The Macroeconomic Effects of Tax Competition: The Brazilian "Fiscal War", Public Goods Provision, and Economic Development.

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Abstract

Social welfare and economic development can be hindered by a heterogeneous corporate tax system. I study the role of tax competition between state governments in lowering overall public goods provision and income levels. To do so, I build a multi-region general equilibrium model with endogenous state taxes, public expenditures, and firm location choices. I then estimate the model to match novel data encompassing state-level tax exemptions at the sector level in Brazil. I find that tax competition costs Brazil 11 percent of its citizens' real income and 19 percent of its state public goods provision. Centralized taxation emerges as a potential remedy to mitigate these losses, although it would inevitably create both winning and losing states.

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1 Introduction

Developing countries consistently raise less tax revenue than advanced economies (Besley and Persson (2014)). While multiple explanations have been proposed (Acemoglu (2005), Besley and Persson (2009)), the causes of this taxation gap remain debated. What is clear, however, is that economic development and tax collection are closely linked. In this paper, I examine one potential amplifier of low tax revenues in developing economies: tax competition.

Tax competition occurs when subnational governments use tax incentives to attract mobile economic resources. Decentralized tax structures allow states and municipalities significant autonomy to set their own tax policies. Such federalist arrangements exist to varying degrees across Latin America, but Brazil stands out as a prominent example. In Brazil, aggressive competition among states for firms is so widespread that it is widely referred to as the country's own *fiscal war* in public debate and the media.[1] Since fiscal wars may erode state tax revenues and place firms far away from their consumer markets, many have raised concerns about their potential to undermine public goods provision and reduce income.

In this research paper, I first develop a baseline theoretical model to analyze the core tradeoffs of subnational tax competition. The baseline model clarifies the fundamental tradeoff facing state governments when setting corporate tax rates. Workers in each state prefer a tax rate (t_ℓ^{w*}) that maximizes their utility, partially through public goods provision, while firms prefer a tax rate (t_ℓ^{f*}) that maximizes after-tax profits. I show that under reasonable parametric assumptions $t_\ell^{f*} < t_\ell^{w*}$. Although local governments would like to set $t_\ell = t_\ell^{w*}$ to benefit citizens, competition for mobile firms gives them an incentive to set t_ℓ closer to t_ℓ^{f*}, effectively "stealing" firms from other states. As in a prisoner's dilemma, states cannot credibly commit to high tax rates and are driven to inefficiently low taxation. I formally characterize the equilibrium and show that any decentralized tax system with multiple states is not Pareto efficient: equilibrium tax rates are too low in all locations. The intensity of tax competition depends on how responsive firm location is to local tax changes.

[1] It is also commonly referred to as a "race to the bottom" in the United States and the economics literature

I then extend my baseline model to add credibility to my counterfactual exercises. I calibrate this enhanced spatial general equilibrium model to estimate the aggregate effects of Brazil's fiscal war on income and public goods provision. The model features four types of agents—state governments, firms, workers, and capitalists—interacting in a spatial economy with heterogeneous value-added and corporate income tax rates. Firms choose production location(s) and which markets they will serve, subject to local wages, rents, public goods, marketing costs, and idiosyncratic multivariate Pareto shocks. State governments set tax rates, raise VAT revenues, and receive federal transfers. Workers endogenously select their location based on amenities, local labor markets, public goods, and idiosyncratic preferences. Additionally, profits and rents can flow freely across state borders, reflecting portfolio ownership of capitalists. Furthermore, a federal government collects taxes and provides federal tax revenue transfers to state governments.

I calibrate this enhanced spatial general equilibrium model to match key features of the Brazilian data, including state value-added shares, labor value-added shares, state trade deficits, federal tax transfer patterns, among others. I use a gravity-model framework to estimate the elasticities that govern firm and worker mobility across states. The calibrated model implies that Brazil's fiscal war reduces aggregate real state public expenditure by 19 percent and consumption per capita by 11 percent, relative to a scenario with uniform country-wide corporate taxation. However, the gains from limiting tax competition are unevenly distributed, with some states benefiting and others experiencing losses. Tax centralization is analyzed as a remedy to tax competition. Centralization is predicted to increase aggregate real income and public goods provision by 6 and 99 percent, respectively.

Brazil provides an ideal setting for this analysis for three reasons. First, Brazilian states have a long history of aggressive tax competition, commonly referred to as a "fiscal war," in which states use VAT tax incentives to attract firms from one another.[2] Second, the country underperforms on a range of public goods provision indicators even relative to similar

[2] See, e.g., De Mello (2008), da Costa Campos et al. (2015), and Ferreira et al. (2005)

developing countries (Mendes (2014)), which makes public expenditure a key aspect for the country's development. Only 65 percent of households are connected to a sewerage system (Census 2022), and public primary education remains weak, with just 27 percent of students achieving basic mathematics proficiency (PISA 2022). [3] Third Brazil's transparency laws require states to publicly report the value of tax incentives granted, allowing for the construction of a novel, comprehensive panel of state-level effective tax rates.

Data on state-level tax expenditures are publicly reported by Brazilian states, detailing the amount of tax revenue forgone through sector-specific tax incentives each year. I compile and categorize these reports to construct a measure of effective tax rates at the sectoral level for each state in Brazil in 2023.

Analysis of the constructed panel reveals that, on average, Brazilian states forgo approximately 31 percent of potential VAT tax revenues through tax incentives, amounting to US$44.66 billion in 2023. This figure represents about 25 percent of total state tax revenues, net of federal transfers. The state of Amazonas illustrates the intensity of such incentives: in 2023, it waived US$3.27 billion[4] in VAT revenues—equivalent to 53 percent of all the revenue to which it was entitled.

1.1 Literature Review

This paper is related to several strands of the literature. This paper contributes to the fiscal federalism literature, which studies tax competition among subnational governments and its welfare implications (Oates (1972),Wilson (1999)). Much of this work has focused on the United States, where competition for mobile resources is frequently described as a "race to the bottom" (e.g., Oates (1993); Wilson (1985),Wilson (1987),Wilson (1991)). Theoretical models in this tradition typically assume cross-state symmetry and representative firms for tractability, but rarely provide empirical or counterfactual assessments of the aggregate costs of tax competition. In contrast, this paper quantifies the fiscal and welfare impacts of tax

[3] Census 2022.

[4] R$ 16.36 billion

competition using a calibrated model and administrative data from Brazil.

On the theoretical front, a growing literature develops models with mobile firms (e.g., Kleinman (2022); Castro-Vincenzi (2023)). The modeling of tax competition across governments is also explored in Ossa (2011), Ossa (2012), and Ossa (2014), although these studies focus on international settings and trade tariffs. Recent research has further examined the effects of firm taxation on various economic outcomes (see, for example, Suárez Serrato and Zidar (2017); Nallareddy et al. (2018); Suárez Serrato and Zidar (2023)). This paper relates to these strands by analyzing tax competition and its effects in a spatial context.

This paper also relates to seminal work in trade economics by borrowing tools of general equilibrium spatial modeling to estimate the aggregate effects of policy changes. My enhanced model uses input-output loops at the sector level (Caliendo and Parro (2015)), firm selection, multi-region production (Melitz (2003)) and (Arkolakis et al. (2018)), and several other features of the international trade literature.

Finally, I highlight four recent publications that are most closely related to this work. Chirinko and Wilson (2017) examines whether there is a race to the bottom in capital and corporate income taxes among U.S. states, focusing on the dynamic co-movement of statutory state taxes rather than on the aggregate consequences of fiscal competition. Fajgelbaum and Gaubert (2020) analyzes optimal spatial subsidy policy with an emphasis on workers' spatial allocation, but does not explicitly model tax competition. Ferrari and Ossa (2023) demonstrates how states seek to attract firms in order to leverage agglomeration spillovers under different subsidy schemes; in their framework, U.S. state subsidies are found to be more cooperative than non-cooperative across states. Fajgelbaum et al. (2019) focuses on misallocation generated by state-level tax rate dispersion and its welfare implications for the United States. I, on the other hand, extend their framework to study the effects of tax competition on public capital provision and aggregate consumption. Furthermore, my main specification considers a dimension of tax heterogeneity that was ignored in their paper: sectoral heterogeneity. By considering multiple sectors, state-sector-specific taxation, and input-output loops, I argue that I present a more accurate set of estimates of tax reforms in economies with a high degree of sectoral tax heterogeneity.

Section 2 presents relevant background information and institutional details of tax cuts and the Brazilian tax system. Section 3 introduces the dataset built and empirical facts about the effective tax rates and tax cuts in Brazil. Section 4 develops a baseline model and derives propositions for this model. Section 5 presents the enhanced spatial model. Section 6 calibrates my model. Section 7 performs counterfactual exercises. Section 8 concludes.

2 Institutional background and overview of the state VAT

In Brazil, state governments are responsible for setting the value-added tax on goods (ICMS), which is the primary source of subnational tax revenue. Unlike conventional VAT systems that follow the destination principle, ICMS revenues accrue to the state where goods are produced, rather than where they are consumed. This origin-based structure effectively transforms the ICMS into a production tax, rather than a pure consumption tax, and has led to significant inter-state fiscal competition and extensive tax-related litigation within the Brazilian court system.

The complexity of the Brazilian tax system is reflected in the determination of ICMS tax rates, which in some cases may vary by product, transaction type, and occasionally by specific buyer and seller characteristics. In practice, Brazilian states have historically imposed higher ICMS rates on relatively inelastic goods such as water, electricity, and oil—often among the highest rates observed across the economy. Despite the intricacy of the statutory framework, Appendix A shows that manufacturing and services statutory tax rates can be reasonably summarized as 18 percent for intrastate and 12 percent for interstate transactions.

2.1 Tax cuts

When tax cuts are granted, effective ICMS rates may diverge substantially from statutory rates. In these cases, the statutory rate provides only an upper bound for the average effective tax rate at the state level. Tax cuts can be broadly classified into two types: general and targeted.

General tax cuts are sector- or product-specific reductions available to all firms producing the relevant goods or operating in a particular sector. These reductions, which often apply to final goods, are typically implemented through federal-state agreements (Convênios ICMS) and tend to yield relatively uniform rates across participating states.

Targeted tax cuts, in contrast, are granted to individual establishments, commonly in manufacturing and intermediate goods sectors. States create programs that grant a pre-established tax rate reduction for all firms approved by the state government. These cuts often take the form of tax credits, allowing firms to deduct a percentage of their tax liability. Determining which firms are eligible for such cuts involves both legislative parameters—such as eligible sectors, duration, and intensity of cuts—and considerable administrative discretion by state agencies, often based on broad criteria like job creation or firm expansion. While program design is similar across states, the generosity and prevalence of local tax cuts vary widely.

Even though it is economically relevant to understand the political economy and nuances of firm selection into these tax cuts, I abstract from these topics in this research paper to focus on macroeconomic variables and aggregate data on average effective state-level tax rates across sectors.

3 Dataset

3.1 *Tax revenues waived*

The primary dataset used in this analysis is a novel cross-sectional database constructed from official state budget projection documents (Leis de Diretrizes Orçamentárias, LDOs) submitted annually by each of Brazil's 27 states. These documents include a standardized section on tax revenue waivers (*Renúncia Fiscal*), as mandated by federal guidelines, which report projected foregone tax revenue by tax base, tax instrument, and beneficiary sector. While some variation exists in reporting practices across states, the vast majority of LDOs follow a similar structure. The projected tax revenue waivers for a given year t are calculated as the net present value of tax expenditures realized in year $t-2$, updated for expected inflation as documented in the LDOs. Using these projections, effective aggregate ICMS tax revenue waivers were recovered for all 27 states in 2023 across 3 sectors: agriculture, manufacturing, and services. Further details on data aggregation and calculation procedures are provided in the data appendix.

This dataset is merged with a second panel, obtained from federal government records compiled by the National Economic Policy Council (CONFAZ), which provides data on state-level ICMS collections disaggregated by sector. By combining information on collected revenues, forfeited revenues, and statutory rates, it is possible to construct effective tax rate measures for each state-sector-year observation.

3.2 State Trade flows

Another important source of data is sectoral interstate trade flows within Brazil. The dataset constructed by Haddad et al. (2017) provides detailed information on trade flows between Brazilian states, disaggregated by sector. Sector-level trade shares from this dataset are used to construct corresponding trade share measures in the present analysis, ensuring consistency with the sectoral classification employed throughout the study.

3.3 Other datasets

For calibration, additional data describing state-level economic characteristics—such as gross domestic product, population, and sectoral composition—were obtained from two primary federal sources: the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística-IBGE) and the Institute for Applied Economic Research (Instituto de Pesquisa Econômica Aplicada-IPEA). Further details on the datasets and their usage are presented in the calibration section

3.4 Descriptive statistics

Table 1: Percent of VAT entitlements forgone

State	$\frac{\text{VAT taxes waived}}{\text{VAT taxes entitled}}$	State	$\frac{\text{VAT taxes waived}}{\text{VAT taxes entitled}}$	State	$\frac{\text{VAT taxes waived}}{\text{VAT taxes entitled}}$
AM	61.37%	TO	34.44%	RN	21.42%
PR	52.12%	SP	29.89%	MG	21.32%
MS	46.47%	AL	29.85%	AP	20.53%
DF	44.67%	CE	28.34%	ES	16.64%
GO	40.48%	PE	27.37%	RS	14.17%
MT	40.22%	AC	26.64%	RO	13.92%
RJ	38.43%	SE	24.06%	PI	13.83%
PB	35.66%	BA	23.96%	PA	12.67%
SC	34.44%	MA	23.18%	RR	1.84%

In Brazil, states levy three main taxes: a value-added tax (ICMS), an annual vehicle tax (IPVA), and an inheritance tax (ITCMD). Owing to its broad base, the ICMS is by far the most important source of state revenue. It is therefore striking that states forgo a substantial share of these VAT entitlements through tax exemptions.

The table illustrates the substantial magnitude and heterogeneity of ICMS tax incentives across states. In some years, states forgo as much as 50 percent of their ICMS entitlements. While Rio de Janeiro and São Paulo waive 38.43 and 29.89 percent, respectively, Amazonas relinquishes 61.37 percent, whereas Rio Grande do Sul waives only 14.17 percent.

