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Vertical tax competition in Brazil: Empirical evidence for ICMS and IPI in the period 1995–2009

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Abstract

The main objective of this study is to quantify the impact caused by changes in federal tax on the tax policy of the Brazilian states, considering the presence of horizontal tax competition between states. Using panel data covering 26 Brazilian states plus the Federal District during the period 1995–2009, two models were estimated representing the average reaction of the states in response to changes in federal tax rates. In the first model, both levels of government act simultaneously, whereas in the second model, reaction is sequential, with the federal government acting as the leader in defining its effective tax rates. The results indicate a positive and significant response of states to increases in the federal tax rate, resulting in an over-taxation of the common tax base and higher tax rates. Additional tests show that the first model is the most suitable to represent the problem analysed.

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Resumo

Objetivo principal desse trabalho é quantificar qual o impacto provocado por mudanças no imposto federal sobre a política tributária dos estados, considerando a presença de competição tributária horizontal entre os estados. Utilizando um painel de dados que abrange os 26 estados brasileiros mais o Distrito Federal no período 1995–2009, foram estimados dois modelos que representam a reação média dos estados em resposta a mudanças nas alíquotas do governo federal. No primeiro modelo ambos os níveis de governo agem simultaneamente, enquanto que no segundo a reação é sequencial com o governo federal atuando como líder na definição de suas alíquotas efetivas. Os resultados apontam para uma resposta positiva e significante dos estados à aumentos na alíquota tributária federal resultando em uma sobretaxação da base tributária comum e alíquotas elevadas. Testes adicionais mostram que o primeiro modelo é o mais indicado para representar o problema analisado.

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Palavras-chave: Federalismo Fiscal; Competição Tributária; Externalidades Horizontal e Vertical; Funções de Reação

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1. Introduction

A federal system is characterised by the existence of interdependent levels of government acting in the same federation with a decentralised governance structure. Adopting a system based on fiscal federalism implies distributing constitutional powers of taxation according to the levels of government, where each level is autonomously responsible for the procedures of contribution and budget management, fiscal transfers, composition and dimensioning of expenses to allow a Pareto efficient situation among the levels of government. Therefore, a country that is politically organised according to the patterns of fiscal federalism shares, among the levels of government, the responsibility for managing allocative, distributive and stabilising functions.

However, it is not always possible to find a situation where the levels of government in the federation act efficiently in a Pareto sense. In federal systems, where the various levels operate simultaneously in the same tax regime and set tax rates on the same bases, there may be the existence of externalities. In this context, one might see a phenomenon known as tax competition. Keen (2008) defines tax competition as a strategy of fiscal adjustment in a non-cooperative game among government levels, where each level adjusts the parameters of its tax system taking into account the tax policy movements of other governments.

The phenomenon of tax competition arises when the decisions of fiscal and tax policy taken by a level of government affect the tax revenues of other governments in the federation (Mintz and Tulkens, 1986; Goodspeed, 1998). Thus, each government entity has the ability to modify the size of its tax base when adjusting its tax rates at the expense (or benefit) of its neighbours (Mintz and Tulkens, 1986). In this context, fiscal interactions can lead to two types of externalities: one horizontal and one vertical. In the first case, the externality occurs when governments at the same level in the federation compete for mobile revenue sources (e.g., capital, labour, firms), setting their tax rates to attract them into their territories. In the second case, the externality arises when different levels of government (e.g., state and federal governments) are taxing the same economic base. This co-occupancy may be explicit or implicit when tax bases are somehow inter-related in some economic sense. The vertical interaction can result in overtaxing, creating a situation in which the tax rates are higher than those that would prevail in the social optimum (Keen and Kotsogiannis, 2002). In both cases, the decisions regarding the adjustment of tax rates in one level of government end up affecting the tax revenues of the other level of government, whether they are distinct or not.

The theoretical model proposed by Flowers (1988) and its developments made by Boadway and Keen (1996), Boadway et al. (1998), Keen (1998), Flochel and Madies (2002) and Keen and Kotsogiannis (2002, 2003, 2004) show two important aspects of vertical interaction: interdependence among different government levels and the equilibrium levels of taxation. The theoretical analysis of interdependence explores how the lowest government levels react to a change in the tax rate of the highest level of government.¹ The theoretical prediction for this analysis is generally ambiguous in the sense that there may be positive or negative reactions from the lower levels of government in response to increases in the tax rates of the highest level. An increase in taxes at one government level results in a revenue reduction for another government level, due to contraction in the shared tax base. In the equilibrium, the result is usually an over-taxation of the common base at higher tax rates.

The focus of this work is the vertical tax competition between states and the federal government in Brazil. Once tax competition between levels of government may distort the levels of taxation, the main purpose of this work is to estimate the reaction functions that quantify the average effects of states' tax policy in defining their effective tax rate of ICMS, in response to increases in the effective tax rates of IPI, because they both focus on the same tax base (consumption, in general). In other words, this work aims to determine empirically whether, on average, there exists a significant strategic interaction – from a statistical point of view – between states and the federal government in setting their tax rates. The analysis of these results provides empirical evidence to determine whether, in the Brazilian tax system, the states and the federal government are overcharging the same tax base.

Empirical studies on vertical tax competition have been focusing on the estimation of a reaction function that shows how subnational governments respond to tax policy choices from the federal government. The works of Besley and

¹ The works of Boadway and Keen (1996), Keen (1998) and Besley and Rosen (1998) provide a theoretical framework for the analysis of interdependence in tax policies among different levels of government that share a common tax base.

Rosen (1998) and Goodspeed (2000) were the first to analyse vertical tax competition using this strategy. However, both studies do not take into account the existence of horizontal tax competition among subnational levels of government. Subsequently, the works proposed by Hayashi and Boadway (2001), Esteller-Moré and Solé-Ollé (2001), Brulhart and Jametti (2006), Devereux et al. (2007), Karkalakos and Kotsogiannis (2007) and Fredriksson and Mamun (2008) introduced tax interaction among subnational levels of government (horizontal tax competition) in this type of analysis. Based on research carried out by Devereux et al. (2007) and Fredriksson and Mamun (2008), Politi and Mattos (2012) analyse the vertical and horizontal externalities in cigarette and gasoline taxation in Brazil, using a database covering the 26 Brazilian states (the capital Distrito Federal was excluded from the analysis) between the years 1995 and 2007. As state tax rates, the authors used the ICMS tax rate for cigarettes and gasoline; as federal tax rates, the IPI for cigarettes and CIDE for fuel were used. The federal tax rates vary only over time, remaining constant for each state in the analysis. The results point to empirical evidence of vertical tax competition in the cigarette case.

In the specification of the reaction function, two assumptions regarding the strategic behaviour of government levels were considered in our work, resulting in the estimation of two empirical models. The first model considers the assumption that states and the federal government adjust their tax rates simultaneously, as in a Cournot–Nash strategic game. The second model assumes that the federal government behaves as a Stackelberg leader within the federation, defining its taxes in the first stage. In the second stage, the states, after observing the movements of federal tax policy, adjust their tax rates simultaneously with the other competing states in the federation.

