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Vertical versus horizontal tax externalities: An empirical test☆

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Abstract

We study taxation externalities in federations of benevolent governments. Where different hierarchical government levels tax the same base, one can observe two types of externalities: a horizontal externality, working among governments of the same level and leading to tax rates that are too *low* compared to the social optimum; and a vertical externality, working between different levels of government and leading to suboptimally *high* tax rates. Building on the model of Keen and Kotsogiannis [Keen, Michael J., Kotsogiannis, Christos, 2002. Does federalism lead to excessively high taxes? American Economic Review 92 (1) 363–370], we derive a discriminating hypothesis to distinguish vertical and horizontal tax externalities based on measurable variables. This test is applied to a panel data set on local taxes in a sample of Swiss municipalities that feature direct-democratic fiscal decision making, so as to maximize the correspondence with the "benevolent" governments of the theory. We find that vertical externalities

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dominate – they are thus an observed empirical phenomenon as well as a notable extension to the theory of tax competition.

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1. Introduction

Competition among governments vying for mobile tax bases is one of the most hotly debated economic policy issues. This debate concerns policy interactions both within and between countries, since tax competition can arise among nation states as well as among sub-national jurisdictions in federal countries. The standard "horizontal" view of tax competition among same-level governments is straightforward: competition for mobile tax bases induces a race to the bottom in the relevant tax rates, potentially resulting in inefficiently low provision of public goods and an inequitable reallocation of the fiscal burden towards immobile tax bases.[1]

A starkly different verdict is reached in a relatively recent literature on "vertical" tax externalities. Such externalities arise out of a common-pool problem among lower-level independent jurisdictions that tax the same base as the upper-level federal government. If production factors are mobile, taxes levied by lower-level jurisdictions affect the size of these jurisdictions' own tax base as well as that of the higher-level government. Yet, the lower-level authorities will not fully internalize the impact of their decisions on the size of the federal tax base, since their subjects only receive a fraction of the federation tax income. Assuming that tax setters seek to maximize the welfare of their own subjects, vertical tax externalities therefore imply tax rates that are too high relative to the social optimum.[2]

The direction of the distortion from uncoordinated tax setting with vertical externalities is thus exactly opposite to the standard horizontal paradigm. Our aim is to explore whether vertical tax externalities are a mere theoretical curiosity, or whether they can be identified empirically as a significant phenomenon.

On the face of it, there is good reason to believe that the scope for vertical tax interactions is expanding. Across the globe, fiscal policy responsibilities are becoming increasingly vertically fragmented. One tendency is to delegate tax policy from central governments to regional and local authorities.[3] The other tendency is for central governments' independence in fiscal matters to be increasingly circumscribed "from above", by international treaties and institutions. It therefore seems timely to look for evidence of vertical externalities by analyzing existing fiscal federations.

An empirical investigation of this issue faces three major challenges. First, a way must be found to identify the two types of externalities based on measurable variables. The structural parameters that determine the relative magnitude of horizontal tax externalities are inherently unobservable. We therefore derive a discriminating criterion based on a reduced form of a model featuring both types of externalities. In a nutshell, the reduced form we employ predicts that, other things equal, more

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[1] Wilson (1986) and Zodrow and Mieszkowski (1986) provide the seminal formal statements.

[2] Note that we focus on "bottom-up" vertical tax externalities, whereby interactions *among lower-level governments* are affected by the existence of a federal government. This differs from a definition of vertical tax externalities that focuses directly on the strategic interaction between lower-level and upper-level governments (see Keen, 1998, for a survey).

[3] In the words of Oates (1999), "fiscal decentralization is in vogue". For a quantification of the global tendency toward fiscal decentralisation, see Arzaghi and Henderson (2005).

fragmented federations (and thus smaller sub-federal jurisdictions) will have lower local tax rates if horizontal externalities dominate and higher local tax rates if vertical externalities dominate. Fragmentation, i.e. the number of sub-federal jurisdictions, is of course an observable variable.

Second, for the discriminating criterion to be estimable, an empirical setting is required that provides sufficient variation in the main explanatory variable, fragmentation. Although subfederal redistricting is not an uncommon occurrence, time-series variation in the number of subfederal jurisdictions of any particular country is unlikely to provide sufficient variation for an estimation of our discriminatory criterion. Cross-sectional regression analysis across federal countries in turn faces the formidable difficulty of controlling for all relevant constitutional and economic differences across these countries other than fragmentation, for the fragmentation effect to be estimable without bias. Our solution is to exploit the rich structure of the Swiss fiscal system. Switzerland is in fact a federation of federations: three hierarchically nested layers of government account for similar shares of total tax revenue and public spending, and they all enjoy a very high degree of autonomy in fiscal matters. Switzerland therefore provides an empirical setting of 26 autonomous federations (cantons) subdivided into different numbers of autonomous subfederal jurisdictions (municipalities) all taxing the same bases – exactly what we need to estimate the discriminating criterion.