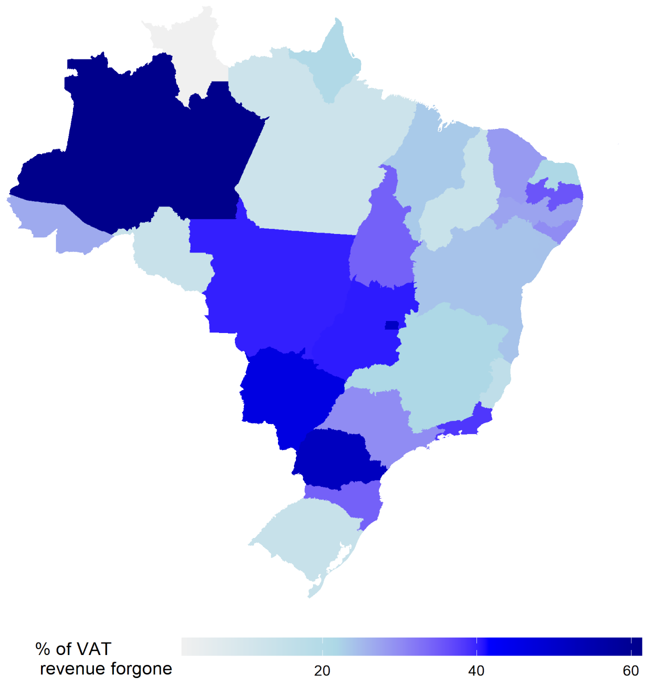
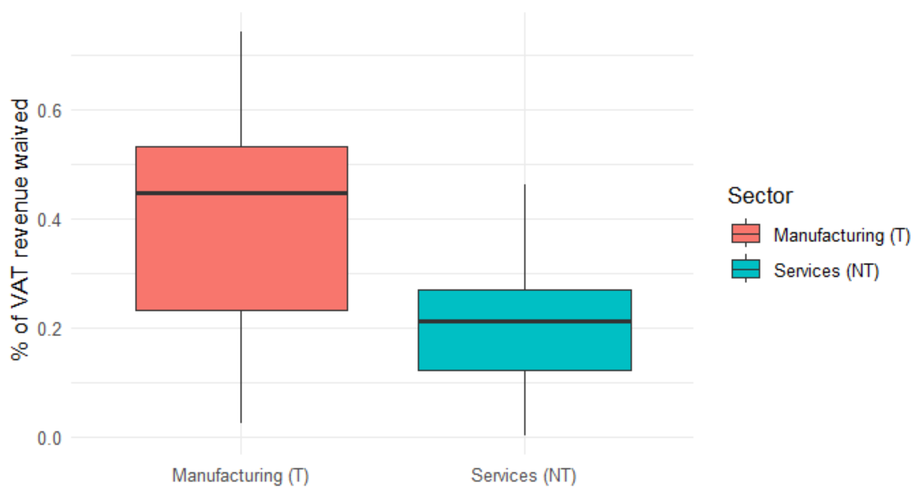


Figure 1: Share of VAT revenues waived through tax exemptions across states.

Figure 2: Percent of VAT entitlements waived by sector



Finally, there is substantial heterogeneity in tax rates across sectors. Although some states report foregone revenues disaggregated into 21 sectors, the absence of a consistent sectoral breakdown across all states forces the analysis to be conducted at a more aggregated level, distinguishing only among agriculture, manufacturing, and services.

Agricultural products are generally subject to very low tax rates, irrespective of state-level incentives. Federal legislation requires states to set low ICMS rates on agricultural goods. By contrast, manufacturing and services are subject to similar statutory rates. Table 1 in the Appendix 7 reports these default statutory rates across states for 2025. Any difference in the share of VAT entitlements waived therefore translates directly into differences in effective rates across these two sectors. Figure 2 illustrates that manufacturing faces substantially lower effective rates than services. For example, under a statutory rate of 20 percent, the median effective rate is roughly 11 percent for manufacturing compared with 15.8 percent for services.

4 Baseline Model

This section presents a baseline model that illustrates the key mechanisms and trade-offs local governments face when setting tax rates in a competitive environment. I generalize the notion of state-level tax competition to a framework in which abstract locations compete for firms and workers. The economy is closed and static, with L locations indexed by $\ell \in \{1, \dots, L\}$.

A continuum of workers, normalized to have total measure one, is distributed across locations. Workers collectively supply $\{L_\ell\}_{\ell=1}^{L}$ units of labor to local markets and derive utility from private consumption and public goods. A continuum of firms, also of measure one, chooses locations to maximize expected profits, which depend on local wages, tax rates, and idiosyncratic shocks. Firms produce a homogeneous good traded without friction in the national market.

Each location is governed by a local authority that sets tax rates to maximize per capita household welfare. Higher tax rates increase the provision of public goods, but at the cost of discouraging firm entry and lowering local wages. The resulting trade-off between revenue generation and labor income underpins the analysis that follows.

The following section augments the baseline model with additional firm and worker mechanisms in order to generate more precise estimates of aggregate effects from tax policy changes in counterfactual exercises.

4.1 Households

A continuum of workers, indexed by $h \in [0,1]$, each inelastically supplies one unit of labor to a single location ℓ. Workers are immobile across locations, and their distribution is denoted $\{L_\ell\}_{\ell=1}^{L}$. If N_ℓ^d denotes aggregate labor demand in ℓ,labor market clearing must satisfy:

$$N_\ell^d = L_\ell \tag{1}$$

Each worker earns the local wage w_ℓ and derives utility from private consumption c_ℓ and access to public goods g_ℓ. Consumption must be financed with labor income. Since wages are uniform within a location, consumption is homogeneous across workers:

$$c_\ell(h) = \frac{C_\ell}{L_\ell} = w_\ell. \tag{2}$$

Similarly, individual utility is constant across all households within a location ℓ. Therefore, utility for a household h in ℓ is simply a function of its access to public capital g_ℓ and average household consumption c_ℓ.

4.2 Firms

A continuum of firms, indexed by $i \in [0,1]$, produces a homogeneous final good, with the price normalized to one. Each firm chooses a single location in which to operate and the amount of labor to employ. Firm i's decisions depend on three factors:

1. idiosyncratic firm–location productivity shocks $\{z_\ell^F(i)\}_{\ell=1}^{L}$,
2. location-level productivity shifters $\{\zeta_\ell\}_{\ell=1}^{L}$, and
3. location-level effective tax rates $\{t_\ell^y\}_{\ell=1}^{L}$.

The taxation structure is flexible and will later be restricted to mirror Brazil's system. In particular, the ICMS is modeled as a local revenue tax, consistent with its treatment as a value-added tax accruing to the jurisdiction of production.[5]

Conditional on location ℓ, firm i produces according to

$$y_\ell(i) = f\big(N_\ell(i); \zeta_\ell, z_\ell(i), G_\ell, t^y_\ell\big), \tag{3}$$

where output depends on labor input $N_\ell(i)$, local productivity shifters, idiosyncratic shocks, public capital, and local revenue taxes.

A firm locates in ℓ if and only if it attains the highest after-tax profits there. I denote firm i's decision to locate in location ℓ as:

$$i \in \ell \iff \pi_\ell(i) \geq \pi_j(i) \quad \forall j \in \{1, \dots, L\}. \tag{4}$$

Aggregate variables in location ℓ are denoted by $\{N^d_\ell, N^s_\ell, L_\ell, Y_\ell, \Pi_\ell\}$, corresponding to labor demand, labor supply, households, output, and profits, respectively.

Profits accrue to a representative foreign capitalist and therefore do not enter local household income. Under a Cobb–Douglas technology with decreasing returns to scale, rebating profits locally to households would yield identical equilibrium outcomes up to a scale factor α.

4.3 Local Government

Brazilian states can independently set their own tax policy, in a decentralized fashion. The tax system considered will, therefore, be a decentralized tax system. Each location is endowed with a local government. Each local government picks local tax rates to maximize per capita welfare, taking other locations' tax rates as given and subject to a local government's budget constraint:

[5] The model is isomorphic to one with local labor taxation $(1 + t^L_\ell)$.

$$\max_{t^y_\ell} \frac{U_\ell}{L_\ell} \quad \text{s.t.} \quad P^G G_\ell = t^y_\ell \int_{i \in \ell} y_\ell(i)\, di \tag{5}$$

As locations choose tax rates independently to maximize their objective functions, this environment sets up a simultaneous game that locations play. The relevant concept of equilibrium, thus, involves a notion of Nash Equilibrium, in which locations best respond to each other by picking tax rates and taking other locations' tax rates as given. Under this game, the first-order conditions are key to determining the equilibrium of the game, as they pin down best-response tax rate of state ℓ, t^y_ℓ, given other states' tax rates $\{t^y_j\}_{j \neq \ell}$.

4.4 Decentralized Equilibrium

A general equilibrium with a decentralized tax system in this economy consists of a distribution of workers and firms $\{L_\ell, M_\ell\}_{\ell=1}^L$, aggregate quantities $\{Y_\ell, C_\ell, G_\ell\}_{\ell=1}^L$, wages and local tax rates $\{w_\ell, t^y_\ell\}_{\ell=1}^L$, consumption prices, so that:

1. Labor market clears in each location as in (1)

2. Consumers' budget constraint holds for every consumer, as in (2)

3. Firms choose labor employment and their plant location optimally, according to (4)

4. Local governments maximize local per capita welfare and local governments' budget constraint holds, according to (5)

5. Goods market clearing:

$$Y_\ell = C_\ell + \Pi_\ell + G_\ell \tag{6}$$

4.5 Parametric assumptions

The utility function is assumed to be a Cobb-douglas composite of their private consumption and public goods:

$$u_\ell(h) = g_\ell^{1-\gamma} c_h^\gamma = \left(\frac{G_\ell}{L_\ell^{\chi w}} \right)^{1-\gamma} c_h^\gamma \tag{7}$$

Therefore, per capita welfare in a given location ℓ can easily computed solely as a function of aggregate public goods and aggregate consumption.

The production function is also assumed to be Cobb-douglas but with decreasing returns to scale on public goods. Firms take in public capital and labor to produce their homogeneous good.

$$y_\ell(i) = \zeta_\ell z_\ell(i) G_\ell^\beta N_\ell(i)^\alpha \tag{8}$$

Firms will also observe a set of firm-location-specific idiosyncratic TFP shocks $\{z_\ell(i)\}_{\ell=1}^L$ and a fixed set of productivity shifters $\{\zeta_\ell\}_{\ell=1}^L$ before making their location choice. Let $Z_\ell = \left(\int_{i \in \ell} [z_\ell(i)]^{\frac{1}{1-\alpha}} \right)^{1-\alpha}$ denote a measure of aggregate productivity. I assume $z_\ell(i)$ are i.i.d random variables, so that $z_\ell(i) \sim \text{Fréchet}(1, \theta)$. The properties of the extreme value distribution and Fréchet yield a tractable expression for aggregate productivity across locations.

Where M_ℓ is the share of national production that takes place in location ℓ. Furthermore, I normalize $P_C = P_G = 1$, so that the public good is the same as the final private consumption good.

The parametric assumptions give rise to the main elasticities of the model (see appendix). One particularly important feature is the *cross-regional tax-output elasticity*. In this setup, when a location changes its tax rate, the aggregate output of all other locations responds in exactly the same way. This happens because the Fréchet shocks are assumed to be i.i.d., which forces the elasticity of Y_j with respect to t_ℓ^y to be constant whenever $\ell \neq j$.

4.6 Nash Equilibrium

Under these parametric assumptions, first-order conditions can be manipulated to yield the intuitive marginal cost and marginal benefit interpretation of first-order conditions. The first-order conditions boil down to:

$$\underbrace{\underbrace{(1-\gamma)}_{\text{Direct utility effect}} + \underbrace{\frac{\beta}{1-\beta}}_{\text{Multiplier effect}}}_{\text{MB}} = \underbrace{\underbrace{\gamma\frac{t_\ell^y}{1-t_\ell^y}}_{\text{Consumption appropriation effect}} + \underbrace{\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M_\ell)\left(\frac{t_\ell^y-\beta}{(1-t_\ell^y)}\right)}_{\text{Firm production and relocation effect}}}_{\text{MC}} \tag{9}$$

To further highlight the key dynamics of the model I propose the analysis of 3 extreme cases of firm mobility. If condition (12) holds, then the following results must hold:

Monopoly problem. Suppose firms only have one potential location, i.e. $L = 1$. Then in a decentralized equilibrium, the condition reduces to

$$t_\ell^y = \beta + (1-\gamma)(1-\beta) \quad \forall \ell \in \{1, \dots, L\}. \tag{10}$$

Perfect competition. Suppose there are infinitely many equally appealing locations for firms, i.e. $\zeta_\ell = L_\ell = 1$ and $L \to \infty$ for all i, ℓ. Then in a decentralized equilibrium,

$$t_\ell^y = \beta + (1-\gamma)\big(\alpha + \tfrac{1}{\theta} - \beta\big) \quad \forall \ell \in \{1, \dots, L\}. \tag{11}$$

A clear ranking arises from these 2 cases. Tax rates are highest in the monopoly problem, followed by perfect competition. In fact, it can be shown that the Monopoly problem serves as the upper bound of the tax rate of this game, while the perfect competition is the lower bound for tax rates set by local governments.

Moreover, it is possible to show that the uniform tax rate that maximizes aggregate profits is β.

4.7 Characterizations of equilibria

All work that follows uses the following equilibrium condition:

$$\beta < \frac{1}{\theta} + \alpha < 1 \tag{12}$$

Condition (12) restricts my analysis to realistic scenarios. Under this condition, firm productivity is tamed to avoid divergent solutions for taxation $\{t_\ell^y\}$ and productivities $\{Z_\ell\}$. Furthermore, it guarantees that states don't gain new firms as they increase effective tax rates. Under this condition, I achieve the following characterizations of equilibria:

Proposition 1. *Under (12), a decentralized equilibrium* ***always exists*** *and* ***is unique****.*

Exploring the equilibrium conditions pinned down by the first-order conditions, I can rank equilibrium tax rates based on location parameters $\{L_\ell, \zeta_\ell\}$.

Proposition 2. *Under (12),in any two locations $\ell \neq j$, the following must hold in a decentralized equilibrium:*

$$\zeta_\ell L_\ell^\alpha > \zeta_j L_j^\alpha \iff t_\ell^y > t_j^y \tag{13}$$

In other words, if local government preferences are held constant, locations that are naturally more attractive to firms will impose greater effective tax rates. One important corollary of such propositions is derived from this proposition. Under the symmetric case ($\zeta_\ell L_\ell^\alpha$ are the same for all ℓ):

$$t_\ell^y = \beta + \frac{(1-\gamma)(\frac{1}{\theta} + \alpha - \beta)}{1 - \frac{1}{L}\left(1 - \alpha - \frac{1}{\theta}\right)\left(\frac{1}{1-\beta}\right)} \qquad \forall \ell \in L \tag{14}$$

Finally, I show that the decentralized equilibrium is both inefficient and a fiscal war. In fact, the centralized equilibrium will always yield greater tax rates in every single location:

Proposition 3. *Under (12), an efficient allocation can be achieved as a decentralized equilibrium* ***if and only if*** *$L = 1$ (there is only one location).*

When the last proposition is considered, the game of decentralized tax setting resembles a Prisoner's Dilemma. Locations have the means to achieve a welfare-enhancing allocation by coordinating tax policy. They, however, are unable to do so as a state has the incentive to undercut other states by setting lower effective tax rates.