This study is innovative in relation to previous work in at least three aspects. The first is the use of time dummies in the econometric model to capture possible common shocks in tax policies of both levels of government. This strategy is only possible because the data used to measure the effective federal tax rate vary on two dimensions of the panel data: cross-section and time. The second aspect is the use of a specific test to define the assumption about the federal government's behaviour in the game of fiscal adjustment with the states (i.e., Cournot–Nash or Stackelberg). To conclude, this study employs a method of two-stage generalised fixed effects estimation, which considers the possibility of endogeneity of the regressors, as well as the presence of heteroskedasticity and first-order serial correlation in the error terms of the panel.

This paper is divided as follows. Section 2 includes a brief analysis of indirect taxation and the Brazilian tax system and, subsequently, an overall analysis of the theoretical models' structures that considers the existence of externalities in the context of tax competition. Section 3 discusses the econometric methodology for analysing vertical tax competition and the database used. Section 4 includes the results of the estimated reaction functions and the econometric tests conducted to guide the choice of assumptions about the behaviour of strategic levels of government. The final section summarises the main conclusions from the results presented by the econometric tests performed, as well as their possible implications related to the economic theory.

2. Theoretical aspects

2.1. Indirect taxation and the Brazilian tax system

The Federative Republic of Brazil is politically and administratively organised into three distinct levels of government: the federal government, states and municipalities. Each government level has internal autonomy, administrative powers and responsibilities defined by a single Federal Constitution, thus having autonomy over revenues and expenditures constitutionally defined. However, before the subnational governments achieved greater administrative and fiscal autonomy, the Brazilian federation went through a long period of centralisation of power and resources within the federal government, which began during the military regime in 1964 and lasted until the end of the 1980s.

During this period, through the 1966 Tax Reform, two value-added taxes (VAT) were created with competences managed by distinct government levels and levied on the same base of consumption (Sampaio, 2004): the IPI (tax on industrialised products), which is a competence of the federal government; and the ICM (tax on movement of goods), which is a competence of the states. These taxes, which are of a non-cumulative nature, came to replace the old taxes that were levied “in cascade” (cumulatively) on consumption.

Initially, the ICM was a uniform tax rate that did not interfere with resource allocation, making tax competition difficult among the states, and at that time, the federal government had restricted the ability of the states to legislate

over this tax. Regarding the IPI, the federal government assigned a different tax rate structure in accordance with the nature of the goods, levying higher tax rates on goods considered less essential.²

In the late 1980s, with the beginning of the re-democratisation, the Brazilian federation started to trigger a process of political and fiscal decentralisation, having its peak with the 1988 Federal Constitution. Under the tax reform promoted by the new constitution in 1988, taxes on electricity, fuel, communication services and interstate transportation were incorporated into the base of the old ICM, which became known as a tax on operations for moving goods and services and was rendered on interstate transportation, intermunicipal transportation and communication (ICMS).

The new constitution granted to states exclusive taxing powers and autonomy to manage, legislate, raise and spend the revenues from this new tax. Thus, each state could set its internal ICMS rates, defined by ICMS regulations appropriate to each of the Brazilian states and the Federal District, provided that such did not exceed the interstate tax rates. Being able to set their tax rates according to their fiscal goals, states were then stimulated to engage a sort of “war” for tax bases.

On the other hand, because it is also a VAT, in many situations, the ICMS occupies the same tax base as the IPI, namely consumption. This suggests a possible competition for the same tax capacity between two different levels of government. The most common cases of co-occupation of these taxes on the same tax base are those concerning cigarettes and liquor. High federal and state tax rates are levied on the production and commercialisation of those goods. One can also cite the case of the automobile industry, which is taxed by both mentioned taxes.

2.2. Theoretical analysis of fiscal interdependence among levels of government: effects of a vertical tax externality

The starting point in analysing the effects of a vertical tax externality within a federation considers the reactions of subnational governments to a change in the federal government’s tax rate, when government levels share the same tax base. In this sense, the theoretical analysis of the matter distinguishes four possible factors that can affect the direction of this reaction: expenditure effect, complementarity or substitutability of taxes effect, revenue effect and deadweight loss effect. The first two effects mentioned were analysed by [Boadway and Keen \(1996\)](#), considering the consequences of a federal tax on state taxes, both levied on labour income. In a comparative statics exercise, the authors found ambiguous signs for these two effects. [Besley and Rosen \(1998\)](#) developed a model that involves the four effects and applied it to a commodities tax in the United States.

The expenditure effect represents the reaction of one government level to tax rate increases from another government level, which adjusts its spending levels in response to a revenue decrease when both share that same base. In this sense, when the federal government increases its tax rate, a subnational government may react by reducing its expenditure, thus lowering its tax rate. Therefore, the expenditure effect has a negative sign. The complementarity or substitutability effect occurs when a change in one tax rate affects the fiscal revenues of taxes levied on other tax bases. This effect can lead to very complex and ambiguous responses from different government levels, and its sign is usually uncertain.³

Increases in tax rates by one government level affect the amount of revenue collected by the other government level when these two levels share the same base. Thus, as noted by [Besley and Rosen \(1998\)](#), the revenue effect represents the reaction of subnational governments to maintain their tax revenues, when the federal government increases its tax rates. An increase in federal tax rates leads to a decrease in the tax revenues of subnational governments that, in turn, react by raising their rates due to erosion in the tax base shared by both government levels in order to maintain their tax revenues. The effect of this reaction is therefore positive.

The deadweight loss effect arises from the fact that the marginal disutility of tax on a particular good increases with its tax rate. According to [Besley and Rosen \(1998\)](#), when states consider only the effect of increasing their tax burden on their citizens – ignoring the excess tax burden created by the federal government – an increase in the federal excise rate requires an increase in the state tributes, so that the indirect utility function of the consumer is maximised. On the other hand, if the states adjust their tax rates to minimise the excess of a total tax burden, given the federal

² In addition to the creation of these two taxes, the 1966–67 Tax Reform also created the ISS (Tax on Services of Any Nature), which is a competence of the municipalities and replaced the old Tax on Industries and Professions, as well as the IOF (Tax on Financial Transactions), which is a competence of the federal government.

³ In the model analysed by [Boadway and Keen \(1996\)](#), this effect is present in the situation where revenues on government incomes are affected by changes in the tax on labour income.

tax, an increase in the federal tax rate can lead to a decrease in state revenues, so that the indirect utility function of a representative consumer is maximised. This signal is also ambiguous in the analysis.

In summary, from the analysis of the four effects mentioned above, it is considered that the reaction of subnational governments in relation to changes in federal tax rates is theoretically ambiguous. Therefore, an empirical analysis is needed to determine the direction and magnitude of the response from subnational government levels to tax changes at the federal level.