The third challenge arises from the fact that the theoretical model assumes benevolent governments at subfederal level. This is critical, since introducing an element of revenue maximization into governments' objective function can destroy the one-to-one mapping of fragmentation effects to externality types exploited by our test. Unbiased estimation of the discriminating criterion therefore requires that the data be generated in a context of benevolent tax setting at the subfederal level. In this respect too, the specificities of the Swiss system make this a particularly conducive laboratory. Specifically, we can exploit the fact that a considerable number of municipalities submit all decisions on local taxes to direct-democratic scrutiny, be it through a compulsory vote by town-hall assemblies of the entire citizenry, or through voluntary referenda that can be initiated by citizens on every proposal by municipal executives to change local taxes. By focusing on municipalities that set taxes in such direct-democratic fashion, we can base our empirical analysis on a setting that corresponds well to the theoretical framework.

Our results suggest that, in our dataset, the effects of vertical externalities dominate those of horizontal externalities. Vertical externalities are therefore more than a theoretical curiosity and deserve to be considered systematically in discussions of tax competition and tax coordination among sub-federal jurisdictions.

The paper is organized as follows. In the following section, we provide a selective overview of the relevant literature. Section 3 develops the discriminating hypothesis theoretically. Section 4 provides a brief description of the Swiss fiscal constitution and of our data set. The empirical results are reported in Section 5. Section 6 offers a concluding discussion.

2. Literature background

The literature on *horizontal* tax competition is vast, but the main insight is straightforward: with horizontal externalities, uncoordinated governments will set tax rates that are suboptimally low in both efficiency and equity terms.[4] The literature on *vertical* tax

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[4] Horizontal tax competition can be welfare improving if it acts as a constraint on revenue-maximizing "Leviathan" governments (Brennan and Buchanan, 1980) or on rent-seeking private interest groups (Sato, 2003). This paper focuses throughout on governments acting as benevolent social planners.

competition analyzes fiscal externalities among different hierarchical layers of federations. Its most prominent result is that lower-level jurisdictions may have an incentive to overtax relative to the social optimum, even if all tax setters are social-welfare maximizers.[5]

However, federal political structures do not necessarily imply overtaxation, even if we abstract from horizontal tax competition as a potential counterweight. As shown by Boadway et al. (1998), it may be possible for the higher-level jurisdiction (the "federation") to correct for externalities that distort the tax decisions of lower-level jurisdictions ("states"), if the federal government acts as a Stackelberg leader. In a model with multiple tax bases, Hoyt (2001) finds that it may even be possible for the federal government to correct for the vertical externality in a simultaneous-move Nash game with the lower-level jurisdictions. The distortion-correcting power of the federation government, however, relies on strong assumptions, namely that the federal government has complete information and that it fully controls vertical transfers between government levels. Finally, Dahlby and Wilson (2003) present a model where the vertical externality can result in suboptimally *low* state-level tax rates. A key element of their model is the assumption that taxes are levied *ad valorem* and that rents on immobile tax bases are fully taxed, which can imply that federal revenues increase in state-level tax rates. While the effect they identify implicitly hinges on a change in the composition of tax rates across tax bases, our empirical analysis is primarily concerned with across-the-board shifts in tax burdens.

In view of the contrasting consequences of horizontal and vertical externalities, it is natural to enquire about the conditions for dominance by one or the other of these forces. In a federation with a given relative size of federal and state governments (determined in turn by citizens' preferences for federal and local public goods), the balance between horizontal and vertical externalities is determined, on the one hand, by the elasticity of the federation-wide tax base relative to the consolidated federation tax rate, and, on the other hand, by the elasticity of the state tax base relative to the state tax rate. Keen and Kotsogiannis (2002) show that the strength of vertical externalities increases in the tax elasticity of the federation tax base and decreases in the tax elasticity of the state tax base. In addition, the importance of vertical externalities increases in the size of the federal government relative to the total (federal plus lower-level) government sector. Whether equilibrium tax rates are too high or too low depends therefore on the two tax-base elasticities and on the relative government sizes.[6]

The tax-base elasticities are of course essentially unmeasurable, which is why we take an alternative route to identify the two types of tax externalities based on observable variables. Although our resulting empirical test has no precedent in the literature, there exist a number of related empirical studies, which fall into four broad categories.

First, a sizeable empirical literature documents horizontal interactions among tax-setting authorities (for a survey, see Brueckner, 2003). This work confirms the existence of significant fiscal "reaction functions" among jurisdictions, both inter- and intra-nationally. Linking these empirical results to particular theoretical priors, however, is difficult. The problem is that non-zero slopes for interjurisdictional tax reaction functions are consistent

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[5] Vertical externalities can yield inefficiently high tax rates also if sub-federal governments act as Leviathans (Keen and Kotsogiannis, 2003).

[6] An exception arises where the states fully tax rents on immobile factors before taxing the mobile factor. In that case, the horizontal externality always dominates (Proposition 2 in Keen and Kotsogiannis, 2002).

with a number of theoretical explanations, of which horizontal tax competition is but one.[7] In our context, it is interesting to note Revelli's (2003) finding that what could appear to reflect horizontal fiscal interdependencies among sub-national jurisdictions may in fact to a large extent be driven by vertical interdependencies, i.e. common reactions to the fiscal policy of a higher-level fiscal authority. Our focus is not on the strategic interaction between federal and subfederal tax setters, but Revelli's (2003) result shows that in studying interactions among same-level governments one may not safely ignore the existence of higher-level governments. This strand of the literature furthermore highlights the desirability of theory-based discriminating hypotheses.

