, β_i, and its policy impact, γ_i. These two indicators are represented in Figure 8 for all taxing counties.

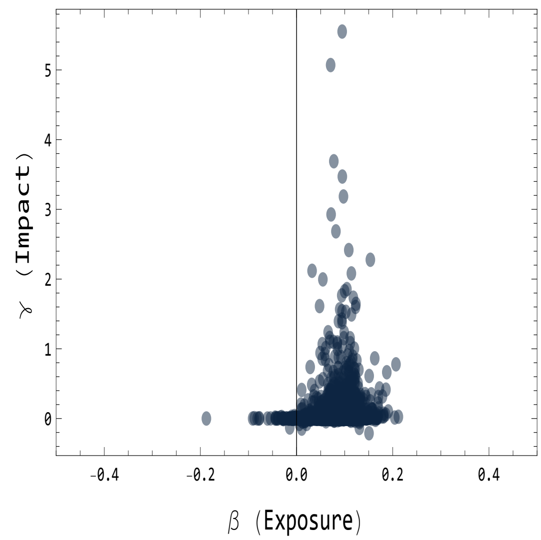


Figure 8. Policy Responsiveness (PR) and policy impact (PI). The figure represents the PR and PI of all counties.

The main insight carried by Figure 8 is that although the exposure to tax competition is similar across counties, their tax influence varies significantly. This heterogenity is particularly striking for larger couties which represent the points on the upper part of the graph, as will be showed hereafter. This striking result is intuitive. If all counties in the U.S. increase their tax rate by one percentage point, it is not obvious to know whether a large county will respond more or less than a small county. Indeed, a large county may be viewed as less subject to a small number of county's policy. However, in the same time, a large county trades with a much larger number of counties all across the country, unlike small counties whose market areas only includes nearby counties, if any. These opposite forces make the quite homogeneous PR rather rational. The significant heterogeneity of the PI is also intuitive. Indeed, it is reasonable to think that most counties have very a small aggregate influence on all other counties in the country. On the opposite, bigger counties which are connected to many other counties may have a significant impact on the country.

Further evidence of this difference between PR and PI are reported in Figure 9 which represents these two indicators with respect to population quantiles —Figure A.15 in the Appendix reports the specific cases of the states of New York and California.

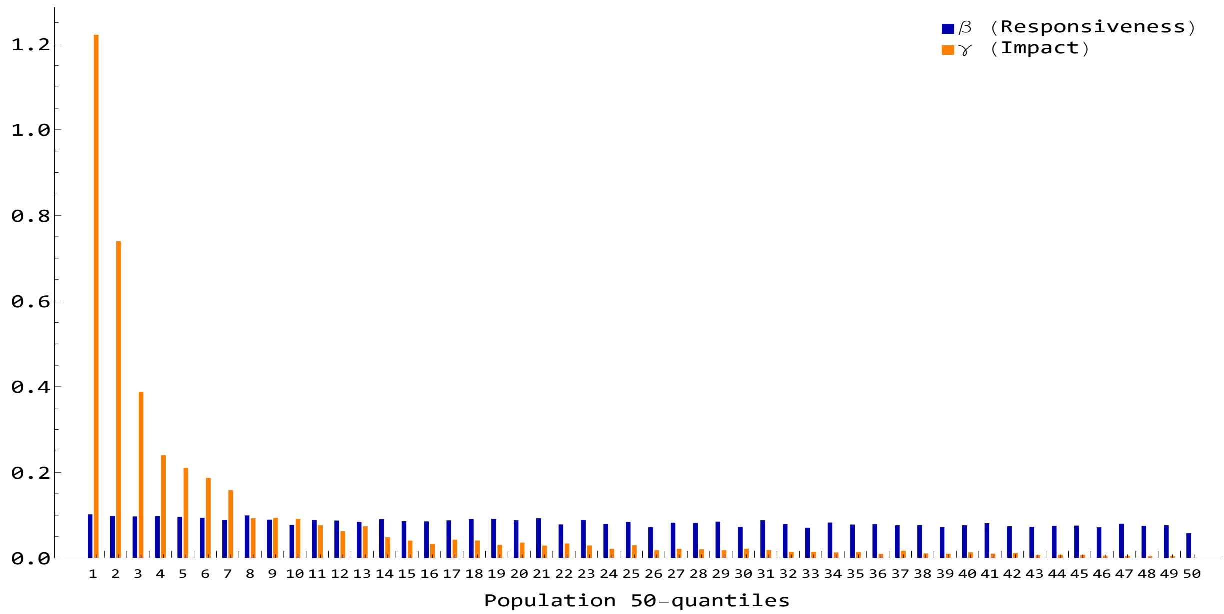


Figure 9. Policy responsiveness and policy impact with respect to the county population.