In the theoretical model of tax competition developed by Keen and Kotsogiannis (2002) and modified by Karkalakos and Kotsogiannis (2007), the federal government overlaps sub-national governments and, by assumption, the policy-makers involved are considered benevolent⁴ in the sense that they act in the best interest of their own individual jurisdictions. It is also considered an equalisation system.⁵ Their model consists of a federation with $N \geq 1$ states indexed by $i = 1, \dots, N$, where for each state i , there is a firm that produces according to the production function $F_i(K_i)$, with $F'_i(K_i) > 0$ and $F''_i(K_i) < 0$, where K_i is the capital invested in state i . Capital is freely mobile among the states of the federation and produces a single return, ρ , once taxed. It is assumed that capital is taxed by both federal and state governments. The state charges a unit tax t_i , whereas the federal government charges a unit tax T , which is equal for all states. Thus, capital is taxed by $\tau_i = t_i + T$. Capital mobility implies that the return on capital after tax in state i is $F'_i(K_i) - \tau_i = \rho$. This condition implicitly defines the demand for capital in state i by $K_i(\rho + \tau_i)$, where:

$$K'_i(\rho + \tau_i) = \frac{1}{F''_i(K_i)} < 0 \tag{2.1}$$

Capital is paid by its marginal product; hence, the income generated by capital in state i is expressed as the difference between the value of production and the cost of capital:

$$\Pi_i(K_i) = F_i(K_i) - F'_i(K_i)K_i \tag{2.2}$$

From (2.1) and (2.2), we have:

$$\Pi'_i(\rho + \tau_i) = -K_i(\rho + \tau_i) < 0 \tag{2.3}$$

Considering that a population of M_i citizens resides in each state i , a typical citizen j located in state i has preferences defined over two periods of private consumption, C^j_{i1} and C^j_{i2} , over the level g_i of public goods provided by state i and over the level G of public goods provided by the federal government. The utility function of consumer j of state i is represented by $u^j_i(C^j_{i1}, C^j_{i2}, g_i, G)$, where it is assumed that without loss of generality, $u^j_i(\cdot)$ is strictly increasing and concave in all of its parameters. Each resident j of state i has a fixed endowment e^j_i of income in the first period and in the second period, receives principal and interest on his/her savings plus *per capita* income produced after taxes in his/her jurisdiction, defined by:

$$\Pi^j_i(\rho + \tau_i) = \frac{\Pi_i(\rho + \tau_i)}{M_i} \tag{2.4}$$

From the utility maximisation problem, aggregate savings of state i , $S^j_i(\rho)$, such that $S'(\cdot) \geq 0$, and the indirect utility function, $V^j_i(\rho, \tau_i, g_i, G)$, are derived. Denoting aggregate savings in state i by $S_i(\rho) = \sum_{i=1}^{M_i} S^j_i(\rho)$, the net return $\rho(\tau)$ ⁶ is implicitly defined by the market equilibrium condition $\sum_{i=1}^N S_i(\rho) = \sum_{i=1}^N K_i(\rho + \tau_i)$. Thus, it follows that:

$$\frac{\partial \rho}{\partial \tau_i} = \frac{K'_i(\rho + \tau_i)}{\sum_{l=1}^N S'_l(\rho) - \sum_{l=1}^N K'_l(\rho + \tau_l)} \in (-1, 0) \tag{2.5}$$

⁴ In the literature on tax competition, some authors consider that policymakers are benevolent in the sense that they act in order to maximise the welfare of their residents (Boadway and Keen, 1996; Boadway et al., 1998; Keen, 1998; Keen and Kotsogiannis, 2002, 2004). On the other hand, the theory also admits that policymakers behave like leviathans, where the goal of their policies is to maximise tax revenues (Flowers, 1988; Keen, 1998; Wrede, 1996; Flochel and Madies, 2002; Keen and Kotsogiannis, 2003).

⁵ One can consider, for the Brazilian federation, that the variable in the model described as equalisation entitlements is transfers from the federal government to the state and/or municipal governments. As an example, one can cite the Participation Fund of the States and the Federal District and the Participation Fund of the Municipalities. These issues will be discussed in the empirical part of this work.

⁶ τ is defined as the N -vector of consolidated rates such that $\tau \equiv (\tau_1, \dots, \tau_N)$.

From (2.1) and the equilibrium condition defined above, the following expressions are obtained:

$$\frac{\partial K_i}{\partial \tau_i} = K'_i \left(1 + \frac{\partial \rho}{\partial \tau_i} \right) < 0, \quad i = 1, \dots, N. \tag{2.6}$$

$$\frac{\partial K_l}{\partial \tau_i} = K'_l \frac{\partial \rho}{\partial \tau_i} > 0, \quad i \neq l, \quad i = 1, \dots, N. \tag{2.7}$$

These expressions have an important meaning for the analysis. From (2.6), one can conclude that a tax increase on capital in state i reduces the capital in state i . Moreover, from (2.7), a tax increase from state i increases the capital in state l .

The expenditures of the states are given by tax revenues plus equalisation entitlements. In relation to the model by Keen and Kotsogiannis (2002), in the case of the Brazilian federation presented here, it is considered an equalisation system that can be exemplified as the system of intergovernmental transfers between the federal government and states. Keen and Kotsogiannis (2002) consider that the federal government equally allocates revenues among the states and that there are no intergovernmental transfers vertically, among levels of government, or horizontally, among governments of the same level.

The equalisation system is defined as follows: a base for the revenue source is chosen so that it represents, as closely as possible, the real base of the revenue source. The total revenue of all states is then divided by the national base, resulting in an average proportion of state revenue in relation to the federation. This proportion is then applied to the base in a particular state, and the resulting tax is divided by the state population to obtain the *per capita* income tax in relation to the average national proportion. The difference between *per capita* state income and *per capita* national income, multiplied by the state’s population, represents the equalisation due to the state in relation to this revenue source.

Applying this equalisation structure to the capital tax of state i , the *per capita* equalisation payment received by state i is given by $\omega_i = \tilde{t}(\tilde{k} - k_i)$, where the proportion of national revenue state average (\tilde{t}), national *per capita* income (\tilde{k}) and *per capita* tax base of state i (k_i) are given, respectively, by $\tilde{t} = (\sum_{i=1}^N t_i K_i) / \sum_{i=1}^N K_i$, $\tilde{k} = \sum_{i=1}^N K_i / \sum_{i=1}^N M_i$, $k_i = K_i / M_i$.

Assuming the existence of equalisation entitlements, the budget constraints on the states and federal government may be represented by the following expressions:

$$g_i = t_i K_i + M_i \omega_i \tag{2.8}$$

$$G = \frac{T \sum_{l=1}^N K_l - \sum_{l=1}^N M_l \omega_l}{N} \tag{2.9}$$

The government of state i , on choosing its tax rate, takes as given the tax rates of other states and the federation to maximise the aggregate welfare in such state, denoted by $W_i(\rho, \tau_i, g_i, G, \xi_i) = \sum_{j=1}^{M_i} V_i^j(\rho, \tau_i, g_i, G, \xi_i)$, subject to constraints (2.8) and (2.9), where vector ξ_i represents the vector of characteristics common to all states. Considering this behaviour by state governments and using the expressions defined in (2.1), (2.3) and (2.5), the necessary condition is obtained for states to maximise the welfare of its citizens, which can be implicitly represented by:

$$\frac{\partial W_i(t_i, \tau, T, \xi_i)}{\partial t_i} \equiv \psi_i(t_1, \dots, t_i, \dots, t_N, \omega(t), T, \xi_i) = 0, \quad i = 1, \dots, N \tag{2.10}$$

where vector $\omega(t)$ denotes the dependence of the states on the rights of equalisation in vector $t = (t_1, \dots, t_i, \dots, t_N)$. A detailed analysis of expression $W_i(\rho, \tau_i, g_i, G, \xi_i)$ may conclude that states, when adjusting their tax t_i , give rise to vertical and horizontal externalities. When states increase their taxes, they ignore the benefit incurred to other states by shifting their mobile tax base out of their domains and thus generating horizontal externalities. This effect can be illustrated by the expression defined in (2.7). The vertical externality is derived from the fact that states ignore the damage incurred to other states, leading to a contraction in the federal tax base, as can be observed in Eq. (2.9).⁷ These interactions become more involved with the existence of equalisation rights.