Second, a number of authors have explored vertical interactions in tax policies of hierarchically nested governments. Besley and Rosen (1998), who studied excise taxes, and Esteller-Moré and Solé-Ollé (2001), who looked at personal income and general sales taxes, found that US state taxes historically reacted positively to increases in federal taxes. Analyzing Canadian income taxes, Esteller-Moré and Solé-Ollé (2002) have also discovered a positive response of provincial tax rates to changes in the federal tax rate. This suggests that tax rates of upper-level and lower-level jurisdictions are strategic complements. Other studies, however, found the opposite relationship. Studying local and central-government income taxes in a panel of OECD countries, Goodspeed (2000) concluded that higher central-government tax rates lead to lower local income tax rates. Similarly, Hayashi and Boadway (2001) found that provincial corporate tax rates in Canada respond negatively to the federal tax rate. Finally Devereux et al. (2004) have detected no significant relationship between federal and state excise taxes in the United States. The seeming inconsistency of empirical results is in fact not surprising, since the sign of the relationship is theoretically ambiguous (for discussions, see Besley and Rosen, 1998; Keen and Kotsogiannis, 2002). What matters to us is that a statistically significant relationship among central and lower-level tax rates was found in most previous studies, which confirms that the existence and behavior of a tax-base co-occupying central authority significantly affects the tax-setting behavior of lower-level jurisdictions.

Third, our empirical specification bears close resemblance to those applied in several prior studies which, following Oates (1985), estimated the relationship between government expenditure and measures of sub-federal jurisdictional fragmentation (for a survey, see Feld et al., 2002). These estimations were historically interpreted as tests of the Leviathan hypothesis. However, in models of horizontal tax competition, tax rates fall in the degree of fragmentation even with benevolent governments; and, in models featuring vertical externalities, the relationship between government size and fragmentation could be *positive* even in a federation of Leviathan governments (Keen and Kotsogiannis, 2003). Hence, Oates-style regressions need to be reinterpreted against the background of recent models of fiscal federalism and estimated in an appropriate empirical context. Our study, while bearing superficial resemblance to this literature, is couched in a rigorous theoretical framework and based on a specifically chosen empirical setting that provides a particularly pure representation of the institutional structure assumed by the theory.

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[7] Some authors have devised ways of narrowing down the range of possible explanations for observed fiscal interdependencies. For instance, Besley and Case (1995), combine the estimation of reduced-form reaction functions with the estimation of structural equations arising from a model of "yardstick competition", thereby overcoming the identification problem. Büttner (2003) tests for horizontal tax competition by estimating interjurisdictional dependencies of tax bases as well as tax rates.

Fourth, the decentralized structure of the Swiss fiscal system has been exploited before for research on tax interactions. Most similar in spirit to our study, Feld et al. (2002) have regressed government revenues of sub-federal jurisdictions (the sum of cantonal and municipal revenues) on the fragmentation of cantons. They find no statistically significant effect of fragmentation on total tax revenue, but some evidence of a negative effect on revenue from income taxes. The main differences between their study and ours are that we derive and apply an alternative estimating specification; and that, in keeping with the theory, we estimate fragmentation effects on tax *rates* of the lowest-level fiscally autonomous jurisdictions (*municipalities*), retaining only those with direct-democratic fiscal systems.[8]

3. Derivation of a discriminating hypothesis

3.1. The model: horizontal and vertical externalities in an "international" setting

Assume a federation consisting of a central government and $N>1$ identical sub-federal states. In each state j, a single firm produces a private good according to a concave production function $F(K_j)$, using capital K_j as the only input.[9]

Due to free capital mobility inside the federation, capital earns a unique post-tax return ρ. The central and state governments tax capital at a consolidated rate $\tau_j = T + t_j$, where T is the central government's unit capital tax rate and t_j denotes the state's unit capital tax. Normalizing the price of the private good to one, the profit maximizing condition $F'(K_j) = \rho + \tau_j$ implies the demand for capital in each state:

$$K_j = K(\rho + \tau_j),$$

with $K'(\rho+\tau_j) = 1/F''(K_j) < 0$.