Centralized tax systems are a natural benchmark to decentralized tax systems. If the country follows a centralized tax system, the federal government sets tax rates to maximize:

$$\max_{\{t_\ell^y\}} \left(\sum_k \left(\frac{U_k}{L_k} \right)^{\sigma_G} \right)^{\frac{1}{\sigma_G}} \quad \text{s.t.} \quad P_G G_k = \tau_k^y \left(\int_{i \in k} y_k(i) \right) \tag{15}$$

A general equilibrium with a centralized tax system in this economy consists of a distribution of workers and firms $\{L_\ell, M_\ell\}_{\ell=1}^L$, aggregate quantities $\{Y_\ell, C_\ell, G_\ell\}_{\ell=1}^L$, wages and local tax rates $\{w_\ell, t_\ell^y\}_{\ell=1}^L$, so that:

1. Labor market clears in each location as in (1)
2. Consumers' budget constraint holds for every consumer, as in (2)
3. Firms choose labor employment and their plant location optimally, according to (4)
4. Goods market clearing (6)
5. The federal government maximizes its objective function and local governments' budget constraint holds, according to (15)

Similarly to the decentralized case, it is possible to show the uniqueness and existence of an equilibrium under reasonable parametric conditions:

$$\frac{1-\beta}{1-(\frac{1}{\theta}+\alpha)} \leq \sigma_G \tag{16}$$

Proposition 4. *Under (12) and (16), a centralized equilibrium* ***always exists*** *and* ***is unique****.*

Condition (16) bounds the extent to which local objective functions can be complementary in the eyes of the federal government. Finally, I demonstrate that, in addition to being inefficient, a decentralized equilibrium also causes fiscal war. In fact, the centralized equilibrium will always yield greater tax rates in every single location:

Proposition 5. *For a set of parameters* $\{\chi_W, \sigma_G, \alpha, \beta, \theta, \gamma, \{\zeta_\ell, L_\ell\}_{\ell \in L}\}$*, denote* $\{t_\ell^{dec}\}_{\ell \in L}$ *the associated decentralized equilibrium tax rate and* $\{t_\ell^{cen}\}_\ell$ *the associated centralized equilibrium tax rate. If* $L > 1$ *and* $[\zeta_\ell L_\ell^\alpha] > 0$ *for every* $\ell \in L$*, it must be that:*

$$t_\ell^{dec} < t_\ell^{cen} \qquad \forall \ell \in L \tag{17}$$

5 Enhanced Model

I added several features to the baseline model to perform counterfactual exercises. While the core of the baseline model is kept, this section will highlight features to add robustness to my counterfactual analysis. The model is static and represents a closed economy comprised of $\ell = 1, ..., L$ locations (states).

5.1 Households

A continuum of households $h \in [0, 1]$ supplies labor and chooses a residential location. Each household i simultaneously selects its location and labor supply in order to maximize utility $\widetilde{u}$. The utility of household i residing in location ℓ is given by

$$\widetilde{u}_\ell(i) = \zeta_\ell^u \, z_\ell^u(i) \, u_\ell(i) \, d_\ell\big(h_\ell(i)\big). \tag{18}$$

The term ζ_ℓ^u is a location-specific utility shifter, capturing the amenity value of residing in ℓ. The second component, $z_\ell^u(i)$, represents an idiosyncratic preference shock, allowing for household-specific heterogeneity in location choice. The third component, $u_\ell(i)$, reflects systematic utility from objective location characteristics. Namely, $u_\ell(i)$ depends on household i's access to public capital $g_\ell(i)$ and private consumption $c_\ell(i)$. Finally, $d_\ell(h_\ell(i))$ captures the disutility from supplying labor.

Following Fajgelbaum et al. (2019), I parameterize the disutility of labor and the objective consumption–public capital aggregator as

$$d_\ell\big(h_\ell(i)\big) = \exp\left(-\alpha_\ell^W \, \frac{h_\ell(i)^{\,1+1/\eta}}{1+1/\eta}\right), \tag{19}$$

$$u_\ell(i) = \left(\frac{G_\ell}{L_\ell^{\chi_w}}\right)^{\gamma_\ell} c_\ell(i)^{\,1-\gamma_\ell}. \tag{20}$$

The additive separability of the CRRA formulation of labor disutility implies that equilibrium hours worked are constant within regions. The specification of public capital access captures the degree of rivalry in the consumption of public goods by households: $\chi_W = 1$ corresponds to perfectly rivalrous provision, whereas $\chi_W = 0$ represents the polar case of non-rivalry. Household consumption is financed entirely out of after-tax labor income,

$$P_\ell^C \, c_\ell(i) = (1 - t_\ell^w)\, w_\ell \, h_\ell(i). \tag{21}$$

Each household is assumed to draw a vector of shocks $\{z_\ell^W(i)\}_{\ell=1}^L$ from a standard Fréchet distribution, and choose to reside in the location that maximizes its utility.

$$\Pr(z_\ell^u(i) < Z) = \exp\big(-Z^{-\theta^u}\big)\,. \tag{22}$$

5.2 Capital Owners

Each location ℓ is endowed with a mass of capitalists who receive the non-labor income in the economy. Capitalists are assumed to be immobile and to have measure zero. This measure-zero assumption guarantees that any labor supply decisions by capitalists are inconsequential in the aggregate and that the degree of rivalry in the consumption of public goods is unaffected by their presence.

Capitalists residing in location ℓ hold fractions of regional portfolios $\{\nu_{\ell,k}\}_k$, which entitle them to a share $\nu_{\ell,k}$ of all the rental income and net profits generated in location k. By definition, it must be that $\sum_j \nu_{j,k} = 1$ and $\nu_{j,k} \geq 0$. Although the model and its solution algorithm can accommodate heterogeneity in portfolio ownership $\nu_{\ell,k}$ across k, I assume for tractability that portfolio shares are constant across locations. This restriction allows portfolio ownership rates to be calibrated such that net profit and rental flows offset the trade imbalances across states observed in the data.

5.3 Firms

A continuum of goods indexed by $\omega^s \in \Omega^s$ is available in the economy. Each good ω^s is produced by a single firm operating under monopolistic competition within sector $s = 1, \ldots, S$. For simplicity, I use the notation ω^s to denote both the variety and the firm producing it.

Firms may operate multiple plants across locations. Conditional on serving a destination market d, the firm chooses the origin location o that maximizes after-tax profits from serving that market. Given entry and location, the firm then sets its price optimally. Finally, conditional on prospective profits from optimal origin location and optimal pricing, the firm decides whether to incur the fixed marketing costs required to serve market d.

On the demand side, each region is endowed with an aggregate goods sector that combines individual varieties ω^s into sectoral composites. These sectoral composites are subsequently aggregated into two higher-level bundles: an intermediate composite used in production and a final composite allocated to private consumption and government expenditure.

5.3.1 Differentiated variety goods: Intensive margin of production

Conditional on location choices and abstracting from marketing costs, the firm's profit maximization problem takes a standard Cobb–Douglas form. Each firm ω^s operating in sector s draws a vector of location-specific productivity shocks $\{z_o(\omega^s)\}_{o=1}^{L}$. Given these shocks, a firm located in o and serving destination market d combines labor $n_{od}(\omega^s)$ and structures/land $h_{od}(\omega^s)$ to produce output $q_{od}(\omega^s)$. Productivity depends on local public capital available the production site G_o and an idiosyncratic productivity realization $z_o(\omega^s)$:

$$q_{od}(\omega^s) = G_o^{\beta^s}\, z_o(\omega^s) \left[\frac{1}{\phi^s} \left(\frac{n_{od}(\omega^s)}{1-\delta^s} \right)^{1-\delta^s} \left(\frac{h_{od}(\omega^s)}{\delta^s} \right)^{\delta^s} \right]^{\phi^s} \left(\frac{i_{od}(\omega^s)}{1-\phi^s} \right)^{1-\phi^s}, \qquad (23)$$

where $i^s_{od}(\omega^s)$ denotes intermediate inputs.

When a firm located in o sells to destination d, it incurs iceberg trade costs τ^s_{od}. In addition, firms are subject to value-added taxes $t^{\text{VAT},s}_{od}$ and profit taxes $t^{\pi,s}_o$. As shown in the appendix, this structure yields the following generic net profit function for variety ω^s located in o:

$$\pi_{od}(\omega^s) = \left(1 - t^{\pi,s}_o\right) \left\{ \left(1 - t^{\text{VAT},s}_{od}\right) p^s_{od}(\omega^s)\, q^s_{od}(\omega^s) - \frac{\tau^s_{od}\, c^s_{od}}{G_o^{\beta^s}\, z_o(\omega^s)}\, q^s_{od}(\omega^s) \right\}. \qquad (24)$$

Here, c^s_{od} denotes the marginal cost of producing in origin o to serve destination d. Given the Cobb–Douglas technology, this function takes the form

$$c^s_{od} = \left[(w_o)^{\,1-\delta^s} (r_o)^{\,\delta^s} \right]^{\phi^s} \left((1 - t^{VAT,s}_{od}) P^{I,s}_o \right)^{\,1-\phi^s} \qquad (25)$$

where w_o is the wage, r_o is the rental rate of land and structures, and $P^{I,s}_o$ is the intermediate input price index in location o.

5.3.2 Differentiated variety goods: location and entry choices

Firms choose to establish production in location d to serve market o if and only if the associated after-tax profits are maximal relative to all alternative locations. This formulation departs from the canonical trade-model structure, in which location and outsourcing choices typically emerge from cost-minimization problems. In the present framework, firm ω^s will select its production site according to:

$$o = \text{argmax}_k \;\; \pi_{kd}(\omega^s) \tag{26}$$

where $\pi^s_{ko}(i)$ denotes the after-tax profit of firm i^s producing in k to serve o. This criterion implies that the equilibrium location of production need not coincide with the cost-minimizing allocation. Instead, fiscal incentives may induce firms to tolerate higher marginal costs in exchange for lower tax burdens, thereby maximizing net profitability. Such behavior captures an essential mechanism of tax competition ("fiscal wars"), wherein tax policies distort firms' extensive-margin choices across space. Under the parametric assumptions stated, pre-marketing costs profits in origin o from serving destination d in sector s can be rewritten as:

$$\pi_{od}(\omega^s) = \frac{1}{\sigma^s}\,(1 - t^{\pi,s}_o)(1 - t^{\text{VAT},s}_{od}) \left(\frac{G^{\beta^s}_o\, z_{od}(\omega^s)}{\tau^s_{od}\, c^s_{od}}\right)^{\sigma^s - 1} \left(\frac{P^s_d}{\frac{\sigma^s}{\sigma^s - 1}}\right)^{\sigma^s - 1} X^s_d \tag{27}$$

where X^s_d denotes total expenditure on sector s in destination d, and P^s_d is the corresponding price index for the composite good. This expression isolates an origin-specific profitability component that governs firms' location and entry decisions:

$$\kappa_{od}(\omega^s) = (1 - t^{\pi,s}_o)(1 - t^{\text{VAT},s}_{od}) \left(\frac{G^{\beta^s}_o}{\tau^s_{od}\, c^s_{od}}\right)^{\sigma^s - 1}, \tag{28}$$

It follows that the location-choice condition in equation (26) can equivalently be expressed as

$$[z^s_o(\omega^s)]^{\sigma^s - 1}\, \kappa_{od}(\omega^s) \;\; \geq \;\; [z^s_k(\omega^s)]^{\sigma^s - 1}\, \kappa_{kd}(\omega^s), \quad \forall k \in \{1, \ldots, L\}. \tag{29}$$

Moreover, entry into serving market d is optimal if and only if

$$[z^s_o(\omega^s)]^{\sigma^s - 1} \kappa_{od}(\omega^s) \;\; \geq \;\; \left(\frac{\sigma^s w_d F_d}{X^s_d}\right) \left(\frac{\frac{\sigma^s}{\sigma^s - 1}}{P^s_d}\right)^{\sigma^s - 1} \tag{30}$$

5.4 Sectoral aggregation

Every location is endowed with an aggregation sector that combines differentiated varieties into both intermediate and final goods. At the first stage, varieties are aggregated into sectoral composites according to the CES demand structure implied by monopolistic competition. Formally, the sectoral good in market d is given by:

$$Q_d^s = \left(\sum_k \int_{\omega^s \in \Omega^s} [q_{ok}(\omega^s)]^{\frac{\sigma^s - 1}{\sigma^s}} \ d\omega^s \right)^{\frac{\sigma^s}{\sigma^s - 1}}. \tag{31}$$

In the second stage, sectoral goods are aggregated through Cobb–Douglas production functions into intermediate and final composites. For sector s, the intermediate input bundle in location ℓ is defined as

$$I_d^s = \prod_u (Q_d^u)^{\alpha_d^{u,s}}, \tag{32}$$

while the final consumption good in d is defined as

$$Q_d^f = \prod_s (Q_d^s)^{\alpha_d^{s,F}}. \tag{33}$$

5.5 Aggregation

Productivity shocks $\{z_o(\omega^s)\}$ are assumed to follow the Multivariate Pareto (MVP) distribution introduced by Arkolakis et al. (2018). As they demonstrate, the MVP distribution provides a tractable framework for spatial models, as it preserves properties desirable for aggregation while relaxing the standard i.i.d. assumption on firm-level productivity. In particular, it allows productivity shocks to be correlated across locations, thereby capturing spatial dependence in firm performance. Further details on aggregation and derivations are provided in the Appendix.