⁷ The analysis of the theoretical model developed by Karkalakos and Kotsogiannis (2007) considers that the federal government behaves as a Stackelberg leader with respect to the states of the federation in adjusting its rates. Thus, the states increase their rates in response to an arbitrary increase by the federal government and ignore the contraction of the common tax base resulting from this fiscal adjustment.

From expression (2.10), one can implicitly define a best response function of the state i as:

$$t_i = f_i(t_1, \dots, t_{-i}, t_i, \dots, t_N, T, \xi_i), \quad i = 1, \dots, N. \quad (2.11)$$

The simultaneous solutions of Eq. (2.11) for all states determine the level of Nash equilibrium tax rates of the states as a function of the federal tax T and the vector of characteristics common to all states, $\xi = (\xi_1, \dots, \xi_M)$. The main objective of this study is to estimate the slope of the reaction functions $f_i(\cdot)$ with respect to federal tax T , considering the horizontal interactions (i.e., tax competition of state i with the other j states of the federation), for $j \neq i$ and the vector ξ_i .

3. Empirical methodology

3.1. Specification of the econometric model

The main objective of this study is to estimate a reaction function that characterises the fiscal policy behaviour of states by setting their taxes in relation to changes in federal taxes. The estimation of this fiscal reaction function will follow Eq. (2.11). Assuming that the fiscal reaction function of states is linear, the following equation will be estimated:

$$t_{st} = \alpha_{st} + t_{-st}\beta + T_{st}\gamma + X_{st}\delta + d_t\varphi + \varepsilon_{st} \quad (3.1)$$

The dependent variable t_{st} represents the effective tax rate of state s in year t ; t_{-st} is the weighted tax rate of other states as competitors of state s in year t ; T_{st} represents the effective federal tax rate⁸ at time t ; X_{st} represents the socio-economic characteristics of each state s at time t ; d_t represents a set of binary time variables (*dummies*); and ε_{it} is the random error term of the regression.

The coefficient α_{st} represents the fixed effect term. This term typifies the specific characteristics of each state. The coefficients of interest in the analysis are β and γ , which represent, respectively, the horizontal and vertical interactions in the model. Empirical evidence of horizontal tax interactions is represented in the model by a positive and statistically significant β . A vertical tax interaction is represented by a statistically significant γ , where the negative sign of γ indicates that federal and state taxes are strategic substitutes. On the other hand, a positive sign of γ indicates that federal and state taxes are most likely strategic complements.

3.2. Data description

To empirically investigate vertical and horizontal interactions between government levels in the federation, the econometric model described in (3.1) will be used. The dependent variable of the model is a measure that represents an effective tax rate for each of the states in the analysis, calculated as the ratio between the ICMS tax revenue and the GDP in each state.

Regarding the federal tax rate, which enters into the model as an independent variable, it will also be used as an effective tax rate, represented by the ratio between IPI federal tax revenues collected in each of the Brazilian states and the respective GDP of these states. In all other empirical studies that address vertical tax competition, the federal tax rate is simply the same for all cross-section units of the panel, varying only with time. Such methodology for computing the federal tax rates does not allow the inclusion of a set of time *dummies* in the econometric model that capture possible aggregate shocks that may occur each year, generating different effects on their tax rates. In this work, the federal tax rates were built through the IPI tax revenue collected by a state, divided by the respective GDP of each state. Therefore, it is possible to find an effective tax rate for the federal tax specific to each state, allowing the use of time *dummies* in the econometric model.

The measures for tax rates used in this study may also represent a type of tax burden of those taxes (state or federal) for each state. Several other studies calculate tax rates in this manner, such as [Goodspeed \(2000\)](#), [Esteller-Moré and Solé-Ollé \(2001\)](#) and [Hayashi and Boadway \(2001\)](#).

⁸ The subscript s indicates the federal rate referring to the state where the federal tax revenue was collected. It will be subsequently explained how each rate (state and federal) was computed.

The variable used to measure horizontal interactions in the model was constructed by multiplying an exogenous weight matrix by the vector of states' tax rates, so that this constructed variable indicates the relevance of other governments in the process of interaction. In the literature, these weights are generally related to Euclidean distance (Anselin, 1988) or socio-economic characteristics (Case et al., 1993) among the states. In the econometric model described above, this variable is represented by:

$$t_{-st} = \sum_{i \neq s} W_{si} t_{it} \quad (3.2)$$

where W_{si} represents the exogenous weighting matrix, normalised such that the sum over the elements of each row equals one (i.e., $\sum_{s \neq i} W_{si} = 1$). Following this approach, two different weighting schemes were used in this research. The first weighting scheme (Matrix $W1$) uses a matrix whose elements are based on the criterion of contiguity between states, where it is assumed that the interaction occurs only between states that share the same geographic boundaries, defining weight 1 for states that have borders in common and weight 0 otherwise. The second criterion (Matrix $W2$) uses the inverse of the road distance between the capitals of states.⁹ This weighting scheme gives more weight to states closer to the geographical boundaries of a given state, whereas states farther away receive less weight on their tax rates. In both matrices, the standardisation of lines was considered, where the sum over the elements in the rows of the matrix equals 1, according to the following formula:

$$W_{si} = \frac{w_{si}}{\sum_{i=1}^N w_{si}} \quad (3.3)$$

where w_{si} is the i th element of row s of matrix W_{si} .

The fiscal policy decisions of the states can be affected by characteristics of an economic or demographic nature. To control such characteristics in the model, a set of exogenous variables was included to characterise the economic and demographic situation of each state, represented by the variable X_{st} : resident population (*POP*); unemployment rate (*TAXDESEMP*); number of people employed (*POPOCUP*); household income *per capita* (*RENDPC*); total expenditure of the states in *per capita* terms (*DESPTOTPC*); the Theil index (*ITHEIL*); and the poverty rate (*POBRE*). Fiscal policies taken by the federal government that are not related to the adjustment of federal taxes also affect states' decisions in setting tax rates. To control this phenomenon, it will be added the amount of current transfers from the federation to the states, in *per capita* terms (*TRCORRPC*).

The population size (*POP*) was included in the model to capture the demand for public goods and services. According to Leprince et al. (2007), more populous states have economies of scale in providing public services, and for this reason, such states' tax rates tend to be lower. Therefore, it is expected that the sign of the coefficient for this variable will be negative. The variable total expenditure *per capita* (*DESPTOTPC*) was also included in the model to capture the demand for public goods. Positive changes in government spending should be associated with higher levels of taxation in the states; thus, it is expected that the sign of the estimated coefficient for this variable will be positive.