We define the state-level rent, $\pi(\rho+\tau_j)$, as the difference between the value of production and the cost of capital:[10]

$$\pi(\rho + \tau_j) = F[K(\rho + \tau_j)] - (\rho + \tau_j)K(\rho + \tau_j). \tag{1}$$

In addition to the private good, there exist two distinct publicly provided goods (which, although specific to each state, we shall refer to as "public goods"): states provide g_j, financed through t_j, and the central government uses T to finance G. G and g_j express spending per state,

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[8] Research on Swiss data has furthermore confirmed that tax rates of sub-federal Swiss jurisdictions do affect the corresponding tax bases. Kirchgässner and Pommerehne (1996) and Feld and Kirchgässner (2001) show that a jurisdiction's share of residents belonging to a particular income class responds with the expected negative sign to the relevant tax rate. Not surprisingly, this effect is most pronounced for high-income individuals. Similar evidence is produced in Feld and Kirchgässner (2003), who document a negative relationship between corporate tax rates on employment and firm numbers. Finally, Feld and Matsusaka (2003) find that constraints on the fiscal autonomy of cantonal executives matter, since cantons with stronger direct-democratic controls over fiscal matters have significantly lower levels of public spending. This result suggests that cantonal executives do have a taste for public expenditure that is higher than the level preferred by the citizenry.

[9] Our model is a variant of the framework developed by Keen and Kotsogiannis (2002). We use their notation where possible, in order to facilitate comparability. Note that K does not necessarily represent capital but could in principle stand for any mobile factor (and tax base). For example, if the model were interpreted in terms of taxes on personal income, the rate of return (ρ) would mean wages, and the "investable endowment" (e) would mean available working time. We return to this issue in Section 5.3.

[10] Note that we have $\pi' = -K$.

taxes are spent exhaustively on the respective public goods, and public goods are produced with constant returns. The governments'. budget constraints can be written as

$$g = t_j K(\rho + \tau_j),$$

$$G = \frac{1}{N}\sum_j TK(\rho + \tau_j). \tag{2}$$

Each state is populated by a large number of identical residents. We assume that the mass of residents in each state is equal to one. Residents are endowed with identical stocks of investable capital, e. Capital can be invested within the federation (S_j), where it provides the stock of capital for the productive sector ($\sum_j S_j = \sum_j K_j$), or in the rest of the world (ROW). Inward investment by ROW residents is assumed to be zero.[11] Returns on investment are given by ρ^* for the ROW and by ρ for the federation. For simplicity, and without loss of generality, we normalize ρ^* to zero. Thus, ρ will take negative values if after-tax returns in the federation are lower than in the ROW.[12] Rents accruing in state j are distributed equally among residents. Individuals derive utility from investment income and from public goods. We assume that they perceive income from domestic and foreign investment as imperfect substitutes. Specifically, we assume the following aggregate indirect utility function for state j:

$$U_j = (e - S_j) + u[(1+\rho)S_j + \pi(\rho + \tau_j)] + \Gamma(g_j; G),$$

where $u(\cdot)$ and $\Gamma(\cdot)$ are strictly increasing concave functions.

Indirect utility is linear in ROW investment income and concave in home income, which implies a degree of "home bias" in capital allocation.[13]

Maximizing utility with respect to S_j, and using the rent function (1) and the government budget constraints (2), we can write the indirect utility function for state j as

$$\begin{aligned} W_j = {} & (e - S(\rho,\tau_j)) + u[(1+\rho)S(\rho,\tau_j) + \pi(\rho+\tau_j)] \\ & + \Gamma\left[t_j K(\rho+\tau_j);\ \frac{1}{N}\sum_j TK(\rho+\tau_j)\right]. \end{aligned} \tag{3}$$

The post-tax rate of return ρ in the federation is determined by the capital-market clearing condition

$$\sum_j S(\rho,\tau_j) = \sum_j K(\rho+\tau_j), \tag{4}$$

which implies the effect of a change in state j's tax rate on ρ:

$$\frac{\partial \rho}{\partial t_j} = -\frac{S_\tau - K'}{\sum_j (S_\rho - K')}. \tag{5}$$

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[11] This is an assumption of convenience. Two-way investment flows complicate the model without changing our qualitative results.

[12] In order to have positive K in equilibrium, we assume that $(\rho+\tau_j)>0$.

[13] Our "international" framework differs from the intertemporal setting of Keen and Kotsogiannis (2002). The main change is that we switch the concave part of the utility function to the investment destination that is of interest (the domestic economy in our case, the second period in theirs). One implication is that, quite realistically but unlike the Keen–Kotsogiannis model, capitalists' investment decision function depends on tax rates.

If we impose symmetry of state tax rates, such that $t_j = t$, $\forall j$, then

$$\frac{\partial \rho}{\partial t} = -\frac{S_\tau - K_j'}{S_\rho - K_j'} = N \frac{\partial \rho}{\partial t_j} \in [-1,0),$$

where the last equation holds if all regions are identical.

State governments are assumed to be benevolent in the sense that they maximize the welfare of their own subjects, but they do not take into account the effect of their actions on residents of other states. This behavior, combined with the fact that the two levels of government tax the same base, gives rise to the two potential externalities, horizontal and vertical.