Conditional on entry into market j, the probability that a firm serves destination d from origin o is

$$\psi^s_{od} = \frac{[\zeta^F_o]^{\frac{1}{1-\rho^s}} \left[(1-t^\pi_o)(1-t^{VAT,s}_{od})\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}} \left(\frac{\left(\frac{G_o}{M^{XF}_o}\right)^{\beta^s}}{c^s_o \tau_{od}}\right)^{\frac{\theta^F}{1-\rho^F}}}{\sum_k [\zeta^F_k]^{\frac{1}{1-\rho^s}} \left[(1-t^\pi_k)(1-t^{VAT,s}_{kd})\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}} \left(\frac{\left(\frac{G_k}{M^{XF}_k}\right)^{\beta^s}}{c^s_k \tau_{kd}}\right)^{\frac{\theta^F}{1-\rho^F}}}. \tag{34}$$

Furthermore, this structure yields a gravity equation of the form:

$$\lambda^s_{od} = \frac{[\zeta^F_o]^{\frac{1}{1-\rho^s}} \left[(1-t^\pi_o)(1-t^{VAT,s}_{od})\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}-1} \left(\frac{\left(\frac{G_o}{M^{XF}_o}\right)^{\beta^s}}{c^s_o \tau^s_{od}}\right)^{\frac{\theta^F}{1-\rho^F}}}{\sum_k [\zeta^F_k]^{\frac{1}{1-\rho^s}} \left[(1-t^\pi_k)(1-t^{VAT,s}_{kd})\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}-1} \left(\frac{\left(\frac{G_k}{M^{XF}_k}\right)^{\beta^s}}{c^s_k \tau^s_{kd}}\right)^{\frac{\theta^F}{1-\rho^F}}}. \tag{35}$$

Finally, I show in the Appendix that under this aggregation structure, profits net of marketing-cost payments can be expressed directly as a function of sales net of profit and value-added taxes.

5.6 Government side

Taxation in the model is designed to reflect the Brazilian fiscal framework. At the state level, governments levy a value-added tax (ICMS), with revenues accruing to the state of production. At the federal level, the government imposes profit taxes (IRPJ and CSLL), labor-income taxes (IRPF), and a federal value-added tax (IPI). Federal tax revenues are allocated partly as transfers to states and partly as federal expenditures. These instruments represent the most prominent sources of tax revenue at the state and federal levels in Brazil.[6] VAT revenues associated with consumption of sectoral good s in d are:

[6] The model abstracts from social security and unemployment insurance transfers. Accordingly, PIS and Cofins—federal social contributions earmarked to finance unemployment insurance and social security programs—are not included.

$$TR_d^{s,ST} = \sum_k t_{kd}^{VAT,ST,s} \left(X_{kd}^s - P_k^{I,s} I_{kd}^s \right) \tag{36}$$

The allocation of these VAT revenues across locations depends on the distribution rule d_{od}^s. When revenues accrue to the state of production, one can set $d_{od}^s = \lambda_{od}^s$. By contrast, under a conventional VAT structure in which revenues accrue to the location of consumption, this rule is represented by $d_{od}^s = 1$ if $o = d$ and $d_{od}^s = 0$ otherwise.

Finally, the federal government collects labor income, profit, and federal value-added taxes. Federal tax entitlements in location o will then be denoted:

$$T_o^{\text{FED}} = \left[t_o^y w_o N_o \right] + \left[t_o^\pi \, \Pi_o \right] + \left[\sum_S \sum_d \left[X_{od}^S - P_o^{I,s} I_{od}^s \right] t_{od}^{VAT,FED,S} \right] \tag{37}$$

I assume that the federal government retains only a share ι_o of such entitlements. The remaining fraction, $1 - \iota_o$, of federal tax revenues is rebated to households and spent locally. This adjustment is necessary to account for three main sources of tax avoidance.

First, informality is pervasive in the Brazilian economy: many workers and firms operate outside the formal system, such that regional expenditure accounts cannot be used to precisely infer effective tax collections. Second, as in many other countries, Brazil provides legal channels through which smaller firms and lower-income individuals pay reduced taxes relative to their statutory obligations.[7] Third, the federal government deploys tax incentives—such as temporary tax breaks and targeted tax credits—that allow firms in specific sectors to pay below their statutory tax rates.

Given effective federal tax collection, $\sum_k \iota_k T_k^{\text{FED}}$, the federal government allocates a share s of revenues to direct transfers to states, which are subsequently used for the purchase of final goods. The remaining share, $1 - s$, is devoted to federal expenditures on final goods across locations. Transfers and expenditures in location o are given, respectively, by:

[7] The two most prominent examples are the so-called "Simples Nacional" and "Lucro Presumido" regimes. The *Simples Nacional* regime, established by Lei Complementar nº 123/2006, unifies and simplifies taxation for micro and small enterprises. The *Lucro Presumido* regime, created by Lei nº 9.249/1995, provides a simplified presumptive-profit system for corporate taxation.

$$T_o^{\text{FED,transf}} = s\,\xi_o^T \sum_k \iota_k T_k^{\text{FED}}, \tag{38}$$

$$T_o^{\text{FED,exp}} = (1-s)\,\xi_o^D \sum_k \iota_k T_k^{\text{FED}}, \tag{39}$$

where $\{\xi_k^T\}_k$ and $\{\xi^D\}_k$ denote empirically consistent distribution rules governing the allocation of federal transfers and expenditures across states.

Public goods in a location o, however, are financed jointly by state-level tax revenues:

$$P_d G_d = \sum_s \sum_k d_{kd}^s TR_k^{s,ST} \tag{40}$$

where d represents the distribution rule d_{od}^s. The assumption that public goods depend solely on a state's own tax revenues is motivated by a body of work estimating the effects of intergovernmental transfers and tax revenue changes in Brazilian municipalities. This literature generally finds that exogenous increases in government grants translate poorly into outcomes associated with greater provision of public goods, whereas increases in local tax revenues are more strongly associated with improvements in such outcomes. See, among others, Gadenne (2017), Caselli and Michaels (2013), and Brollo et al. (2013).

5.7 Equilibrium

I begin by defining income and expenditure. For each region d, let Y_d^{priv} denote private income and Y_d^{pub} public income. Closely related, let X_d^s denote expenditure on sector s:

$$Y_d^{pub} = T_d^{ST} + T_d^{FED,transf} + T_d^{FED,exp}, \tag{41}$$

$$Y_d^{priv} = \nu_d \left[\sum_k \left(r_k H_k + \widetilde{\Pi}_k \right) \right] + \left(1 - t_d^y\right) w_d N_d + (1-\iota_d) T_d^{FED}, \tag{42}$$

$$X_d^s = \sum_u \sum_k \Big[(1-\phi^u)\Big(1-\tfrac{1}{\sigma^u}\Big)\alpha_d^{s,u}\lambda_{dk}^u X_k^u\Big] + \alpha_d^{s,f}\big(Y_d^{priv}+Y_d^{pub}\big). \tag{43}$$

Next, consider factor-market clearing conditions. Labor is used in production and to cover fixed marketing costs. Hence, in equilibrium:

$$\begin{aligned} w_d N_d = & \sum_s \sum_k \left(1-\frac{1}{\sigma^s}\right)\phi^s(1-\delta_s)(1-t_{dk}^{VAT,s})\lambda_{dk}^s X_k^s \\ & + \sum_s \sum_k \left(\frac{1}{\sigma^s} - \left(1-\frac{1}{\sigma^s}\right)\frac{1}{\theta^s}\right)(1-t_{kd}^{VAT,s})(1-t_d^{\pi})\lambda_{kd}^s X_d^s, \end{aligned} \tag{44}$$

and similarly, the market for land and structures clears:

$$r_d H_d = \sum_s \sum_k \left(1-\frac{1}{\sigma^s}\right)\phi^s \delta_s (1-t_{dk}^s)\lambda_{dk}^s X_k^s. \tag{45}$$

Goods-market clearing requires that net imports equal the trade surplus term Δ_d:

$$\sum_s \sum_k \lambda_{kd}^s X_d^s - \sum_s \sum_k \lambda_{dk}^s X_k^s = \Delta_d. \tag{46}$$

In this model, trade surpluses are endogenously determined by rent and profit transfers, federal transfers, and state VAT transfers. Denoting $\widetilde{\Pi}_k$ as net profits in market k, it follows that:

$$\begin{aligned} \Delta_d = & \nu_d \left[\sum_k \big(r_k H_k + \widetilde{\Pi}_k\big)\right] - \big(r_d H_d + \widetilde{\Pi}_d\big) \\ & + s\xi_d^T \sum_k \iota_k T_k^{FED} + (1-s)\xi_d^D \sum_k \iota_k T_k^{FED} - \iota_d T_d^{FED} \\ & + \sum_s \sum_k d_{dk}^s TR_k^{s,ST} - \sum_s \sum_k t_{dk}^{VAT,st}\big(X_{dk}^s - P_k^{I,s} I_k^S\big). \end{aligned} \tag{47}$$

5.7.1 Equilibrium in relative changes

Rather than solving directly for the equilibrium in levels, I compute macroeconomic effects using the method formalized by Dekle et al. (2007). This approach, commonly referred to as "hat algebra," expresses counterfactual outcomes as ratios of equilibrium variables relative to their baseline values under a proposed tax schedule $\mathbf{t}$. By construction, it eliminates the need to recover unobserved fundamentals such as productivity levels, state population shifters, or iceberg trade costs. Instead, the computation requires only observable baseline trade shares $\{\lambda_{od}^s\}$, population allocations $\{L_k\}$, and calibrated elasticity and expenditure parameters to determine general-equilibrium effects. The exact closed-form equations used for such a counterfactual exercise are detailed in the appendix.

6 Calibration

Several structural parameters must be calibrated in order to conduct the counterfactual exercises. To discipline some of these values, I rely on a log-linearized version of the gravity equation (35), which can be written as:

$$\log(\lambda_{od}^s) = \alpha_o + \alpha_d + \left[\frac{\theta^s}{1-\rho^s}\frac{1}{\sigma^s - 1} + \phi^s \frac{\theta^s}{1-\rho^s} - 1\right] \log\left(1 - t_{od}^{VAT,s}\right) - \frac{\theta^s}{1-\rho^s}\log(\tau_{od}^s) + \varepsilon_{od}^s, \tag{48}$$

where α_o and α_d denote origin and destination fixed effects, respectively. The dependent variable, λ_{od}^s, represents bilateral trade shares, taken from Haddad et al. (2017). Iceberg trade costs τ_{od}^s are proxied by standard gravity variables: the log of the distance between state capitals, an indicator for whether states o and d share a border, and an intrastate trade indicator. Estimation results are summarized in table (2).

Given estimates of the value-added share ϕ^s, and the elasticity of substitution σ^s (which also determines markups), the estimated regression allows me to back out the elasticity $\frac{\theta^s}{1-\rho^s}$.

Table 2: Gravity equation log-linearized regression

	(Agriculture)	(Manufacturing)	(Services)
Intercept	-0.307	-1.365	5.074^{**}
	(1.371)	(1.085)	(1.528)
$\log(1 - t_{od}^{VAT,s})$	6.241	8.308^{**}	21.377^{***}
	(4.333)	(3.167)	(4.902)
log(distance in km)	-0.599^{***}	-0.538^{***}	-0.940^{***}
	(0.073)	(0.053)	(0.058)
Border	0.476^{***}	0.400^{***}	0.028
	(0.081)	(0.084)	(0.102)
Origin FE	Yes	Yes	Yes
Destination FE	Yes	Yes	Yes
SEs clustered	Origin & Dest.	Origin & Dest.	Origin & Dest.

Notes: Coefficients with two-way clustered standard errors (in parentheses) at origin and destination.

This combination of 2 parameters governs an object analogous to the trade elasticity and thus plays a central role in determining the responsiveness of firm-location to changes in costs or taxes within the model.

Even under the flexible characterization of the "hat algebra" relative equilibrium transition, a set of parameters must be calibrated to perform counterfactual exercises. The table (3) summarizes the strategy to calibrate these key parameters.

7 Counterfactual Exercises

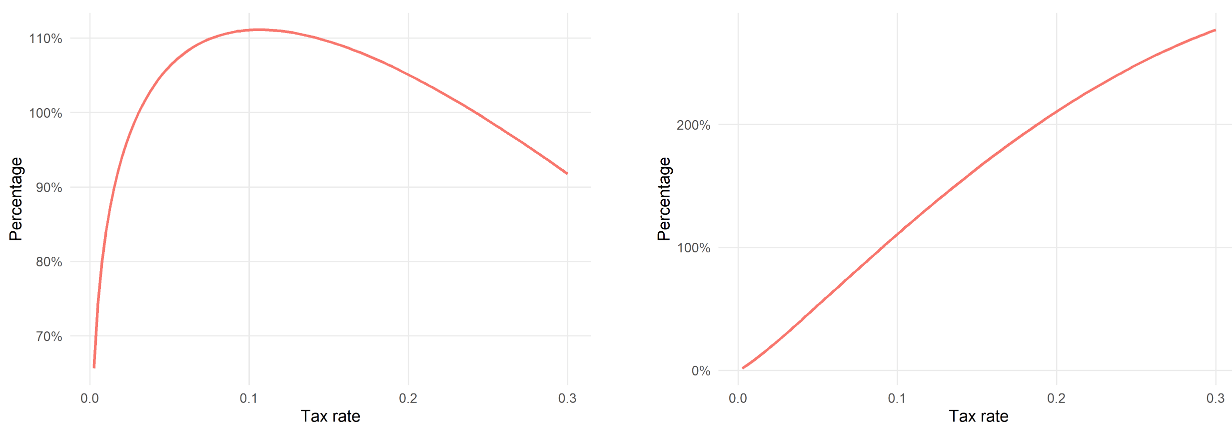
The only way to eliminate inefficiencies associated with firm location decisions—while respecting the optimal location condition in (26)—is to impose a uniform effective tax rate across all states. Accordingly, the natural counterfactual benchmark is the harmonization of VAT rates across states. To further address inefficiencies arising from heterogeneous cross-sector taxation, sectoral tax rates are also assumed to be uniform. I report how aggregate consumption and aggregate state tax revenues vary as a function of a uniform VAT rate, $t^{VAT} \in [0.0025, 0.30]$.