Esteller-Moré and Solé-Ollé (2001) argue that rich populations (i.e., with higher income *per capita*) will demand more public goods from the state and will therefore tolerate higher tax rates on their income. However, the effect of an income increase in the tax rate of the state is uncertain because with higher income, a higher level of revenue can be sustained with a lower tax rate. Therefore, there is no expected sign (i.e., positive or negative) in relation to the variable income *per capita* (*RENDPC*). This variable also captures the possible effects of economic cycles, as well as the unemployment rate (*DESEMP*) and employed population (*POPOCUP*). Thus, these variables control the exogenous shocks that alter both state and federal tax rates, capturing possible co-movements between the effective tax rates.

As the unemployment rate is negatively correlated with the level of economic activity, it is expected that the coefficient for this variable will be negative, in the sense that higher state revenue of ICMS is positively correlated with economic activity. On the other hand, it is expected that the coefficient for the variable employed population will be positive by the same factors related to unemployment.

The poverty rate (*POBRE*) and the Theil index (*ITHEIL*) were used to control the social and income inequalities among Brazilian states that may affect taxation policies in adjusting state taxes. There are no theoretical predictions for these two variables, and the analysis of their coefficients is performed after estimating the suggested empirical models.

⁹ For the state of Amapá, the aerial distance was considered as its capital has no road links with other capitals of the country.

Table 1
Descriptive statistics of the main variables used in the analysis.

Variable	Description of variable	Obs.	Mean	Standard deviation	Minimum	Maximum
<i>Taxicms</i>	Measure of the tax rate of ICMS from the states. It is represented by the ICMS revenue divided by the GDP of the states.	405	0.0726	0.0162	0.0311	0.1237
<i>Taxipi</i>	Measure of the IPI tax rate. It is represented by the IPI revenue collected in each state divided by the respective GDP of the state where this revenue was generated.	405	0.0086	0.0081	0.0004	0.0722
<i>Pop</i>	Resident population of the states.	405	6,446,296	7,703,930	254,499	41,400,000
<i>Desemp</i>	Percentage of people who sought but did not find remunerated professional occupation among all those considered “active” on the labour market; group that includes all persons 10 years old or older who were working or looking for employment in the reference week of the National Household Sample Survey (Pnad).	405	9.0312	2.7617	2.7099	20.537
<i>Popocup</i>	Number of people who were working in the reference week of the National Household Sample Survey (Pnad/IBGE), estimated from the microdata of the survey.	405	2,770,064	3,505,528	67,049	20,106,470
<i>Rendpc</i>	Average income of the population.	405	504.3676	210.4311	223.5479	1468.051
<i>Desptotpc</i>	Total expenditures <i>per capita</i> .	405	2134.188	1055.313	664.7784	7996.581
<i>Itheil</i>	Measures the degree of inequality in the distribution of per capita household income among individuals. It is the logarithm of the ratio between the arithmetic and geometric averages of individual incomes, being null when no income inequality exists between individuals and tending to infinity when income inequality tends to the maximum.	405	0.6594	0.1163	0.3388	1.0531
<i>Pobre</i>	Percentage of people in the total population with <i>per capita</i> household income below the poverty line.	405	37.2856	16.7635	6.3574	72.5071
<i>Trcorrpc</i>	Current transfers <i>per capita</i> .	405	862.6239	859.9439	160.8479	5142.264
<i>Eletind</i>	Industrial electric energy consumption of the states.	405	5161.205	9218.119	7.624	54,033

Source: Own elaboration.

The amount of current transfers *per capita* (*TRCORRPC*) is also included. High levels of transfers increase the states’ revenues, allowing lower average state tax rates. Thus, this variable shall present the estimated coefficient with a negative sign.

The consumption of industrial electric power (*ELETIND*) was used as a *proxy* for the federal tax rate in tests carried out for exogeneity of the federal tax rate, which will be explained in the next section. Table 1 includes the main descriptive statistics of the variables mentioned above. The data obtained are of annual frequency, and the period of analysis covers the years 1995–2009 and includes the 26 states plus the Federal District (i.e., 27 cross-section units in the panel data), totalling 405 observations. All financial series were deflated by the IGP-DI.

Lastly, all analysed models included a binary time variable (*dummy*) to capture the effects that may have occurred in each year over the analysis in question. This strategy is not possible in studies that employ federal tax rates that remain constant for each cross-section of the panel. In this work, the federal tax rate that is used varies both in the temporal dimension and in cross-sections of the panel, allowing the inclusion of these variables.

3.3. Empirical strategy and methodology of analysis

In addition to the treatment for fixed effects,¹⁰ another problem found in the estimation of Eq. (3.1) is the endogeneity of competing states' weighted tax rates in the model. According to Brueckner (2003), either by tax competition, welfare competition or spillover effects,¹¹ changes in fiscal policy in a particular state may affect decisions regarding the setting and adjustment of tax rates in other states within the federation, indicating a dependence on fiscal policy among the states. Therefore, it is expected that the tax rate of competing states is endogenous and correlated with the regression error term (ε_{st}). A least squares estimation of Eq. (3.1) will produce biased and inconsistent estimates of the parameter that measures the horizontal interactions in the model due to the existence of common shocks in the decision of fiscal policy among the states. To address these problems, the approach of two-stage fixed effects will be employed where, in the first stage, the reduced form of the endogenous variables of the model are estimated, and in the second stage, the adjusted values are replaced in the original regression.¹²

In the first-stage regression, the exogenous variables of the model multiplied by the weighting matrices ($\sum_{i \neq s} W_{si} \times X_{it}$) were used as instruments for the weighted tax rates of competing states, as suggested by Kelejian and Robinson (1993) according to the criteria used in each of the matrices. The adjusted values have been computed and used as instruments in the second stage-regression.

In the adjustment of the tax rates on the simultaneous game, the federal and state taxes can move simultaneously within the federation due to some common factor. Exogenous shocks in the regression errors not controlled by the model regressors may change both the state tax rates as well as the federal tax rate. In this context, the federal tax rate may be endogenous in the econometric model. Esteller-Moré and Solé-Ollé (2001) argue that although it is difficult for the federal government to react separately to each state in the federation and considering the federal tax rate to be exogenous within the model, there may still be some correlation between this variable and the error term due to common shocks in both tax rates. For this reason, the Durbin–Wu–Hausman exogeneity test (*DWH*) was employed to check whether there is any correlation between the residuals of the regression and the federal tax variable. The results of the *DWH* tests pointed to the non-rejection of the null hypothesis of exogeneity of the federal tax rate. Thus, it was decided that this should be considered an exogenous variable in the econometric model, instrumentalising only the weighted tax rate of competing states.

However, the presence of heteroskedasticity among the cross-section of panel units and serial correlation in the regression residuals create additional problems usually encountered when using panel data. To detect the presence of heteroskedasticity, the modified Wald test for panel data was used, where the null hypothesis for this test is homoscedasticity between the error terms of the panel. In all models, the null hypothesis of homoscedasticity was rejected. To test whether the regression errors are serially correlated, the Wooldridge test for serial correlation in panel data was employed. The null hypothesis of this test is that there is no first-order serial correlation in the error terms of the panel. Panel data with serially correlated errors can produce inefficient estimates of the parameters. In all models, the null hypothesis that the errors are not serially correlated has been rejected.

To address these problems, in addition to fixed effects and two-stage approaches, the method of feasible generalised least squares (*FGLS*) was used, which considers the possibility of heteroskedasticity and first-order serial correlation in the error terms of the panel.