The first-order condition of the government in state j, evaluated at a symmetric equilibrium, is given by

$$E \equiv \left.\frac{\partial W_j}{\partial t_j}\right|_{t_j = t} = -\frac{K}{(1+\rho)} + \Gamma_g \left[K + tK'\left(\frac{\partial \rho}{\partial t_j} + 1\right)\right] + \Gamma_G \left[TK' \frac{\partial \rho}{\partial t_j} + \frac{T}{N} K'\right] = 0. \tag{6}$$

Condition (6) implicitly determines the (symmetric) equilibrium state tax rate. Furthermore, we define W as indirect utility under symmetry of tax rates; so that, taking the derivative of W with respect to the (symmetric) state tax rate, we obtain

$$W_t = -\frac{K}{(1+\rho)} + \Gamma_g \left[K + tK'\left(\frac{\partial \rho}{\partial t}\right) + 1\right] + \Gamma_G \left[TK'\left(\frac{\partial \rho}{\partial t} + 1\right)\right]. \tag{7}$$

Setting Eq. (7) to zero implicitly defines the *socially* optimal state tax rate for a given federal tax rate. More generally, the expression indicates the effect on social welfare of a small symmetric change in the equilibrium state tax rate. Thus, if states play Nash and the equilibrium outcome is determined by (6), W_t indicates which externality dominates. In a situation where W_t, evaluated at equilibrium, is positive, a slight increase in all state taxes would increase social welfare, and state taxes are therefore too low from a social viewpoint. Conversely, if W_t is negative, state taxes are too high.

We can rewrite Eq. (7) in a more easily interpretable form. Subtracting (6) from (7) and introducing notation for the elasticity of utility with respect to the supply of public goods (ε_g and ε_G), we obtain:

$$W_t = -\frac{K'}{K} \Gamma \left(1 - \frac{1}{N}\right) \left[-\varepsilon_g \frac{\partial \rho}{\partial t} - \varepsilon_G \left(\frac{\partial \rho}{\partial t} + 1\right)\right]. \tag{8}$$

The term in square brackets determines whether equilibrium state taxes are too high or too low, the first term being unambiguously positive (the negative sign of K' cancels the initial negative sign). The term $-\varepsilon_g \frac{\partial \rho}{\partial t}$, which is positive since $\frac{\partial \rho}{\partial t} < 0$, represents the horizontal externality. Conversely, the vertical externality is represented by $-\varepsilon_G \left(\frac{\partial \rho}{\partial t} + 1\right) < 0$.

Expression (8) allows us to identify the determinants of the different tax externalities. The two determinants are (i) the elasticities of the public goods in the utility function (ε_g and ε_G), and (ii) the sensitivity of the rate of return to changes in the state tax rates $\left(\frac{\partial \rho}{\partial t}\right)$, which in turn depends on the elasticities of demand and supply of capital (see (5)). Loosely speaking, vertical externalities are more likely to dominate the greater is the utility share of the federal public good, and the higher is the sensitivity of capital to relative returns between the federation and the outside world compared to relative returns among states inside the federation. Fig. 1 illustrates these forces. The

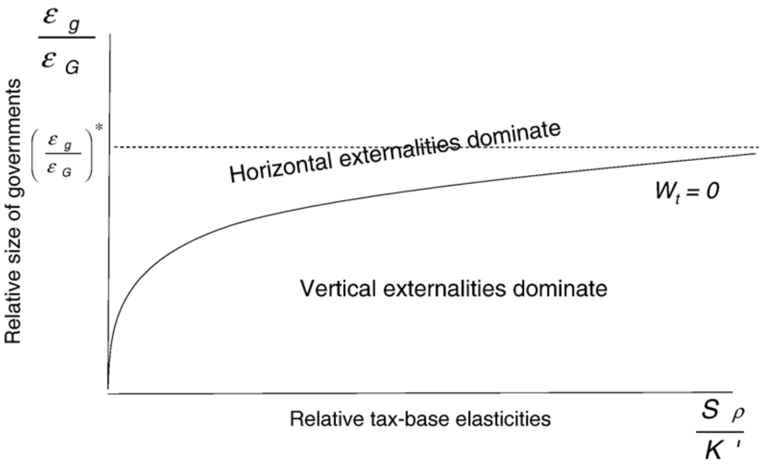

Fig. 1. Parameter ranges for dominance of vertical/horizontal externalities.

boundary for which $W_t=0$ is drawn in the space $\left(\frac{\varepsilon_g}{\varepsilon_G};\ -\frac{S_\rho}{K'}\right)$. All parameter configurations above the boundary imply dominance of horizontal externalities, and the area below the boundary is characterized by dominant vertical externalities. There exists a threshold ratio on public good preferences $\left(\frac{\varepsilon_g}{\varepsilon_G}\right)^*$ above which horizontal externalities dominate regardless of relative capital sensitivity.

Given (8), equilibrium state taxes could be either too high or too low. The model yields unambiguous predictions only in some special cases. For example, if we assume that the federation is a small open economy, such that $\rho=\rho^*$, then one state's tax decision will not affect the supply of capital available to other states.[14] In this case, only vertical externalities exist. On the other hand, if the federation exists in autarky, so that the federation supply of capital is completely inelastic ($S=\overline{S}$), then state tax policies do not affect the federation tax base, and thus only horizontal externalities exist ($W_t>0$). In configurations that fall between these polar cases, the sign of W_t can be positive or negative, depending on which externality dominates.