Figure 9 confirms that the exposure (PR) of all counties are rather similar even though larger counties like New York and Los Angeles are usually in the lower range. It also confirms that the influcence (PI) are strongly heterogeneous with only a few large counties having an influence being non-negligible. Among them, the largest counties have strikingly high PIs.

Finally, the state in which the county is located plays an important role in the level of the PR and PI. Interestingly, this effect is essentially due to the population of the other counties in the state, and it differs in nature for the PR and for the PI. This is shown in Table 7. These results first confirm that the county's population has a significantly positive impact on the policy impact and no significant impact on the policy responsiveness. Columns (2), (3), (4) and (5) provide new insights into the importance of the population size of neighboring counties. Column (2) and (3) indicates that in states with larger counties, a county's tax rate responds more to a joint increase in its neighbors' tax rates. This effect is intuitive, as bigger neighbors are expected to generate larger tax base spillovers.

Table 7. Policy responsiveness, policy impact and state populations.

	(1)	(2)	(3)	(4)	(5)	(6)
	Responsiveness β			Impact γ		
Popuplation n_i ($\times 10^{-6}$)	0.0139		0.0149	1.617**		3.591***
	(0.0104)		(0.00905)	(0.518)		(0.338)
Population per county in state n^S ($\times 10^{-6}$)		0.643***	0.677***		−0.277	1.465*
		(0.135)	(0.138)		(0.703)	(0.551)
Interaction $n_i \times n^S$			−0.126			−14.27***
			(0.0742)			(2.084)
N	2146	2146	2146	2146	2146	2146

Standard errors in parentheses are clustered at the state level
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

NOTE— The sample includes all taxing counties. Controls include all county variables (from Area to Coastline) reported in Table A.2 and the population weighted avearage of these variables at the state level.

This contrasts with the absence of conclusive direct effect of the neighbors' population on the PI as reported in columns (5) and (6). However, the population per county in the state influences significantly the marginal effect of having a larger population on the PI. Column (6) indicates that although a larger county has a larger impact on its neighbors than a smaller one (first row), this impact is smaller if its neighbors are bigger (third row). This intuitive results shows that to understand the influence of a county one needs to consider not only its size, but also the size of the other counties with which it directly interacts.

Subsection 5.3 showed that the PNM can be instrumental for evaluating small policy changes like tax reforms. As the PNM is a local approximation of the tax responses near the observed equilibrium, it is important to get a sense of the accuracy of this approximation. Figure 10 represents the tax change predicted by the PNM along with the tax change obtained by solving for the general equilibrium. It indicates that both are strongly positively correlated, and that and that most points are close to the 45 degree line. As expected, the approximation provided by the PNM appears to be less accurate for larger tax reform (e.g. minimum tax of 4%). But the correlation between PNM and general equilibrium predictions remain positive and relatively close to the 45 degree line. These results suggest that the PNM can be a good instrument for counterfactual evaluation of tax reforms.