Following the empirical strategy mentioned above, two models were estimated. In the first model, it was assumed, a priori, that states and the federal government act simultaneously and together in the federation when adjusting their tax rates – as in a Cournot–Nash game – ignoring the vertical externality they impose on the other level of government. Considering this assumption means that the effect of adjusting state tax rates in relation to changes in the federal tax occurs the same year in which these changes take effect.

¹⁰ Hausman specification tests previously conducted in this study favoured the use of this method.

¹¹ In tax competition models, the tax rate decision influences the migration of capital; in welfare competition models, the decision on the amount of benefits given to the poor encourages the migration of this population. Therefore, in these models, competition between different units of the federation aims to attract capital, labour and/or votes. In models with spillover effects, the optimum level of a decision variable affects the level of such variables at other federal units because these effects may have an influence in a greater area than that of a single jurisdiction. For instance, a state's population can benefit from investment in hospitals, roads, and similar infrastructure carried out by a neighbouring state.

¹² Kelejian and Prucha (1998) demonstrate that this method is also consistent with the presence of spatial correlation in the residuals.

On the other hand, as seen before, the theoretical literature also considers that the federal government can act as a Stackelberg leader within the federation, by setting its tax rates first, and after observing this behaviour, states in the federation simultaneously and together set their tax rates. In this case, the states will react late to changes in federal tax rates. To account for this possibility, the previous model was re-estimated, replacing the contemporaneous values of the federal tax rate with their lagged values to represent the delayed reaction of the states in relation to adjustments in the federal government's tax rate. Mello (2007) adopts a similar approach by including the lagged rate of a given state in the reaction function in his study of horizontal tax competition among the Brazilian states.

After estimating the two models, considering the above specified assumptions about the behaviour of government levels in setting their tax rates, the *J* test approach proposed by Davidson and MacKinnon (1981) was considered to select the most plausible model for the data and Brazilian reality. The estimation results and model selection test are presented in the next section.

4. Results

4.1. Results for the federal tax rate in level: the Cournot–Nash Model

The first model assumes that states and the federal government act simultaneously in setting their tax rates. In all estimates, for both weighting matrices of competing states' tax rates, evidence for the presence of heteroskedasticity and serial correlation was found in the estimated models. The estimation results considering the presence of horizontal interactions in the model are shown in Table 2.

The estimates of interest in the analysis are the coefficients of the federal tax and the weighted tax rate of the states. The coefficient of the variable federal tax has presented, for both specified matrices, statistically significant and positive estimates in all models considered, giving empirical evidence that state and federal taxes (i.e., ICMS and IPI) are most likely strategic complements. This result suggests that, on average, the Brazilian states tend to increase their ICMS effective tax rates in response to increases in the IPI effective tax rates observed in their territories and practiced by the federal government during the analysed periods. Therefore, when the federal government and states set their tax rates simultaneously and together, the result may be an over-taxation of the tax base at high state and federal tax rates. This result can be explained by the revenue effect, mentioned in the previous sections.

The coefficient that measures the horizontal interaction in the model is statistically significant and positive for both weighting schemes used. This result can be interpreted as the reaction of states to changes in other states' fiscal policies. On average, a state will reduce its effective ICMS tax rate in response to a reduction in this tax rate observed in other Brazilian states. As observed in Table 2, it is found that when the weighting matrix considers only the border states (Matrix W1), then the reaction on the tax rates seems to be lower in magnitude than considering the inverse distance matrix (Matrix W2), which considers the influence of all federation states on a given state's fiscal policy. This result suggests that when a state sets its tax rate considering the fiscal reaction of all other states involved in the federation, then the magnitude of the reaction will be greater than if considering only the states contiguous to it.

Regarding the other variables in the model, the coefficient of the unemployment rate was statistically insignificant in all estimations presented in Table 2. The coefficient of the employed population in the model is positive and significant in the regression that utilise Matrix W2 as weighting scheme. This sign is in accordance with expectations, as explained in Section 3.2. Total expenditures *per capita* were positive and statistically significant in all estimations. This result suggests that high levels of spending are associated with a higher level of taxation, indicating that higher levels of spending will demand a higher budget constraint, which is achieved through higher tax rates.

The estimates for the coefficient of the Theil index were positive and statistically significant in all regressions. The positive sign for this variable suggests that, on average, the higher the level of income inequality in a state, the higher is the effective ICMS tax rate in this state. This is consistent with the prediction of theoretical models for the median voter, where a strong positive correlation is expected between income inequality and tax burden in a federation.

The negative sign was expected for the population variable coefficient, which proved to be significant from the statistical point of view for the results that used the weighted Matrix W2. This may reflect, as already explained, the idea that states with larger populations has economies of scale in the provision of public goods to its population. The negative sign for the coefficient of the variable income *per capita* suggests that states with higher income *per capita* do not need high tax rates to maintain a balanced budget because higher income levels allow greater revenues, even with the application of a lower effective tax rate.

Table 2

2FGLS estimates for the states' reaction function with the exogenous federal tax rate at level.

	Weighting matrices	
	Matrix W1	Matrix W2
Dependent variable: ICMS effective tax rate of state i ($taxicms$)		
Federal tax rate ($taxipi$)	0.5215*** (0.08932)	0.5938*** (0.0935)
Weighted tax rate of states j ($taxicmsj$)	0.1828*** (0.0589)	0.5157*** (0.0939)
Population $\times 10^{-6}$ (pop)	-0.0014 (0.0009)	-0.0018** (0.0008)
Unemployment rate ($desemp$)	0.0007 (0.0212)	-0.0063 (0.0213)
Number of people employed $\times 10^{-6}$ ($popocup$)	0.0029 (0.002)	0.0042** (0.0018)
Household income <i>per capita</i> $\times 10^{-3}$ ($lnrendpc$)	-0.0683*** (0.0067)	-0.0587*** (0.0067)
Total expenditure <i>per capita</i> $\times 10^{-3}$ ($desptopc$)	0.0027*** (0.0009)	0.0022** (0.0008)
Theil inequality index ($itheil$)	0.0274*** (0.0051)	0.0261*** (0.005)
Poverty rate ($pobre$)	-0.0653*** (0.0096)	-0.0642*** (0.0091)
Current transfers <i>per capita</i> $\times 10^{-3}$ ($trcorrpc$)	-0.0052*** (0.0014)	-0.0062*** (0.0013)
Constant	0.0909*** (0.0069)	0.0643*** (0.0086)
Annual dummies	Yes	Yes
Wald test statistic χ^2 (25)	313.67	300.63
p -Value	0.0000	0.0000

Source: Own elaboration.

Observations: (1) Standard errors in parentheses are robust for heteroskedasticity and serial correlation; (2) *Matrix W1*: contiguity matrix among all states; *Matrix W2*: matrix of the inverse of road distances among states.

** Significant at 5%.

*** Significant at 1%.

The poverty rate has presented negative and statistically significant coefficients in all estimations considered. This result suggests that, on average, the higher the poverty rate, the lower is the effective ICMS tax rate within the states when the poverty rate rises. This result, together with the observed sign of the variable intergovernmental transfers, may reflect the greater dependence of the poorest Brazilian states on revenue transfers. Thus, on average, within poorer states with lower average income and with a higher proportion of transferred revenue in relation to total revenues, the ratio of ICMS to GDP is lower, explaining the negative correlation between these variables and the effective ICMS tax rate. As explained previously, the negative sign of transfers can also be related to a lower fiscal effort of state governments in raising tax revenue because the revenue transferred to the states has a direct positive impact on their budgets, reducing the pressure for states to increase their effective ICMS tax rates.