It is important to note that expression (8) and all our subsequent derivations do not rely on assumptions about the determination of the federal tax rate. In fact, expression (8) holds irrespective of whether the federal government sets taxes simultaneously with the states in a Nash game or sequentially in a Stackelberg game. Obviously, however, (8) provides no indication of whether overall taxes (τ) are too high or too low.

3.2. The discriminating hypothesis

Given their starkly different implications for equilibrium tax rates, it is of evident interest to distinguish between horizontal and vertical externalities empirically. The problem is that the relevant structural parameters defining ε_g, ε_G and $\frac{\partial \rho}{\partial t}$ are unobservable. We therefore seek a reduced form of the model that is based on observables yet allows to distinguish rigorously between dominance of horizontal externalities and dominance of vertical externalities. We show

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[14] In order to fix $\rho=\rho^*$, the model would have to allow for capital inflows.

that the relationship between the number of states (N) and the equilibrium tax rate provides us with such a discriminating hypothesis.

Based on the equilibrium condition for state tax rates (6), we can compute the effect of a change in the number of states on the equilibrium tax rates as

$$\frac{\partial t_j}{\partial N} = -\frac{\partial E/\partial N}{\partial E/\partial t} \equiv -\frac{E_N}{E_t}. \tag{9}$$

The denominator E_t is analytically involved and cannot be signed *a priori*. Keen and Kotsogiannis (2004) justify E_t being negative by resorting to some additional assumptions. We have conducted extensive simulations, detailed in Appendix A, which confirm that E_t is negative in an overwhelming majority of parameter configurations.

Thus, we accept that $E_t < 0$ and concentrate on the numerator E_N, which, from (6), is given by

$$E_N = -\frac{1}{N^2}\Gamma_g tK'\frac{\partial \rho}{\partial t} - \frac{1}{N^2}\Gamma_G TK'\left(\frac{\partial \rho}{\partial t} + 1\right).$$

Hence,

$$E_N = -\frac{1}{N^2}\frac{K'}{K}\Gamma\left[\varepsilon_g\frac{\partial \rho}{\partial t} + \varepsilon_G\left(\frac{\partial \rho}{\partial t} + 1\right)\right].$$

Using (8), we can rewrite this expression as

$$E_N = -\frac{1}{N(N-1)}W_t.^{15} \tag{10}$$

Hence, the effect of an increase in the number of states is inversely related to the balance between horizontal and vertical externalities expressed by W_t. This, together with (9), implies the discriminating hypothesis expressed in the following proposition.

Proposition 1. *In symmetric equilibrium with dominant horizontal externalities ($W_t > 0$) the state tax rate decreases in the number of states. Conversely, in symmetric equilibrium with dominant vertical externalities ($W_t < 0$) the state tax rate increases in the number of states.*

Proposition 1 is illustrated in Figs. 2 and 3. We show the effect of an increase in the number of states on W_t for different relative elasticities of federal capital supply and state capital demand (details on the underlying simulations are given in Appendix A). In Fig. 2, each solid line (labeled $W_t(\varepsilon_G)$) represents W_t for different capital supply and demand elasticities. When ε_G increases, $W_t=0$ holds for lower values of the ratio of elasticities, which implies that a higher utility weight of the federation public good expands the domain of dominant vertical externalities. The dashed lines in the figure represent the effect on W_t of an increase in N relative to the base case of the solid line, and the dotted lines illustrate the effect of a decrease in N. We observe that changes in N pivot W_t around the point where neither externality dominates ($W_t=0$). Hence, when horizontal

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[15] Although the underlying models are not identical, this expression turns out to be exactly the same as expression (32) in Keen and Kotsogiannis (2004).

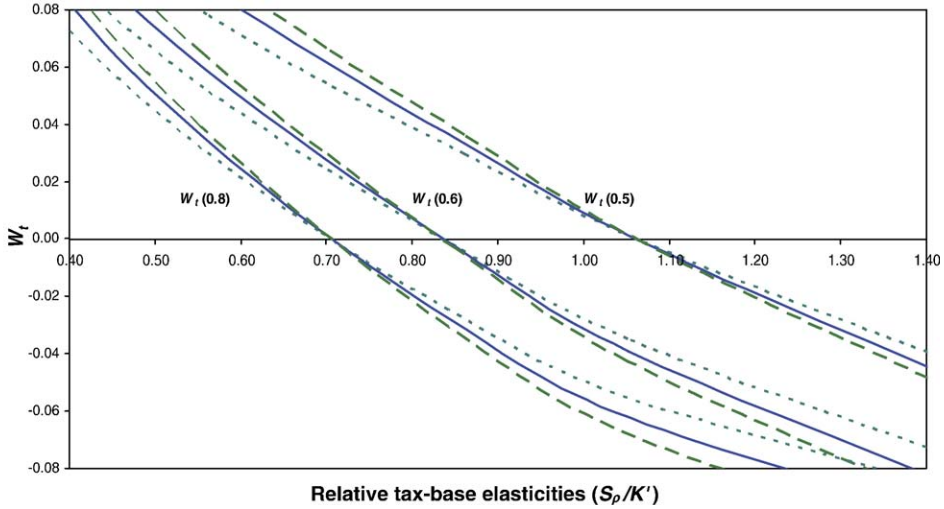

Fig. 2. Relative tax-base elasticities, tax distortions, and fragmentation. Assumed functional forms are described in Appendix A. Parameter values are: $A=B=5$, $\varepsilon_g=0.2$, $T=0.21$. $W_t(x)$ implies $x=\varepsilon_G$. Variation in the relative size of government is obtained by changing α. Solid lines: $N=10$, dotted lines: $N=5$, dashed lines: $N=50$.