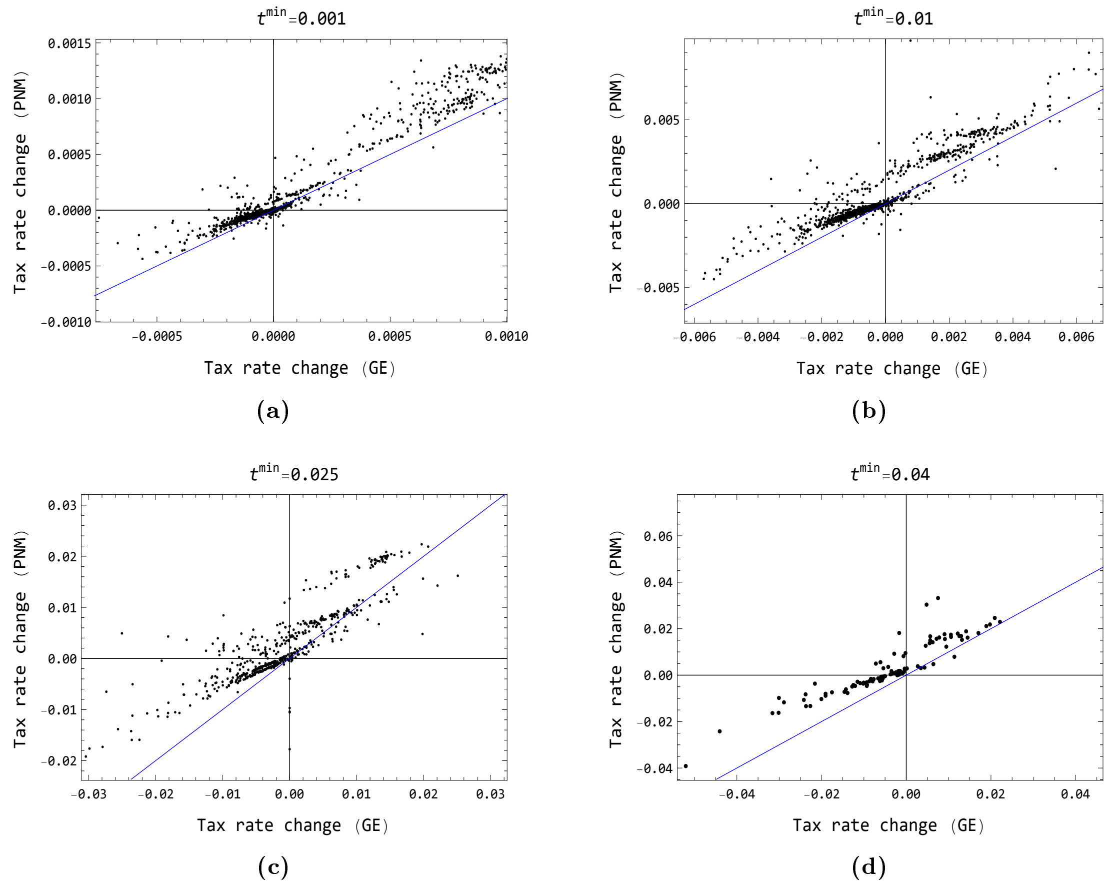


Figure 10. Prediction of effect of the reform on tax responses of non-treated counties, using the PNM versus solving for the full general equilibrium. The blue line represents the 45 degree line. The tax rate changes have been multiplied by 100, so they need to be interpreted as percentage points.

6.3. Policy Impact and Welfare Effects

The policy network matrix provides useful information for designing potential tax reforms. It may help targeting subgroups of jurisdictions according to their policy impacts. To illustrate this, this section considers two different experiments. The first imposes a minimum increase of 1 percentage point in the tax rate of the bottom 20% counties with lowest policy impacts. The second imposes a minimum increase of 1 percentage point in the tax rate of the top 20% counties with highest policy impacts. In Appendix H.4, Table A.14 provides descriptive statistics on these two groups of treated counties and Figure A.16 represents their spatial distribution. In line with the results reported in the previous section, counties with larger policy impacts are also much more populated, they are richer and choose lower tax rates.

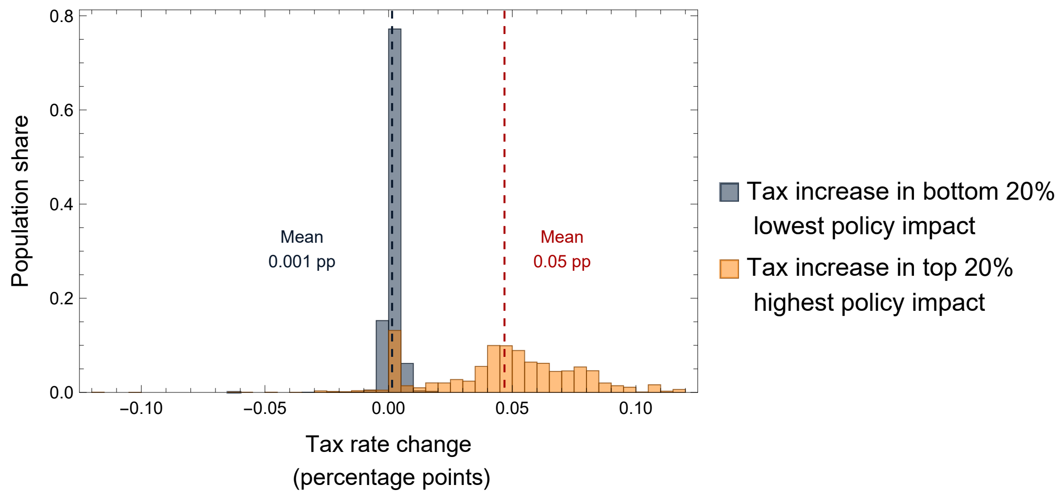


Figure 11. Tax rate change following a targeted 1 percentage point minimum tax increase. The reported effects are those on the 60% counties that are never treated

Figure 11 represents the tax responses of the 60% counties that are never treated. As expected, a tax increase at the top of the distribution of the policy impact induces sinificanltly larger tax responses than a tax increase at the bottom of the distribution does. The policy network matrix is thus informative of the expected tax responses from policy reforms. The tax responses in Figure 11 are indeed of the same magnitude as the policy impact measures. The treated group of countieswith low impacts has slighlty negative policy impacts close to zero.