Table 3: Calibration of Structural Parameters

Notation	Value	Description	Targeted moment / source
Preferences and mobility			
η	2.84	Frisch elasticity of labor supply	Chetty et al. (2011)
θ^u	1.73	Migration elasticity	Fajgelbaum et al. (2019)
χ_W	0	Public goods rivalry degree to consumers	—
Technology and shares			
ϕ^{AG}	0.39	Value-added share in agriculture	Value-added share of gross revenues
ϕ^T	0.21	Value-added share in manufacturing	Value-added share of gross revenues
ϕ^{NT}	0.45	Value-added share in services	Value-added share of gross revenues
$1-\delta^{AG}$	0.35	Labor share of value-added in agriculture	Labor to land/structure cost ratio
$1-\delta^T$	0.25	Labor share of value-added in manufacturing	Labor to land/structure cost ratio
$1-\delta^{NT}$	0.48	Labor share of value-added in services	Labor costs to net sales ratio
Firm tax responsiveness			
$\theta^{AG}/(1-\rho^{AG})$	10.07	Firm-mobility parameter (agriculture)	Gravity equation
$\theta^T/(1-\rho^T)$	17.27	Firm-mobility parameter (manufacturing)	Gravity equation
$\theta^{NT}/(1-\rho^{NT})$	28.48	Firm-mobility parameter (services)	Gravity equation
Shocks and substitution			
ρ^s	0.55	Correlation of MVP shocks	Arkolakis et al. (2018)
σ^s	4	Elasticity of substitution	Head and Mayer (2014)
β^s	0.05	Marginal effect of public goods on productivity	Fajgelbaum et al. (2019)
Fiscal and expenditure shares			
$\{\nu_\ell\}$	—	Portfolio ownership share	Trade imbalances across states
$\{\alpha_\ell^{s,u}\}$	—	I/O material cost shares	Expenditure in intermediate goods by sector
$\{\xi_\ell^T\}$	—	Share of federal transfer entitlements	Federal transfers by state, 2002–2023
$\{\xi_\ell^D\}$	—	Share of federal government expenditure	Federal expenditure by state in 2023
$\{\gamma_\ell\}$	0.16	Public goods utility weight	Fajgelbaum et al. (2019)
$\{\iota_\ell\}$	—	Effective federal tax collection relative to model prediction	Ratio of effective-to-predicted tax revenue in 2018

Notes: Dashes indicate objects calibrated outside the main parameter vector (state-level shares or residuals). Abbreviations: AG = agriculture, T = manufacturing, NT = services, MVP = marginal value product.

In addition, I present counterfactual aggregate effects evaluated under tax harmonization and a regime in which VAT revenues accrue to the state of consumption rather than the state of production. These results are presented in figure 3[8]. It is important to emphasize that all counterfactual exercises approximate agricultural VAT rates to zero in both the baseline and counterfactual scenarios. This assumption reflects the longstanding practice whereby agriculture has benefited from federally mandated VAT exemptions and has contributed only a negligible share of VAT revenues to Brazilian states. Moreover, maintaining a zero VAT rate on agricultural products is consistent with political preferences for food subsidies and enhances the political feasibility of the proposed tax reform.



(a) Aggregate private income (b) Aggregate state government expenditure

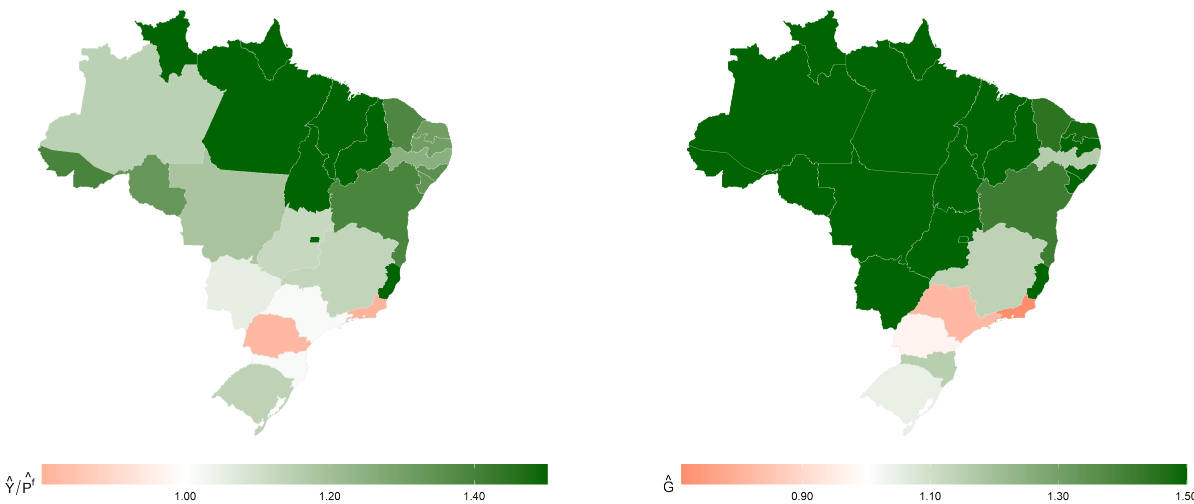
Figure 3: Aggregate effects of tax harmonization

Figure (3a) highlights the sizable aggregate gains from tax harmonization. At a harmonized VAT rate of 10.75 percent, aggregate real income is estimated to increase by approximately 11 percent, maintaining Brazil's VAT structure of revenues accruing to origin states. Figure (3b) further illustrates the potential fiscal benefits of reform. At the private-income–optimal rate of 10.75 percent, states are projected to increase public goods provision by 19 percent under an origin-based taxation system.

It is worth noting that the effects of tax harmonization reported in Figures (4a) and

[8]To estimate aggregate changes, it is necessary to first calibrate initial local price levels. As an approximation, I normalize $P_k^f = 1$ for every state k in the baseline. In the Appendix, I estimate heterogeneous price levels across states and demonstrate that the results are robust to this assumption.

(4b) exhibit considerable spatial heterogeneity. Real (private) income gains are concentrated in northern and parts of northeastern states—regions that are among the poorest in the country. Two main factors account for these outcomes. First, implied iceberg costs are relatively high in these areas, reflecting the fact that infrastructure remains precarious. Consequently, eliminating firm-location distortions induced by heterogeneous taxation yields disproportionately large gains for these states. Second, and perhaps more importantly, the states with the highest gains in the region (MA, PA, PI, TO, AP) have historically had limited engagement in Brazil's fiscal war. Relative to other states, tax exemptions in these jurisdictions have been modest, as illustrated in Figure (1).



(a) Private income (b) Public capital

Figure 4: Heterogeneous effects of tax harmonization across states.

A similar argument helps explain why gains are limited—or even negative—in the South and Southeast regions of Brazil. This is the country's wealthiest region, where implied iceberg costs are relatively small, reflecting the comparatively high quality of transportation infrastructure. Moreover, the two states projected to experience real income losses, Paraná and Rio de Janeiro, have historically relied heavily on tax exemptions to attract firms. Restricting the use of such incentives under a harmonized regime diminishes their ability to be competitive hosts for prospective firms, which in turn translates into consumption losses in these states. The effects of the tax reform on real wages ($\hat{w}/\hat{P}^f$), rental rates ($\hat{r}/\hat{P}^f$), and migration ($\hat{L}$) are presented in Appendix Figures (9), (10), and (11), respectively.

I also use the calibrated model to predict the effects of tax centralization on aggregate outcomes. Under $\sigma_G = 1.2$ (Ferrari and Ossa (2023)), figure 5 showcases how aggregate utility varies as a function of uniform, centralized tax rates.

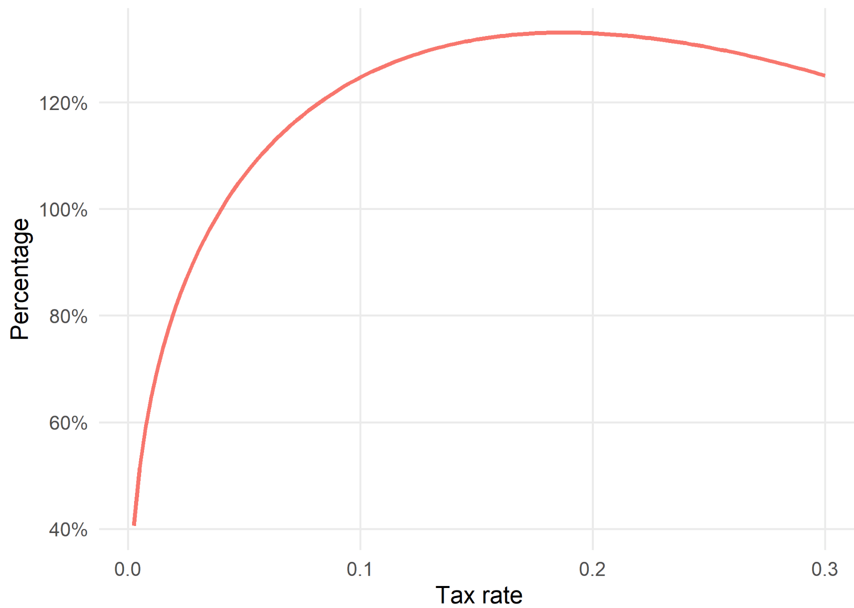
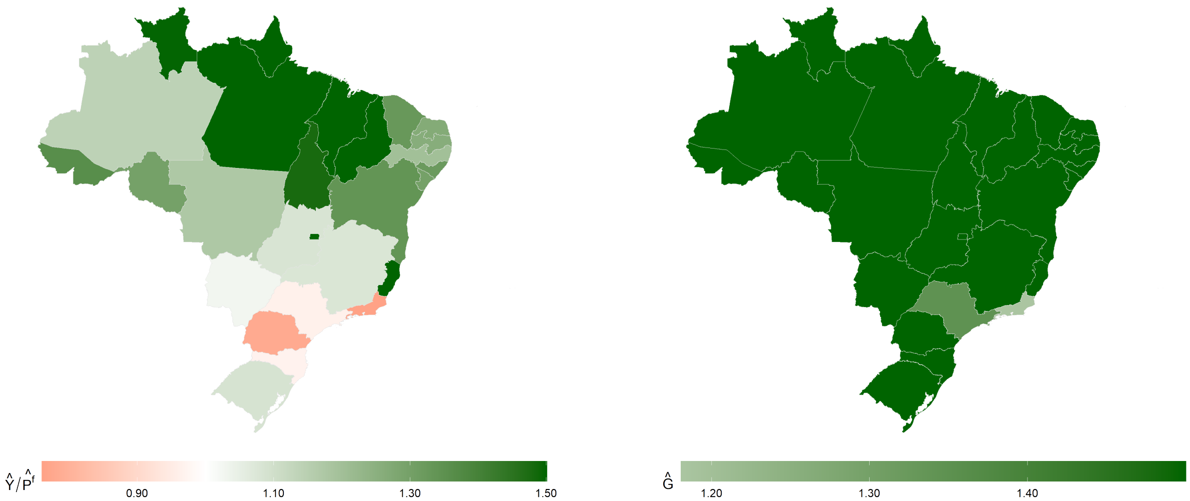


Figure 5: Effects of tax harmonization on the federal government's utility aggregator

Under the maximization problem in 15, the federal government selects a uniform tax rate of 18.75 percent in a centralized system. This policy raises real income by approximately 6 percent and public goods provision by nearly 99 percent. As shown in Figures 6a and 6b, the heterogeneous effects of tax harmonization under centralization closely resemble those obtained under income-maximizing harmonization, with the key distinction that public goods provision is uniformly positive and expands substantially more in the centralized regime.

8 Conclusion

The counterfactual exercises underscore the sizable economic costs associated with the tax competition and the tax heterogeneity it induces. At the private-income–optimal VAT rate,



(a) Private income (b) Public capital

Figure 6: Heterogeneous effects of tax harmonization across states.

distortions from heterogeneous taxation are estimated to reduce aggregate real income by up to 14 percent under destination-based taxation, and by 11 percent under origin-based taxation. Likewise, public goods provision is curtailed by roughly 19 percent relative to an income-maximizing uniform tax system. These figures highlight the efficiency losses generated when states use differentiated tax schedules and firm-location incentives as instruments of competition.

The analysis further reveals that these costs are distributed unevenly across space. Northern and northeastern states—among the poorest in the federation—bear particularly large welfare penalties, due both to their high iceberg costs and their historically limited participation in Brazil's fiscal war. In contrast, some southern states, most notably Paraná and Rio de Janeiro, have leveraged aggressive tax exemptions to attract firms, which explains why they are less adversely affected by the current regime. Taken together, the results suggest that Brazil's system of tax competition imposes significant aggregate and regional costs, reinforcing the case for reform aimed at reducing distortions and leveling the fiscal playing field.

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A Appendix

A.1 Baseline model

The first-order condition (FOC) for the local government's problem is

$$\left[\frac{\partial U_\ell}{\partial G_\ell}\left(\frac{\partial G_\ell}{\partial t^y_\ell}+\frac{\partial G_\ell}{\partial Y_\ell}\frac{dY_\ell}{dt^y_\ell}\right)+\frac{\partial U_\ell}{\partial C_\ell}\left(\frac{\partial C_\ell}{\partial t^y_\ell}+\frac{\partial C_\ell}{\partial Y_\ell}\frac{dY_\ell}{dt^y_\ell}\right)\right]=0. \tag{49}$$

Plugging in functional forms and simplifying yields:

$$\frac{\alpha^\gamma}{L_\ell^{\chi_W(1-\gamma)+\gamma}}\left(\frac{1-t^y_\ell}{t^y_\ell}\right)^\gamma\left[(1-\gamma)-\gamma\frac{t^y_\ell}{1-t^y_\ell}+\varepsilon_{Y_\ell,t^y_\ell}\right]=0 \tag{50}$$

Labor-market clearing implies wages w_ℓ as a function of taxes, productivity, public goods, and labor supply:

$$w_\ell=\frac{\alpha(1-t^y_\ell)(\zeta_\ell Z_\ell)G_\ell^\beta L_\ell^\alpha}{L_\ell}=\alpha(1-t^y_\ell)\frac{Y_\ell}{L_\ell}. \tag{51}$$

Under the Fréchet assumption, aggregate productivity in location ℓ is

$$Z_\ell=\left(\underbrace{\frac{\left([(1-t^y_\ell)]^{1-\beta}(t^y_\ell)^\beta\zeta_\ell L_\ell^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}{\sum_j\left([(1-t^y_j)]^{1-\beta}(t^y_j)^\beta\zeta_j L_j^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}}_{M_\ell}\right)^{1-\alpha-\frac{1}{\theta}}\Gamma\left(1-\frac{1}{\theta}\frac{1}{1-\alpha}\right)^{1-\alpha}. \tag{52}$$