externalities dominate ($W_t>0$), an increase in N reinforces the externality (and lowers the equilibrium state tax rate).[16] Conversely, when vertical externalities dominate ($W_t<0$), an increase in N leads to even stronger vertical externalities (and raises the equilibrium state tax rate). These relationships, via (10), imply Proposition 1. Fig. 3 presents a similar illustration for the second determinant of W_t, the relative size of state and federal governments (implied by the ratio of utility elasticities of state and federal public goods, $\frac{\varepsilon_g}{\varepsilon_G}$). We represent the relationship for different curvatures of the assumed state-level production function $F(K_j)$. Again, we observe that increases in N increase $|W_t|$, i.e. they exacerbate the dominant externality.

Our Proposition offers a ready base for empirical analysis. Equilibrium condition (6) implies that, *ceteris paribus*, the equilibrium state tax (t_j) is a function of two observable variables, the federation tax rate (T) and the number of states (N):

$$t_j = f(N,T)|_{\text{utility fn, production fn}} \tag{11}$$

Our Proposition states that the sign of $\frac{\partial t_j}{\partial N}$ reflects dominance of horizontal or vertical externalities. There is no theoretical prior on the sign of $\frac{\partial t_j}{\partial T}$, which represents the tax reaction function between state and federation governments. Whether the tax rates of hierarchically nested government levels are strategic substitutes or complements is therefore an empirical issue (see, e.g., Besley and Rosen, 1998).

3.3. From theory to an empirical model

According to Proposition 1, the sign of $\frac{\partial t_j}{\partial N}$ reflects the relative dominance of horizontal and vertical externalities. The basic empirical task is therefore straightforward: regress t_j on N.

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[16] This feature of the model mirrors the well known result that small countries compete more vigorously for mobile tax bases and thus set lower tax rates than large countries in models of purely horizontal tax competition (Bucovetsky, 1991, 2004; Wilson, 1991).

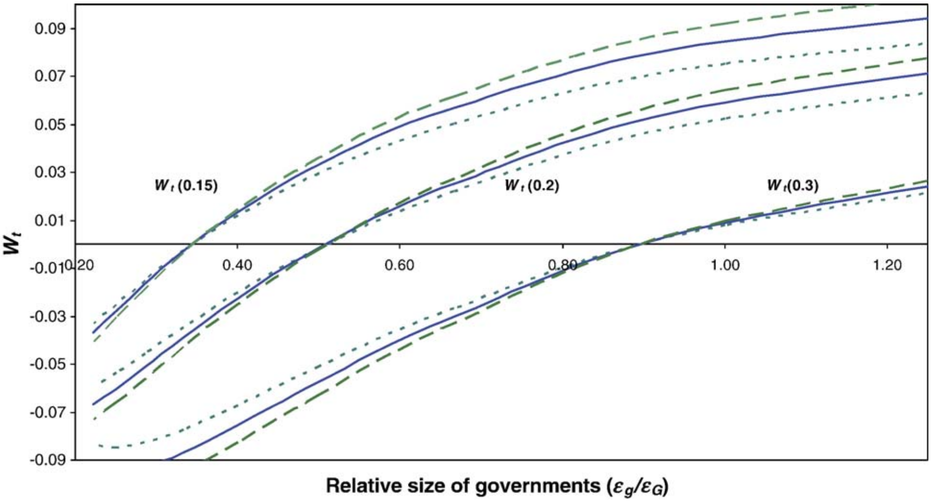

Fig. 3. Relative government sizes, tax distortions, and fragmentation. Assumed functional forms are described in Appendix A. Parameter values are: $A=B=5$, $\varepsilon_g=0.2$, $T=0.21$. $W_t(x)$ implies $x=\alpha$. Variation in the relative size of government is obtained by changing ε_G. Solid lines: $N=10$, dotted lines: $N=5$, dashed lines: $N=50$.

However, when taking expression (11) to data, we need to impose further structure. Theory provides no guidance as to the appropriate functional form. The natural starting point is a linear additive specification:

$$t_j = \beta_0 + \beta_1 N + \beta_2 T + u_j, \tag{12}$$

where u is a stochastic error term.

A number of additional estimation issues need to be addressed. We discuss them in turn.

3.3.1. Multiple federations

The theoretical model features a single federation in static equilibrium. Identification of the parameters in Eq. (12), however, requires varying observations not just on t_j but also on N and T. One approach would be to use *time-series data on a single federation*. Since changes in the definition of sub-federal administrative regions are rare and, when they do occur, mostly marginal, *comparison across multiple federations* is a considerably more promising source of observable variation in N. We work with a panel of the 26 Swiss cantons (the “federations” in our data) comprising varying numbers of municipalities (the “states” in our data). We use the subscript i to denote cantons.