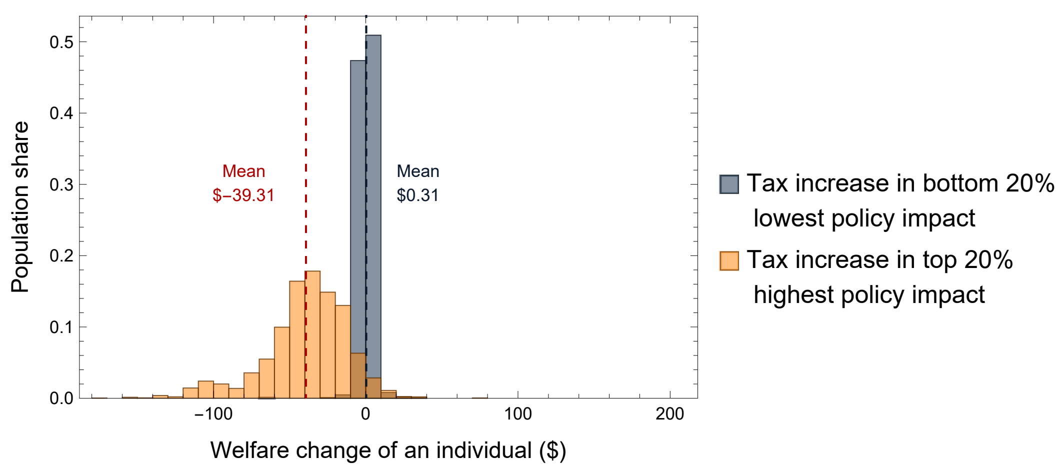


Figure 12. Welfare effects of a targeted 1 percentage point minimum tax increase. The reported effects are those on the 60% counties that are never treated. Tax rates are chosen freely by all counties in states allowing for county-level taxation.

Figure 12 represents the welfare effects of our two experiments on the 60% counties that are never treated. These effects are statistically zero on average for the reform targeting the bottom of the distribution of the policy impacts. However, as the top of the distribution is imposed a tax increase, the welfare decreases significantly in the non-treated counties. This reflects the fact that the significant amount of cross-border shopping to the treated counties becomes more expensive.

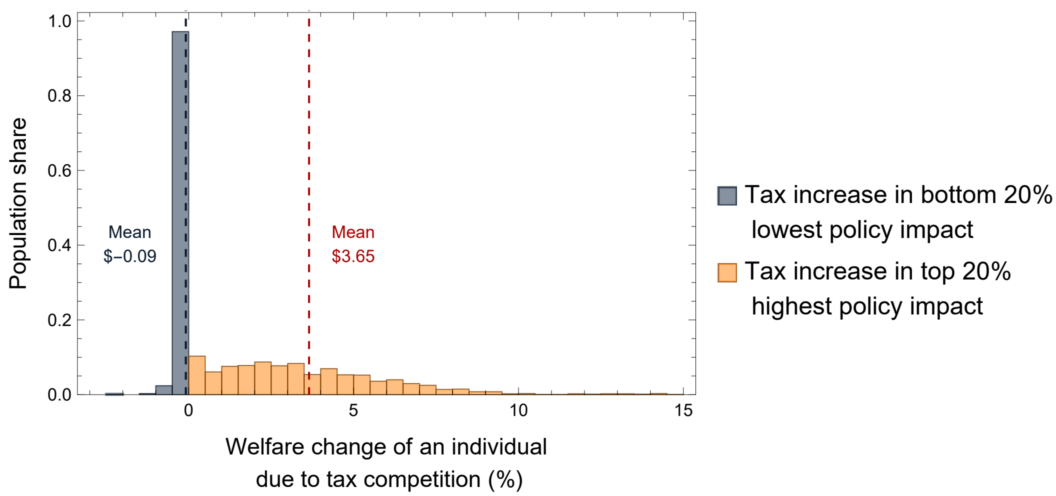


Figure 13. Welfare effects due to tax competition as a targeted 1 percentage point minimum tax increase is imposed. The reported effects are those on the 60% counties that are never treated.

Figure 13 represents the welfare effects due to tax competition. As expected, for the reform affecting the counties with larger policy impacts, tax competition entails significant welfare effects, while the reform on counties with small impact generates small tax competition effects. The signs of the welfare changes are opposite, in line with the signs of the policy impacts. The large-impact counties spur other counties to raise their tax rates and thus improve the welfare by providing more public services there, while the low-impact counties generate tax cuts and thus reduce the welfare elsewhere.

7. Conclusion

This paper provides a new framework to measure the interactions between strategic governments and their impacts on economic outcomes in a spatial general equilibrium economy. This framework is used to quantify the welfare implications of strategic tax decisions. The degree of tax competition is quantified by deriving an endogenous policy network matrix which generalizes the exogenous postulated weight matrix postulated in prior literature. We develop a spatial general equilibrium model with endogenous commodity tax competition. We apply our model to U.S. county sales taxes which allows us to measure the interjurisdictional price incidence of local taxes, to quantify the different components of local governments' tax rules, and to investigate the welfare effects of various tax reforms like the introduction of a minimum tax or the imposition of tax harmonization.

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