Key elasticities used in the Nash system are:

$$\mathcal{E}_{Y_j,t^y_\ell}:=\frac{dY_j}{dt^y_\ell}\frac{t^y_\ell}{Y_j}=\left(\frac{1}{1-\beta}\right)\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)M_\ell\frac{t^y_\ell-\beta}{1-t^y_\ell}, \tag{53}$$

$$\mathcal{E}_{M_\ell,t^y_\ell}:=\frac{dM_\ell}{dt^y_\ell}\frac{t^y_\ell}{M_\ell}=-\left(\frac{1}{1-t^y_\ell}\right)(1-M_\ell)\left(\frac{t^y_\ell-\beta}{\frac{1}{\theta}+\alpha-\beta}\right), \tag{54}$$

$$\mathcal{E}_{Z_\ell,t^y_\ell}:=\frac{dZ_\ell}{dt^y_\ell}\frac{t^y_\ell}{Z_\ell}=-\left(\frac{1-(\alpha+\frac{1}{\theta})}{1-t^y_\ell}\right)(1-M_\ell)\left(\frac{t^y_\ell-\beta}{\frac{1}{\theta}+\alpha-\beta}\right), \tag{55}$$

$$\mathcal{E}_{Y_\ell,t^y_\ell}:=\frac{dY_\ell}{dt^y_\ell}\frac{t^y_\ell}{Y_\ell}=\frac{\beta}{1-\beta}-\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\frac{1}{\theta}+\alpha-\beta}\right)(1-M_\ell)\left(\frac{t^y_\ell-\beta}{1-t^y_\ell}\right). \tag{56}$$

If governments maximize local profits only the FOC simplifies to:

$$\underbrace{\frac{\beta}{1-\beta}}_{\text{MB: multiplier effect}} = \underbrace{\frac{t_\ell^y}{1-t_\ell^y} + \frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M_\ell)\left(\frac{t_\ell^y-\beta}{1-t_\ell^y}\right)}_{\text{MC: appropriation + prod./relocation}}. \tag{57}$$

Solving for t_ℓ yields the after-tax profit-maximizing solution:

$$t_\ell^y = \beta \tag{58}$$

If governments maximize local per capita utility, the FOC simplifies to:

$$\underbrace{\underbrace{(1-\gamma)}_{\substack{\text{Direct utility}\\ \text{effect}}} + \underbrace{\frac{\beta}{1-\beta}}_{\substack{\text{Multiplier}\\ \text{effect}}}}_{\text{MB}} = \underbrace{\underbrace{\gamma\frac{t_\ell^y}{1-t_\ell^y}}_{\substack{\text{Consumption appro-}\\ \text{priation effect}}} + \underbrace{\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M_\ell)\left(\frac{t_\ell^y-\beta}{(1-t_\ell^y)}\right)}_{\text{Firm production and relocation effect}}}_{\text{MC}} \tag{59}$$

Note that the second derivative of the RHS is:

$$\frac{1-(\alpha+\frac{1}{\theta})}{\frac{1}{\theta}+\alpha-\beta}\frac{1}{(1-t_\ell^y)^2} + \frac{\gamma}{(1-t_\ell^y)^2}\big(1-M_\ell\big) + \frac{\gamma t_\ell^y}{1-t_\ell^y}\frac{M_\ell}{t_\ell^y}\left(\frac{1}{1-t_\ell^y}\right)(1-M_\ell)\left(\frac{t_\ell^y-\beta}{\frac{1}{\theta}+\alpha-\beta}\right) \tag{60}$$

In contrast to the decentralized equilibrium, the first-order conditions for location ℓ in a centralized equilibrium consider externalities in location-level taxes and, inherently prevent competition:

$$\underbrace{(U_\ell)^{\sigma_G}\left[(1-\gamma)\left(1+\mathcal{E}_{Y_\ell,t_\ell^y}\right) + \frac{\gamma t_\ell^y}{(1-t_\ell^y)}\left(-1+\frac{(1-t_\ell^y)}{t_\ell^y}\mathcal{E}_{Y_\ell,t_\ell^y}\right)\right]}_{\text{Weighted effects of } t_\ell^y \text{ on } \ell\text{'s welfare}} + \underbrace{\left(\sum_{k\neq\ell}(U_k)^{\sigma_G}\mathcal{E}_{Y_k,t_\ell^y}\right)}_{\text{Externalities on } k\neq\ell} = 0 \tag{61}$$

Derivations of Special Cases

1. Monopoly problem. In the monopoly problem, $M_\ell = 1$. Plugging in this condition into 59 yields $t_\ell^y = \beta + (1-\gamma)(1-\beta)$.

2. Perfect competition problem. One can show that:

$$M_\ell = \frac{\left([(1-t_\ell^y)]^{1-\beta}(t_\ell^y)^\beta \zeta_\ell L_\ell^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}{\sum_j \left([(1-t_j^y)]^{1-\beta}(t_j^y)^\beta \zeta_j L_j^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}} \tag{62}$$

Under $\zeta_\ell = L_\ell = 1$ the expression simplifies to:

$$M_\ell = \frac{\left([(1-t_\ell^y)]^{1-\beta}(t_\ell^y)^\beta\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}{\sum_j \left([(1-t_j^y)]^{1-\beta}(t_j^y)^\beta\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}} \tag{63}$$

It is trivial to show that $t_\ell^y = 0$ or $t_\ell^y = 1$ can never be optimal in the government's eyes, as it yields a utility value of 0. Therefore, as $L \to \infty$, $M_\ell \to 0$, which turns equation 59 into $\beta + (1-\gamma)(\alpha + \frac{1}{\theta} + \beta)$.

The following claims are useful for the proofs:

(I) The function M_ℓ is increasing in t_ℓ^y for $t_\ell^y < \beta$ and decreasing for $t_\ell^y > \beta$:

$$\frac{dM_\ell}{dt_\ell^y} = M_\ell\big(1 - M_\ell\big)\,\frac{\beta - t_\ell^y}{\left(\frac{1}{\theta}+\alpha-\beta\right)\, t_\ell^y(1-t_\ell^y)}.$$

(II)

$$\frac{d\mathcal{E}_{Y_\ell, t_\ell^y}}{dt_\ell^y} = -\frac{1-(\alpha+\frac{1}{\theta})}{\frac{1}{\theta}+\alpha-\beta}\left[\frac{1-M_\ell}{(1-t_\ell^y)^2} - \frac{M_\ell'\,(t_\ell^y-\beta)}{(1-t_\ell^y)(1-\beta)}\right].$$

Proofs of Propositions

4. Proof of Proposition 1.

Proof. The proof of existence is short. For finite L, the first order conditions in (59) are continuous functions defined on a closed and bounded convex subset of an Euclidean space. A solution must exist.

I move on to prove uniqueness. Suppose, for contradiction, that there are 2 equilibria. Without loss of generality, there exists a location ℓ for which $t_\ell^1 < t_\ell^2$. Notice that across equilibria, it must be that any 2 tax rates must satisfy:

$$\gamma \frac{t_\ell^2}{1-t_\ell^2} + \frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M_\ell^2)\left(\frac{t_\ell^2-\beta}{1-t_\ell^2}\right)$$
$$= \gamma \frac{t_\ell^1}{1-t_\ell^1} + \frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M_\ell^1)\left(\frac{t_\ell^1-\beta}{1-t_\ell^1}\right)$$

Therefore,

$$\left(1-M_\ell^2\right)\left(\frac{t_\ell^2-\beta}{1-t_\ell^2}\right) < \left(1-M_\ell^1\right)\left(\frac{t_\ell^1-\beta}{1-t_\ell^1}\right)$$
$$\Rightarrow M_k^2 > M_k^1$$

As in equilibrium, any tax rate $t_k \geq \beta$, it must be that

$$\sum_j \left([(1-t_j^2)]^{1-\beta}(t_j^2)^\beta \zeta_j L_j^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}} > \sum_j \left([(1-t_j^1)]^{1-\beta}(t_j^1)^\beta \zeta_j L_j^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}$$

Each element of the sum is a decreasing function of t_j, for tax rates greater than β. However, it must then be that there exists a location k such that $t_k^2 < t_k^1$. But then in k:

$$\left(1-M_k^2\right)\left(\frac{t_k^2-\beta}{1-t_k^2}\right) > \left(1-M_k^1\right)\left(\frac{t_k^1-\beta}{1-t_k^1}\right)$$

Which implies:

$$\sum_j \left([(1-t_j^2)]^{1-\beta}(t_j^2)^\beta \zeta_j L_j^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}} < \sum_j \left([(1-t_j^1)]^{1-\beta}(t_j^1)^\beta \zeta_j L_j^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}$$

Contradiction. It must be that there exists at most 1 equilibrium.

□

5. Proof of Proposition 2.

Proof. The following must hold given 59 for any two arbitrary t_ℓ^y, t_j^y.

$$\frac{t_\ell^y - \beta}{t_j^y - \beta} = \frac{1 + \dfrac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}(1-M_j)}{1 + \dfrac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}(1-M_\ell)}$$

If $t_\ell^y > t_j^y$, then $M_\ell < M_j$. Then:

$$\left([(1-t_\ell^y)]^{1-\beta}(t_\ell^y)^\beta \zeta_\ell L_\ell^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}} < \left([(1-t_j^y)]^{1-\beta}(t_j^y)^\beta \zeta_j L_j^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}$$

Which implies:

$$\frac{\left([(1-t_\ell^y)]^{1-\beta}(t_\ell^y)^\beta\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}{\left([(1-t_j^y)]^{1-\beta}(t_j^y)^\beta\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}} < \frac{\left(\zeta_j L_j^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}{\left(\zeta_\ell L_\ell^\alpha\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}$$

Finally, in equilibrium any $t_k^y > \beta$, and $[(1-t_\ell^y)]^{1-\beta}(t_\ell^y)^\beta$ is decreasing in $t_\ell > \beta$.

Therefore, if $\zeta_j L_j > \zeta_\ell L_\ell$ it must be that $t_\ell^y < t_j^y$. Conversely, if $t_\ell^y < t_j^y$ it must be that $\zeta_j L_j > \zeta_\ell L_\ell$. □

6. Proof of Proposition 3.

Proof. Consider a Pareto efficient allocation with non-zero weights ($\lambda_\ell > 0$). FOC's are:

$$\lambda_\ell \left[(1-\gamma)\frac{U_\ell}{t^y_\ell}\left(1+\mathcal{E}_{Y_\ell,t^y_\ell}\right) + \gamma\frac{U_\ell}{1-t^y_\ell}\left(-1+\frac{1-t^y_\ell}{t^y_\ell}\mathcal{E}_{Y_\ell,t^y_\ell}\right)\right]$$
$$+\sum_{k\neq\ell}\lambda_k\frac{U_k}{t^y_\ell}\left(\frac{1}{1-\beta}\right)\left(\frac{1-(\alpha+\frac{1}{\theta})}{1-t^y_\ell}\right)M_\ell \;=\; 0$$

Which can be rearranged to:

$$(1-\gamma)+\mathcal{E}_{Y_\ell,t^y_\ell}-\gamma\frac{t^y_\ell}{1-t^y_\ell} = -\sum_{k\neq\ell}\frac{\lambda_k}{\lambda_\ell}\frac{U_k}{U_\ell}\left(\frac{1}{1-\beta}\right)\left(\frac{1-(\alpha+\frac{1}{\theta})}{1-t^y_\ell}\right)M_\ell$$

Which can only be equivalent to the FOCs of the decentralized equilibrium in case if the right-hand side equals to zero (L=1). □

7. Proof of Proposition 4.

Proof. The FOCs of the centralized problem can be expressed as:

$$(1-\gamma)+\frac{\beta}{1-\beta}+\sum_k\left(\frac{U_k}{U_\ell^{\sigma_G}}\right)^{\sigma_G}\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)M_\ell\left(\frac{t^y_\ell-\beta}{1-t^y_\ell}\right)$$
$$=\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\frac{1}{\theta}+\alpha-\beta}\right)\left(\frac{t^y_\ell-\beta}{1-t^y_\ell}\right)+\frac{\gamma t^y_\ell}{1-t^y_\ell}. \tag{64}$$

The argument for existence follows the logic of the decentralized equilibrium. The FOCs above form a set of continuous functions defined in a closed, compact, and convex subset of a finite Euclidean space. A fixed point must exist, which implies an equilibrium exists.

The argument for uniqueness relies on condition 16 and involves several intermediate derivation steps. A complete proof will be provided upon request.

□

8. Proof of Proposition 5.

Proof. The FOCs of the centralized equilibrium can be expressed as:

$$
\begin{aligned}
(1-\gamma) + \frac{\beta}{1-\beta} + \sum_{k\neq\ell} \left(\frac{U_k}{U_\ell^{\sigma_G}}\right)^{\sigma_G} \frac{1}{1-\beta} \left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right) M_\ell \left(\frac{t_\ell^y-\beta}{1-t_\ell^y}\right) \\
= (1-M_\ell)\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\frac{1}{\theta}+\alpha-\beta}\right)\left(\frac{t_\ell^y-\beta}{1-t_\ell^y}\right) + \frac{\gamma t_\ell^y}{1-t_\ell^y}.
\end{aligned} \tag{65}
$$

While the FOCs of the decentralized equilibrium can be expressed as:

$$
(1-\gamma) + \frac{\beta}{1-\beta} = (1-M_\ell)\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\frac{1}{\theta}+\alpha-\beta}\right)\left(\frac{t_\ell^y-\beta}{1-t_\ell^y}\right) + \frac{\gamma t_\ell^y}{1-t_\ell^y}. \tag{66}
$$

While the RHS of both FOCs is the same, the LHS of the centralized condition is weakly higher than the LHS of the decentralized equilibrium. The equation in 60 shows that the RHS of both equations is increasing in t_ℓ. It must be, therefore, that $t_\ell^{cen} > t_\ell^{dec}$ □

Institutional details

Statutory ICMS rates depend on origin and destination. While the effective rate for a product can be administratively complex, a practical approximation is to apply the default statutory rates in Figure (7).