To verify the robustness of these results, the contemporary competition model was estimated again through instrumental variables (IV) in the context of the generalised method of moments (IV-2SLS-GMM), following [Politi and Mattos \(2012\)](#). In the first stage, the endogenous variable, $t_{-st} = \sum_{i \neq s} W_{si} t_{it}$, is regressed on the exogenous variables and on the instrumental variables and the significant regressors are used in an estimation with instrumental variables from Eq. (3.1) without the time dummies in the second stage. The selected instrumental variables for the regression that utilise weighting scheme W1 were population, household income *per capita*, Theil inequality index, current transfers *per capita*, and the third lag of ICMS tax rate weighted by Matrix W1. For the second weighting scheme W2, the selected instrumental variables were population, unemployment rate, household income *per capita*, total expenditure

Table 3
2FGLS estimates for the states' reaction function with the lagged exogenous federal tax rate.

	Weighting matrices	
	Matrix W1	Matrix W2
Dependent variable: ICMS tax rate of state i ($taxicms_i$)		
Federal tax rate in $t - 1$ ($taxipi_{t-1}$)	0.3141*** (0.1082)	0.3963*** (0.1127)
Weighted tax rate of states j ($taxicms_j$)	0.1703*** (0.0622)	0.5254*** (0.0976)
Population $\times 10^{-6}$ (pop)	-0.0011 (0.0009)	-0.0016* (0.0009)
Unemployment rate ($desemp$)	-0.0008 (0.0226)	-0.0083 (0.0225)
Number of people employed $\times 10^{-6}$ ($popocup$)	0.0022 (0.0022)	0.0037* (0.0021)
Household income <i>per capita</i> $\times 10^{-3}$ ($lnrendpc$)	-0.0719*** (0.007)	-0.0622*** (0.007)
Total expenditure <i>per capita</i> $\times 10^{-3}$ ($desptotpc$)	0.0035*** (0.001)	0.003*** (0.001)
Theil inequality index ($itheil$)	0.0287*** (0.0055)	0.02781*** (0.0054)
Poverty rate ($pobre$)	-0.0678*** (0.0101)	-0.0676*** (0.0096)
Current transfers <i>per capita</i> $\times 10^{-3}$ ($trcorrpc$)	-0.0058*** (0.0015)	-0.0071*** (0.0015)
Constant	0.0938*** (0.0074)	0.0663*** (0.0090)
Annual dummies	Yes	Yes
Wald test statistic χ^2 (25)	262.12	259.23
p -Value	0.0000	0.0000

Source: Own elaboration.

Observations: (1) Standard errors in parentheses are robust for heteroskedasticity and serial correlation; (2) *Matrix W1*: contiguity matrix among all states; *Matrix W2*: matrix of the inverse of road distances among states.

* Significant at 10%.

*** Significant at 1%.

per capita, Theil inequality index, poverty rate, current transfers per capita, and second lag of ICMS tax rate weighted by *Matrix W2*.

The results of this estimation are shown in [Table 1A](#) in Appendix in which the reported standard deviations are robust to heteroskedasticity and serial correlation. The estimated parameters of the horizontal and vertical interaction remain positive and statistically significant. The variables population, number of people employed, and current transfers *per capita* were not statistically significant in this estimation procedure, whereas the variable current transfers per capita is significant in the previous one, by 2FGLS. It is worth noting that the standard deviations of the coefficients that measure vertical and horizontal interactions are lower in the first estimation procedure (2FGLS) than those obtained with the latter (IV-2SLS-GMM). Despite these differences, both estimation procedures present empirical evidence of a significant horizontal and vertical interaction among states and between these and the federal government.

4.2. Results for the lagged federal tax rate: Stackelberg Model

It is assumed in this specification that the federal government behaves as a Stackelberg leader, setting its tax rates first, and states behave as followers in the federation. In the empirical strategy of this assumption, the federal tax rate is considered to be exogenous and lagged one period in the econometric model, to represent the movements of states' fiscal policy after observing the tax policy decision of the federal government. The states, in turn, are assumed to behave as Nash competitors in relation to one another in the federation, in a second stage of competition, after observing the fiscal policy decisions from the federal government. Estimation results are shown in [Table 3](#).

Table 4

Coefficient estimates of the predicted values for the Stackelberg Model as an explanatory variable in the Cournot–Nash Model.

Davidson–MacKinnon <i>J</i> test					
Null hypothesis: Cournot–Nash Model					
Matrix W1			Matrix W2		
Estimates	<i>t</i>	<i>Prob. > t</i>	Estimates	<i>t</i>	<i>Prob. > t</i>
–0.1585 (0.3386)	–0.47	0.64	–0.0411 (0.2876)	–0.14	0.886

Obs.: (1) Values in parentheses represent standard errors robust to heteroskedasticity and serial correlation; (2) the null hypothesis of the test is that the Cournot–Nash Model is correctly specified against the alternative hypothesis that the Stackelberg Model is the one correctly specified.

As one can see, the results in Table 3 are similar to those in Table 2. However, the magnitude of the reaction in this model is lower than in the previous case. This result corroborates the theoretical analysis developed by Boadway et al. (1998) and Keen (1998) about the federal government's position within the federation. The authors suggest that the federal government can eliminate some effects of vertical tax externality in the federation, behaving as a Stackelberg leader in setting its tax rates through appropriate fiscal policies. In this sense, the analysis of this result suggests that when states react with a delay to changes in the federal tax rate – with the federal government behaving as a Stackelberg type leader in setting its tax rates – the intensity of the vertical externality is lower than if these two governments acted simultaneously in setting their tax rates.

Regarding the estimates for the coefficient that measures the horizontal interaction in the model, the result is also similar to the case discussed in the previous section and all estimates for this coefficient are positive and statistically significant. The magnitude of the direction of states' reaction is also lower compared to the previous case. The interpretations of this analysis are analogous to the Nash case, as well as for other control variables of the model, which did not show significantly different results from the analysis conducted in the previous case.

4.3. Test of model selection: Cournot–Nash assumption \times Stackelberg assumption

The estimations of the two previous sections naturally bring about the question of which of the two models is the most appropriate to describe the vertical tax competition in Brazil. After all, both models estimated in Sections 4.1 and 4.2 are consistent with theoretical predictions. To determine how the setting of the state tax rates occurs, in relation to changes in federal tax rates, the *J* test methodology proposed by Davidson and MacKinnon (1981) was employed. First, the estimated values for the Stackelberg Model were computed, adding these values as an additional regressor in the Cournot–Nash Model. Then, this new regression was estimated, with the predicted values from the Stackelberg Model, and the significance of the estimated parameter for this variable was verified with the usual *t* test. The estimated parameters for this variable and their *t*-statistics are presented in Table 4.

The coefficients of the predicted values for the Stackelberg Model as an explanatory variable in the Nash Model are statistically insignificant in both weighting matrices employed. According to the *J* test procedure, these results point to the non-rejection of the Cournot–Nash Model. Following the procedure of the Davidson and MacKinnon *J* test, the roles of the hypotheses are reversed, i.e., the roles of the Cournot–Nash and Stackelberg models. The estimated values of the ICMS tax rate for the Nash Model are computed as a regressor in the Stackelberg Model, repeating the same methodology of the previous procedure. The results are shown in Table 5.

In both weighting matrices employed, the coefficients' significance tests of the predicted values for the Nash–Cournot Model as a regressor in the Stackelberg Model were statistically significant. This result suggests no rejection of the Cournot–Nash Model, to the detriment of the Stackelberg Model.

Therefore, the *J* test methodology suggested by Davidson and MacKinnon (1981) leads to the conclusion that the Cournot–Nash Model is the one that best explains the average behaviour of states in setting their tax rates with other states and with the federal government. This result suggests that when the federal government adjusts its tax rates, the states' response to this change occurs during the same year in which such change is made, with both government levels adjusting their tax rates simultaneously and together, as in a Cournot–Nash strategic game.

Table 5

Coefficient estimates of the predicted values for the Cournot–Nash Model as an explanatory variable in the Stackelberg Model.

Davidson–MacKinnon <i>J</i> test					
Null hypothesis: Stackelberg Model					
Matrix W1			Matrix W2		
Estimates	<i>t</i>	<i>Prob. > t</i>	Estimates	<i>t</i>	<i>Prob. > t</i>
1.3035 (0.2485)	5.24	0.0000	1.2743 (0.2319)	5.49	0.0000

Obs.: (1) Values in parentheses represent standard errors robust to heteroskedasticity and serial correlation; (2) the null hypothesis of the test is that the Stackelberg Model is correctly specified against the alternative hypothesis that the Cournot–Nash Model is the one correctly specified.

5. Conclusions

The main objective of this work was to estimate an average reaction function for the Brazilian states that expresses the effect of changes in federal tax rates on states' tax policy. The theoretical models, in general, suggest that states respond by changing their tax rates when the federal government changes its taxes over a tax base common to both government levels, demonstrating an inter-relationship between their tax policies. Given this possibility and considering that horizontal tax competition among states has an important role in setting state excise rates, two models were estimated with different specifications for the federal tax rate, whose parameter measures the strength and direction of the states' adjustment in relation to changes in the federal tax rates.

The first model estimated considers that states and the federal government set their taxes simultaneously and together in the federation, as in a Cournot–Nash strategic game. To represent this assumption in the specification of the empirical model, contemporary values of the federal tax rate were considered as a regressor in the states' reaction function. The results found in this model point to a positive and statistically significant reaction of the states in response to increases in federal government tax rates. That is, states increase their ICMS tax rates in response to increases in federal IPI tax rates.

The second model assumes that the federal government can behave as a Stackelberg leader in setting its tax rates within the federation. In the specification of the empirical model, the values of the federal tax rate lagged one period were used as a regressor in the states' reaction function to represent this assumption. Analogously to the previous case and again introducing horizontal tax competition as a relevant variable in the model, in all estimated regressions, a positive and statistically significant sign was found for this variable's coefficient, which measures the vertical interactions in the model.

However, when comparing the magnitude of the reactions, the absolute values found for this coefficient are smaller than the absolute values found in the previous model, where the government levels involved adjust their tax rates as in a Cournot–Nash strategic game. Regarding the variable that captures the effects of horizontal interaction among states, in both models considered, a positive and statistically significant relation was found for this variable's estimated coefficient when employing matrices W1 (contiguity) and W2 (Inverse Road Distance) as weights for the tax rates of competing states. This result suggests that geographically close states increase or decrease their ICMS tax rates in the same direction as other competing states. Considering the intensity of the effect of horizontal tax competition among states, it was also observed that the values obtained for the coefficient that measures the intensity and direction of this competition are larger in absolute value when the inverse road distance among the states is considered in relation to the contiguity criteria. It seems that states respond with greater intensity when they observe tax policy movements among all of the states involved than when they observe only the tax policies of bordering states.

Although many of the empirical studies consider that states and the federal government behave as in a Cournot–Nash strategic game in setting their tax rates, the theory admits that the federal government may also behave as a Stackelberg leader within the federation. Through the *J* test methodology proposed by Davidson and MacKinnon (1981), the assumption that states and the federal government behave as Nash competitors appears to be most consistent with the data considered in this analysis.

Therefore, the results found in this study point to the existence of vertical tax competition, in average terms, in which federal and state governments adjust simultaneously and together their tax rates, as in a Cournot–Nash game.

The result of this competition is generally over-taxation, at tax rates higher than optimal, of a given common base. This over-taxation can be explained in part by the revenue effect previously explained in this work, where the states respond by elevating their effective tax rates in response to an increase in federal tax rates, due to erosion of their bases and consequent losses of tax revenue. The results also suggest that tax policy movements of other states in the federation are an important variable in the adjustment of state taxes, suggesting the presence of horizontal tax competition among geographically close states.

Appendix.

Table 1A

IV-2SLS-GMM estimates for the states' reaction function with the exogenous federal tax rate at level – Cournot–Nash Model.

	Weighting matrices	
	Matrix W1	Matrix W2
Dependent variable: ICMS effective tax rate of state i ($taxicms_i$)		
Federal tax rate ($taxipi$)	0.5823* (0.3242)	0.4137*** (0.1549)
Weighted tax rate of states j ($taxicms_j$)	1.0544*** (0.3727)	1.5787*** (0.2981)
Population $\times 10^{-6}$ (pop)	−0.0007 (0.003)	0.0013 (0.0026)
Unemployment rate ($desemp$)	−0.0382 (0.0354)	−0.1117*** (0.0305)
Number of people employed $\times 10^{-6}$ ($popocup$)	−0.00008 (0.0036)	−0.00016 (0.0032)
Household income per capita $\times 10^{-3}$ ($Inrendpc$)	−0.0382** (0.016)	−0.0287** (0.0149)
Total expenditure per capita $\times 10^{-3}$ ($desptopc$)	0.0017 (0.0035)	0.0041** (0.0019)
Theil inequality index ($itheil$)	0.01901* (0.0104)	0.0159 (0.0107)
Poverty rate ($pobre$)	−0.0571*** (0.019)	−0.0187 (0.0189)
Current transfers per capita $\times 10^{-3}$ ($trcorrpc$)	−0.0026 (0.0043)	−0.0033 (0.0023)
Annual dummies	<i>No</i>	<i>No</i>
Sargan–Hansen J statistic	4.081	7.192
Chi-sq(8) p -value	0.3952	0.4092

Source: Own elaboration.

Observations: (1) Standard errors in parentheses are robust to heteroskedasticity and serial correlation; (2) Matrix W1: contiguity matrix among all states; Matrix W2: matrix of the inverse of road distances among states; (3) Endogenous variable: weighted tax rate of states; (4) Instrumental variables used: exogenous variables weighted by matrices W1 and W2 (population, unemployment rate, number of people employed, household income per capita, total expenditure per capita, Theil inequality index, poverty rate, current transfers per capita), the third lag of icms tax rate for Matrix W1, and the second lag of icms tax rate for Matrix W2.

* Significant at 10%.

** Significant at 5%.

*** Significant at 1%.

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