States use two broad instruments to grant incentives: *tax credits* and *rate reductions*. Credits, although operationally intricate, aggregate cleanly: the fiscal cost equals the sum of reported credits (from the *Escrituração Fiscal Digital*, EFD). Rate reductions are conceptually

DESTINATION

ORIGIN	AC	AL	AM	AP	BA	CE	DF	ES	GO	MA	MT	MS	MG	PA	PB	PR	PE	PI	RN	RS	RJ	RO	RR	SC	SP	SE	TO
AC	19	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
AL	12	20	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
AM	12	12	20	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
AP	12	12	12	18	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
BA	12	12	12	12	20.5	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
CE	12	12	12	12	12	20	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
DF	12	12	12	12	12	12	20	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
ES	12	12	12	12	12	12	12	17	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
GO	12	12	12	12	12	12	12	12	19	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
MA	12	12	12	12	12	12	12	12	12	22	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
MT	12	12	12	12	12	12	12	12	12	12	17	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
MS	12	12	12	12	12	12	12	12	12	12	12	17	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
MG	7	7	7	7	7	7	7	7	7	7	7	7	18	7	7	12	7	7	7	12	12	7	7	12	12	7	7
PA	12	12	12	12	12	12	12	12	12	12	12	12	12	19	12	12	12	12	12	12	12	12	12	12	12	12	12
PB	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20	12	12	12	12	12	12	12	12	12	12	12	12
PR	7	7	7	7	7	7	7	7	7	7	7	7	18	7	7	19.5	7	7	7	12	12	7	7	12	12	7	7
PE	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20.5	12	12	12	12	12	12	12	12	12	12
PI	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	21	12	12	12	12	12	12	12	12	12
RN	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	18	12	12	12	12	12	12	12	12
RS	7	7	7	7	7	7	7	7	7	7	7	7	12	7	7	12	7	7	7	17	12	7	7	12	12	7	7
RJ	7	7	7	7	7	7	7	7	7	7	7	7	12	7	7	12	7	7	7	12	22	7	7	12	12	7	7
RO	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	19.5	12	12	12	12	12
RR	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20	12	12	12	12
SC	7	7	7	7	7	7	7	7	7	7	7	7	12	7	7	12	7	7	7	12	12	7	7	17	12	7	7
SP	7	7	7	7	7	7	7	7	7	7	7	7	12	7	7	12	7	7	7	12	12	7	7	12	18	7	7
SE	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20	12
TO	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20

Figure 7: ICMS statutory schedule in 2025.

simpler but harder to aggregate. In principle, a lower upstream rate could be partly offset downstream due to VAT chain properties. In practice, Brazilian states rarely design reductions to generate such cascading; reductions typically apply to final goods or terminal supply-chain stages.

For instance, in São Paulo large exemptions have targeted retail, wholesale, transportation, staple foods, machinery, and automotive retail/maintenance. Reductions on final goods propagate uniformly downstream; reductions to retailers/wholesalers face no downstream payer. Thus, aggregating forgone revenues usually requires no major adjustments, though state authorities account for rare responsibility transfers when they occur.

Household side

Under the Fréchet assumption, the equilibrium mass of households in ℓ is

$$L_\ell = \left(\frac{\zeta_\ell \, u_\ell}{\left(\sum_k [\zeta_k u_k]^{\theta^W} \right)^{1/\theta^W}} \right)^{\theta^W}. \tag{67}$$

Firm side

Baseline profits (origin o, destination d, sector s) are

$$\pi^s_{od}(i) = (1 - t^\pi_o)\big\{(1 - t^s_{od})\big[p^s_{od}(i) q^s_{od}(i) - \tau_{od} P^{I,s}_o i_{od}(i)\big] - \tau_{od} r_o h_o(i) - \tau_{od} w_o n_{od}(i)\big\} - w_d F_d. \tag{68}$$

Equivalently, with marginal cost MC^s_{od} and productivity draw $\tilde{z}_{od}(i)$,

$$\pi^s_{od}(i) = (1 - t^\pi_o) \left\{ (1 - t^s_{od}) p^s_{od}(i) q_{od}(i) - \frac{\tau_{od} MC^s_{od}}{\tilde{z}_{od}(i)} \, q_{od}(i) \right\} - w_d F_d. \tag{69}$$

Under monopolistic competition (constant markup $\sigma^s/(\sigma^s - 1)$),

$$\pi^s_{od}(i) = \frac{1}{\sigma^s} (1 - t^\pi_o)(1 - t^s_{od}) \, p^s_{od}(i) q_{od}(i) - w_d F_d. \tag{70}$$

Given sectoral expenditure X^s_d at d,

$$\pi^s_{od}(i) = \frac{1}{\sigma^s} (1 - t^\pi_o)(1 - t^s_{od}) \left(\frac{(1 - t^s_{od}) \, \tilde{z}_{od}(i)}{\tau_{od} \, c^s_o} \right)^{\sigma^s - 1} \left(\frac{P^s_d}{\sigma^s/(\sigma^s - 1)} \right)^{\sigma^s - 1} X^s_d - w_d F_d. \tag{71}$$

Aggregation

Let $\{z_k\}$ be multivariate Pareto with $(\zeta^F_k, \rho^s, \theta^s)$. Then

$$\{z_k^{\sigma^s - 1} \kappa_{kd}\}_k \sim \text{MVP}\left(\zeta^F_k \, \kappa_{kd}^{\frac{\theta^s}{\sigma^s - 1}}, \, \rho^s, \, \frac{\theta^s}{\sigma^s - 1} \right). \tag{72}$$

By Arkolakis et al. (2018), the maximum is univariate Pareto:

$$\max_k\{z_k^{\sigma^s-1}\kappa_{kd}\} \sim \text{Pareto}\left(\left(\sum_k [\zeta_k^F]^{\frac{1}{1-\rho^s}}\kappa_{kd}^{\frac{1}{1-\rho^s}\frac{\theta^s}{\sigma^s-1}}\right)^{\frac{1-\rho^s}{\theta^s}},\ \rho^s,\ \frac{\theta^s}{\sigma^s-1}\right). \tag{73}$$

If fixed costs bind, the mass of entrants and conditional expectation are

$$M_{od} := \Pr\left\{[z_o^s(i)]^{\sigma^s-1}\kappa_{od}^s \geq \underline{C} \cap \arg\max_k [z_k^s(i)]^{\sigma^s-1}\kappa_{kd}^s = o\right\} = \underline{C}^{-\frac{\theta^F}{\sigma^s-1}}\psi_{od}\Upsilon_d, \tag{74}$$

$$Z'_{od} := \mathbb{E}\big([z_o(i)]^{\sigma^s-1}\kappa_{od}^s \,\big|\, \text{entry \& locate in } o\big) = \frac{\theta^F}{\theta^F-(\sigma^s-1)}\underline{C}\, M_{od}. \tag{75}$$

Where

$$\Upsilon_d = \left[\sum_k [\zeta_k^F]^{\frac{1}{1-\rho^s}}\left[(1-t_k^\pi)(1-t_{kd}^s)\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}}\left(\frac{(1-t_{kd}^s)^{\phi^s}\left(\frac{G_k}{M_k^{XF}}\right)^{\beta^s}}{c_k^s\tau_{kd}}\right)^{\frac{\theta^F}{1-\rho^F}}\right]^{1-\rho^F}, \tag{76}$$

$$\underline{C}_d = \left(\frac{\sigma^s w_d F_d}{X_d^s}\right)\left(\frac{\frac{\sigma^s}{\sigma^s-1}}{P_d^s}\right)^{\sigma^s-1}. \tag{77}$$

Price indices satisfy

$$P_d^s = \left[\sum_k\int_i\left(\frac{\sigma^s}{\sigma^s-1}\frac{1}{(1-t_{kd}^s)}\frac{\tau_{kd}c_k^s}{\tilde{z}_k(i)}\right)^{1-\sigma^s}\right]^{\frac{1}{1-\sigma^s}} = \frac{\sigma^s}{\sigma^s-1}\left[\sum_k\frac{Z'_{kd}}{(1-t_k^\pi)(1-t_{kd}^s)}\right]^{\frac{1}{1-\sigma^s}}. \tag{78}$$

Using (75) yields

$$P_d^s = \tilde{\sigma}^s\left[\frac{\theta^s}{\theta^s-(\sigma^s-1)}\Upsilon_d\left(\frac{\sigma^s w_d F_d}{X_d^s}\right)^{1-\frac{\theta^s}{\sigma^s-1}}\sum_k\frac{\psi_{kd}}{(1-t_{kd}^s)(1-t_k^\pi)}\right]^{-\frac{1}{\theta^s}}, \quad \tilde{\sigma}^s := \frac{\sigma^s}{\sigma^s-1}. \tag{79}$$

Gravity for expenditure flows:

$$X_{od}^{s}=(P_{d}^{s})^{\sigma^{s}-1}X_{d}^{s}\,(\tilde{\sigma}^{s})^{1-\sigma^{s}}\frac{Z_{od}'}{(1-t_{od}^{s})(1-t_{o}^{\pi})}. \tag{80}$$

Hence trade shares $\lambda_{od}^{s}:=X_{od}^{s}/X_{d}^{s}$ are

$$\lambda_{od}^{s}=\frac{\frac{Z_{od}'}{(1-t_{od}^{s})(1-t_{o}^{\pi})}}{\sum_{k}\frac{Z_{kd}'}{(1-t_{kd}^{s})(1-t_{k}^{\pi})}}=\frac{\frac{\psi_{od}}{(1-t_{od}^{s})(1-t_{o}^{\pi})}}{\sum_{k}\frac{\psi_{kd}}{(1-t_{kd}^{s})(1-t_{k}^{\pi})}}. \tag{81}$$

In extensive form,

$$\lambda_{od}^{s}=\frac{[\zeta_{o}^{F}]^{\frac{1}{1-\rho^{s}}}\,[(1-t_{o}^{\pi})(1-t_{od}^{s})]^{\frac{\theta^{F}}{(1-\rho^{F})(\sigma^{s}-1)}-1}\left(\frac{(1-t_{od}^{s})\left(\frac{G_{o}}{M_{o}^{XF}}\right)^{\beta^{s}}}{c_{o}^{s}\tau_{od}}\right)^{\frac{\theta^{F}}{1-\rho^{F}}}}{\sum_{k}[\zeta_{k}^{F}]^{\frac{1}{1-\rho^{s}}}\,[(1-t_{k}^{\pi})(1-t_{kd}^{s})]^{\frac{\theta^{F}}{(1-\rho^{F})(\sigma^{s}-1)}-1}\left(\frac{(1-t_{kd}^{s})\left(\frac{G_{k}}{M_{k}^{XF}}\right)^{\beta^{s}}}{c_{k}^{s}\tau_{kd}}\right)^{\frac{\theta^{F}}{1-\rho^{F}}}}. \tag{82}$$

Finally, the compact price index used later is

$$P_{d}^{s}=\tilde{\sigma}^{s}\left[\frac{\theta^{s}}{\theta^{s}-(\sigma^{s}-1)}\Upsilon_{d}\right]^{-\frac{1}{\theta^{s}}}\left(\frac{\sigma^{s}w_{d}F_{d}}{X_{d}^{s}}\right)^{-\frac{1}{\theta^{s}}+\frac{1}{\sigma^{s}-1}}\left[\sum_{k}\frac{\psi_{kd}}{(1-t_{kd}^{s})(1-t_{k}^{\pi})}\right]^{-\frac{1}{\theta^{s}}}. \tag{83}$$

Hat algebra

Price-index hats follow

$$\hat{P}_d^s = \left(\frac{\hat{w}_d}{\hat{X}_d^s}\right)^{-\frac{1}{\theta^s}+\frac{\theta^s}{\sigma^s-1}} \left[\frac{\sum_k (1-t_{kd}^s)'(1-t_k^\pi)'[\lambda_{kd}^s]'}{\sum_k (1-t_{kd}^s)(1-t_k^\pi)\lambda_{kd}^s}\right]^{\frac{1}{\theta^s}} \left(\sum_k (1-t_k^\pi)(1-t_{kd}^s)\lambda_{kd}^s\,\Xi_{kd}\right)^{-\frac{1-\rho^s}{\theta^s}}, \tag{84}$$

$$\Xi_{kd} := \left(\frac{(\widehat{1-t_k^\pi})^{\frac{1}{\sigma^s-1}}(\widehat{1-t_{kd}^s})^{\frac{1}{\sigma^s-1}+\phi^s}(\hat{G}_k/\hat{M}_k^{\chi W})^{\beta^s}}{[\hat{w}_k^{1-\delta^s}\hat{r}_k^{\delta^s}]^{\phi^s}\left[\prod_u (\hat{P}_k^u)^{\alpha_k^{u,s}}\right]^{1-\phi^s}}\right)^{\frac{\theta^s}{1-\rho^s}}. \tag{85}$$

Labor allocation (hats) is

$$\hat{L}_d = \frac{\left[\left(\frac{\hat{G}_d}{\hat{L}_d^{\chi W}}\right)^{\gamma_d}\left(\frac{(\widehat{1-t_d^y})\hat{w}_d}{\hat{P}_d^C}\right)^{1-\gamma_d}\right]^{\theta^u}}{\sum_k L_k\left[\left(\frac{\hat{G}_k}{\hat{L}_k^{\chi W}}\right)^{\gamma_k}\left(\frac{(\widehat{1-t_k^y})\hat{w}_k}{\hat{P}_k^C}\right)^{1-\gamma_k}\right]^{\theta^u}}. \tag{86}$$

Gravity equation and calibration procedure

Value-added ϕ^S and labor share of value-added payment δ^S parameters can be computed as:

$$\phi^S = 1 - \left(\frac{1}{1-\frac{1}{\sigma^S}}\right)\left[1 - \frac{\sum_j X_{\ell j}^S - P_\ell^S I_\ell^S}{\sum_j X_{\ell j}^S}\right] \tag{87}$$

$$\delta^S = \frac{1}{1+\frac{w_\ell N_\ell^S}{r_\ell H_\ell^S}} = 1 - \left(1 - \frac{w_\ell N_\ell^T}{\sum_j (1-t_{\ell j}^S)X_{\ell j}^S}\right)\left(\frac{1}{1-\frac{1}{\sigma_S}}\right)\left(\frac{1}{\phi_S}\right) \tag{88}$$

Note that under symmetry, iceberg costs may also be retrieved. First note that:

$$\frac{X_{\ell\ell}^T}{X_{j\ell}^T}\times\frac{X_{jj}^T}{X_{\ell j}^T} = \left(\frac{\tau_{\ell j}^T\tau_{j\ell}^T}{\tau_{\ell\ell}^T\tau_{jj}^T}\right)^{\frac{\theta^s}{1-\rho^s}} \left[\frac{(1-t_{\ell\ell}^T)(1-t_{jj}^T)}{(1-t_{j\ell}^T)(1-t_{\ell j}^T)}\right]^{\frac{\theta^s}{1-\rho^s}\left[\frac{\sigma^T}{\sigma^T-1}-(1-\phi^T)\right]-1} \tag{89}$$

Which can be rearranged:

$$\tau_{\ell j}^{T} = \left(\frac{X_{\ell\ell}^{T}}{X_{j\ell}^{T}} \times \frac{X_{jj}^{T}}{X_{\ell j}^{T}} \right)^{\frac{1}{2}\frac{1-\rho^F}{\theta}} \left[\frac{(1-t_{\ell\ell}^{T})(1-t_{jj}^{T})}{(1-t_{\ell j}^{T})(1-t_{j\ell}^{T})} \right]^{\frac{1}{2}\frac{1-\rho^F}{\theta} - \frac{1}{2}\left(\frac{\sigma}{\sigma-1} - (1-\phi^T)\right)} \tag{90}$$

Other transfer and network parameters are pinned down as follows. $\{\xi_\ell\}$ targets empirical transfer rules from the federal government and can be calibrated using empirical transfers.

$$\xi_d^T = \frac{T_d^{\text{FED}\to d}}{\sum_k T_k^{\text{FED}}} \tag{91}$$

$\{\iota_\ell\}$ targets deviations from implied tax collection to effective tax collection across states:

$$\iota_\ell = \frac{T_d^{\text{FED,effective}}}{T_d^{\text{FED,implied}}} \tag{92}$$

Where $T_d^{\text{FED,effective}}$ is the observed tax collection in a state d, while $T_d^{\text{FED,implied}}$ is the implied tax revenue collected in d given the statutory federal tax rates $\{t^{\text{VAT,FED}}, t^y, t^\pi\}$

$\{\nu_\ell\}$ targets production-expenditure imbalances after accounting for governmental transfers, which can be rearranged to calibrate ν_ℓ:

$$\nu_d = \frac{\Delta_d + \left(\tilde{\Pi}_d + r_d \overline{H}_d\right) - \left[\left(s\xi_d^T + (1-s)\xi_d^D\right)\sum_j T_j^{\text{FED}} - T_d^{\text{FED}}\right] - \left[\sum_s \sum_k d_{ks}^s \, TR_k^{s,\text{ST}} - \sum_s \sum_k t_{dk}^{\text{VAT,st}} \lambda_{dk}^s X_k^s \left[1 - (1-\phi^s)\left(1 - \frac{1}{\sigma^s}\right)\right]\right]}{\sum_j \left(\tilde{\Pi}_j + r_j \overline{H}_j\right)} \tag{93}$$

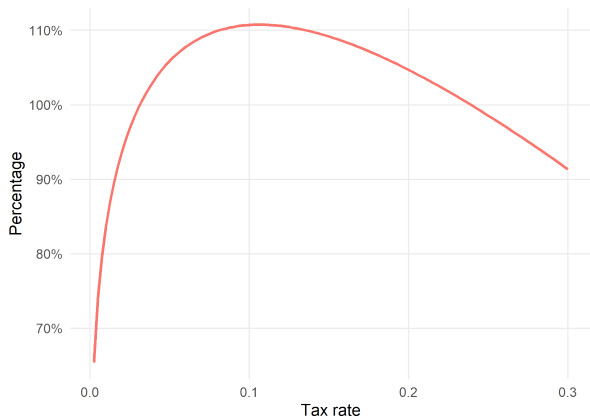
Finally, $\{\alpha_d^{s,u}\}$ pins down the network induced by input–output loops. I can calibrate these parameters by observing expenditure patterns in intermediate goods across sectors:

$$\alpha_d^{s,u} = \frac{P_d^{I,s,u} I_d^{s,u}}{\sum_k P_d^{I,k,u} I_d^{k,u}} \tag{94}$$

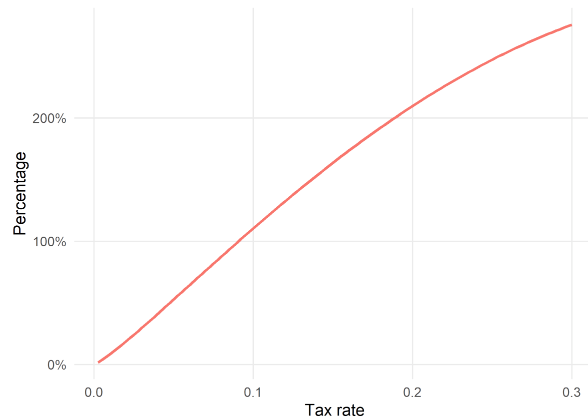
if $P_d^{I,s,u} I_d^{s,u}$ denotes expenditure in intermediate goods in sector s and location d by sector u.

Counterfactual: Tax Harmonization

As a robustness exercise, I allow for heterogeneous baseline price levels across states rather than imposing $P_k^f = 1$. State-level prices are estimated directly from expenditure and revenue data. Figure (8) illustrates that the main qualitative results are robust to this adjustment.



(a) Aggregate private income (estimated prices)



(b) Aggregate state government expenditure (estimated prices)

Figure 8: Macroeconomic effects of VAT tax harmonization with estimated baseline price levels.

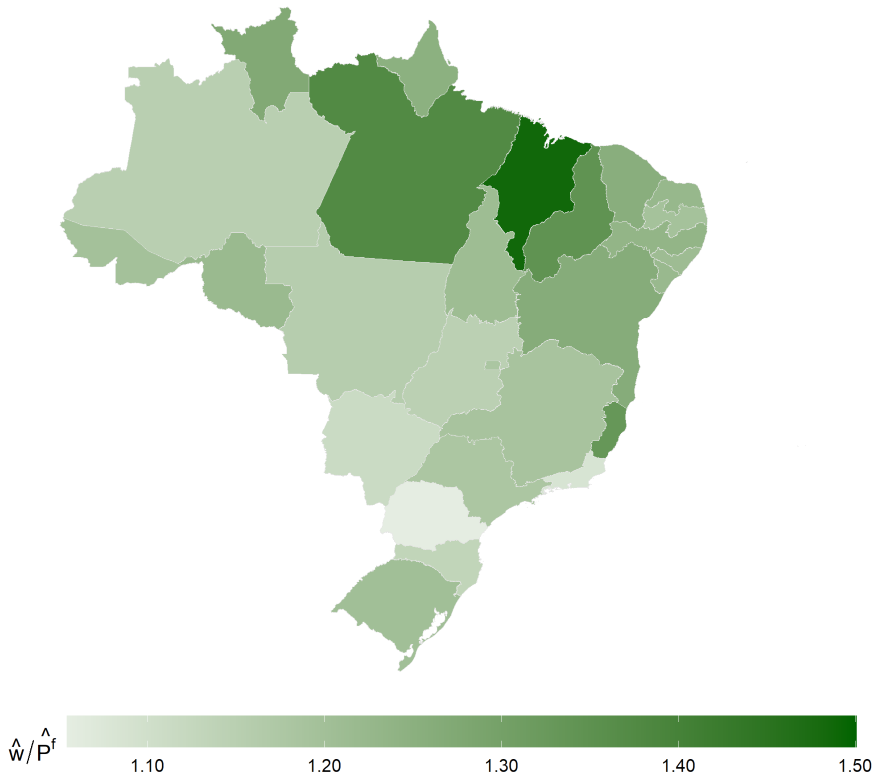


Figure 9: Map of $\hat{w}/\hat{P}^f$ by state.

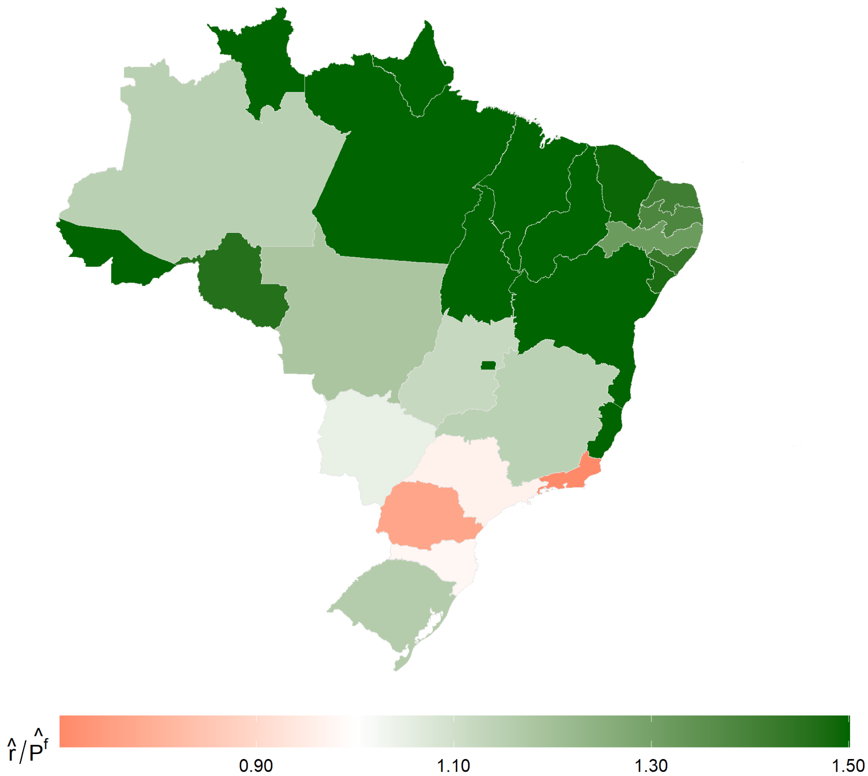


Figure 10: Map of $\hat{r}/\hat{P}^f$ by state.

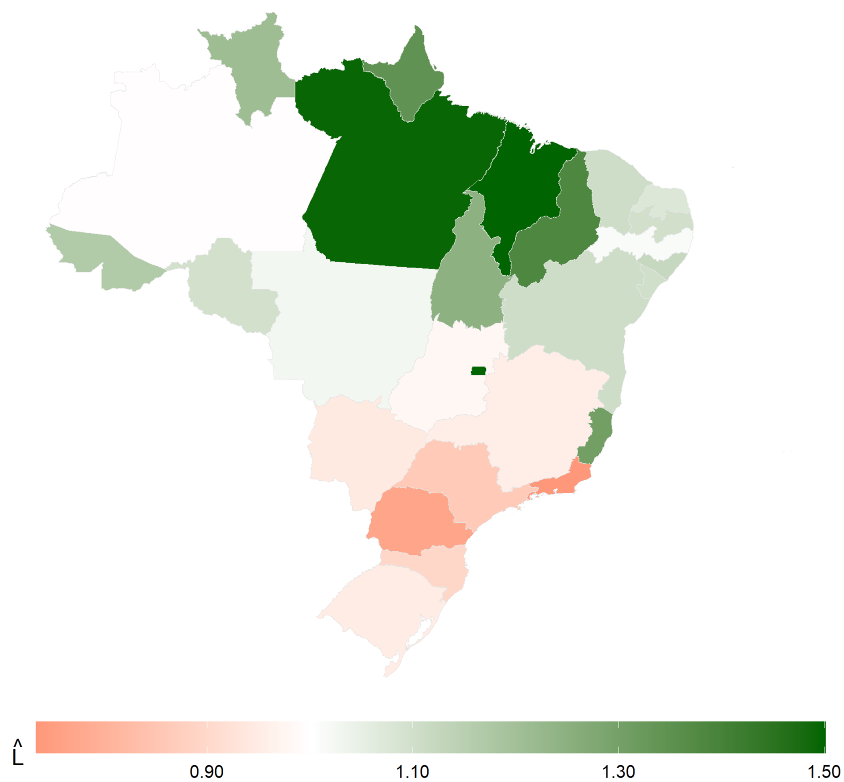


Figure 11: Map of $\hat{L}$ by state.

Fixed point algorithm

I denote M_*, matrices that lead to vectorized versions of equations presented in the main text.

The fixed point algorithm relies, in part, on initial levels of some expenditure-related variables so that relative changes can be computed. To obtain such initial levels, I rely solely on expenditure data stemming from regional accounting data. First, note that one can rewrite equation (43) as:

$$X = [I - M_1]^{-1}\alpha^F Y \tag{95}$$

Furthermore, given X, one must consider equations (44), (45), net profits , gross profits, equation (37), and (40) can be expressed as, respectively:

$$wN = M_4X + M_5X \tag{96}$$

$$rH = M_2X \tag{97}$$

$$\widetilde{\Pi} = M_3X \tag{98}$$

$$\Pi = M_6X \tag{99}$$

$$T^{\text{FED}} = \left[t^y(M_4X + M_5X)\right] + \left[t^\pi M_6X\right] + [M_7X] \tag{100}$$

$$PG = DM_8X + (s\xi^T)\iota\left\{\left[t^y(M_4X + M_5X)\right] + \left[t^\pi M_6X\right] + [M_7X]\right\} \tag{101}$$

Moreover, one can express equation (46) as:

$$[I-\Lambda]X = [\nu-I][M_2+(1-t^\pi)M_3]X+\widetilde{\xi}\left\{t^y(M_4 + M_5) + t^\pi M_6 + M_7\right\}X+[DM_9-M_{10}] \tag{102}$$

Which can be rearranged using (95) as:

$$[(I-\Lambda)-[\nu-I][M_2+(1-t^{\pi})M_3]-\widetilde{\xi}[t^y(M_4+M_5)+t^{\pi}M_6+M_7]-(DM_9-M_{10})][I-M_1]^{-1}\alpha^F Y=0 \tag{103}$$

Where $\widetilde{\xi}=[(s\xi^T)+((1-s)\xi^D)-I]\iota$. Finally, equations (41) and (42) connect income to wages.

$$Y^{pub}=DM_8X+(s\xi^T+(1-s)\xi^D)\iota\left\{\left[t^y(M_4X+M_5X)\right]+\left[t^{\pi}M_6X\right]+[M_7X]\right\} \tag{104}$$

$$Y^{priv}=\nu\left[rH+\widetilde{\Pi}\right]+[(1-t^y)wN] \tag{105}$$

Another useful formulation of equation (95) is X in terms of wN and rH

$$\begin{aligned}X'=&\left[I-M_1-\nu M_3-DM_8-(s\xi^T+(1-s)\xi^D)\iota(t^{\pi}M_6+M_7)-(1-\iota)\left(t^{\pi}M_6+M_7\right)\right]^{-1}\\&\times\left[\nu rH+(1-t^y)wN+(s\xi^T+(1-s)\xi^D)\iota\left[t^y w'N'\right]+(1-\iota)(t^y w'N')\right].\end{aligned} \tag{106}$$

Therefore, to compute an equilibrium in relative changes I use the following procedure:

1. With initial data on expenditure X, compute $\{wN, rH, \widetilde{\Pi}, \Pi, T^{FED}, PG\}$ with equations (95)-(105)

2. Guess change in prices $\hat{P}=\hat{w}=\hat{r}=\hat{L}=\hat{G}=1$

3. In a fixed point algorithm, from inner to outer loop compute the following:

   (a) In the inner most loop compute X', $\hat{P}$ and $\hat{\lambda}$.

   (b) In the 2nd inner most loop compute $Y^{implied}$ so that equation (103) holds. Adjust r and w (with dampening) with this $Y^{implied}$

(c) In the 3rd inner most loop, adjust $\hat{G}$ (with dampening) so that equation (101) holds

(d) Finally, in the outermost loop, adjust $\hat{L}$ (with dampening) so that equation (86) holds