3.3.2. Fragmentation of federations with asymmetric states

What is the empirical counterpart of N? Our theoretical model features symmetric states and identical state taxes in Nash equilibrium. If these assumptions were to hold in reality, the empirical strategy would be to estimate Eq. (12) by regressing federation-level averages of t_j on N and T. However, municipalities have different sizes, they set different tax rates, and they differ in numerous relevant respects other than size. Therefore, we estimate Eq. (12)

municipality-by-municipality.[17] From the municipalities' point of view, a high N in a symmetric federation implies that each municipality is small. Hence, we express fragmentation as a municipality-specific variable "smallness", $n_{ij}=1-s_{ij}$, where s_{ij} is the population share of municipality j in its corresponding canton i. We show in Appendix B that $\mathrm{d}n_j$ is a valid proxy for $\mathrm{d}N$.

Our empirical strategy thereby implies taking a theoretical result which is based on symmetric jurisdictions to a world featuring asymmetric jurisdictions. While the symmetry assumption buys substantial analytical simplification, the basic mechanisms underlying the two externalities do not depend on it. In terms of the vertical externality, what matters directly to the state-level government's calculation is s_{ij}, its own share of the federation's population and thus of federal expenditure, and not the fragmentation among the remaining states. In other words, an autonomous state government places less weight on the federal government the smaller its size relative to the federation, irrespective of how many other states there are. Second, in terms of the horizontal externality, it has been shown that the symmetric tax competition result (larger $N \Rightarrow$ lower equilibrium t) carries over to asymmetric settings (larger $n_{ij} \Rightarrow$ lower equilibrium t_{ij}).[18]

Furthermore, cantons and municipalities are likely to differ in structural parameters affecting T_i and t_{ij} , such as preferences for central and local public goods, federal and local tax-base elasticities, and taxation of immobile factors. Therefore, we control for relevant cantonal and municipal characteristics that impact on equilibrium tax rates in addition to fragmentation, by including relevant municipality-specific and canton-specific explanatory variables.

Our estimating equation thus becomes:

$$t_{ij} = \delta_0 + \delta_1 n_{ij} + \delta_2 T_i + \mathbf{X}_{ij}\gamma + v_{ij}, \tag{13}$$

where $\mathbf{X}$ is a row vector of exogenous controls, and γ is a vector of parameters. The elements of $\mathbf{X}$ can be specific to j or to i.

A potentially important issue concerning δ_1, our main parameter of interest, is the argument of Zax (1989) that small jurisdictions might have to set higher tax rates than large jurisdictions because of scale economies in public goods provision. This argument points towards a positive relation between equilibrium tax rates and fragmentation, ceteris paribus. Hence, we include the size of municipalities among the controls $\mathbf{X}$. With increasing returns to scale, the expected sign of the coefficient on this variable is negative.

3.3.3. Endogenous federation tax rate

As discussed above, our discriminating hypothesis is independent of how the federation government sets its tax rate. Yet, equilibrium federation and state tax rates will of course be interdependent. In addition, since T_i is not independent of N_i (and therefore of n_{ij}), we cannot

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[17] While it might seem more intuitive to regress the mean state tax rate on a number that reflects the fragmentation of the federation and on federation-level averaged controls, such an empirical approach would be inefficient, as it would discard intra-federation information. This inefficiency would be particularly acute in our context, as, given the considerable heterogeneity of municipal decision-making systems even within cantons, identification of cantons with predominantly "benevolent" municipalities would be highly arbitrary.

[18] See, e.g., Bucovetsky (1991, 2004) and Wilson (1991).

Table 1
Sources of municipal and cantonal tax revenue, 1985 and 2000

Tax base	Municipalities				Cantons			
	1985		2000		1985		2000	
	Revenue	%	Revenue	%	Revenue	%	Revenue	%
Private income	8296	73.9	14,283	70.6	10,418	64.2	19,536	68.5
Wealth	690	6.1	1723	8.5	895	5.5		
Corporate inc.	1122	10.0	2378	11.8	1767	10.9	4742	16.6
Capital	350	3.1	458	2.3	547	3.4		
Other taxes	764	6.8	1384	6.8	2640	16.1	4234	14.8
Total	11,222	100.0	20,226	100.0	16,237	100.0	28,512	100.0

Nominal revenues for all Swiss municipalities/cantons in million francs. “Other taxes” include mainly property, gift and inheritance taxes. Breakdown of personal and corporate tax revenues of cantons not available for 2000. Source: Federal Finance Administration.

estimate Eq. (12) consistently without including T_i. We address the endogeneity of T_i via two-stage least squares estimation.[19]

3.3.4. *Benevolent state governments*

Our discriminating hypothesis is derived in a model with benevolent governments. As shown by Keen and Kotsogiannis (2003), revenue maximization by state governments works toward lower state tax rates as fragmentation increases. Hence, with Leviathan governments estimated coefficients on n_{ij} are biased downward. In order to avoid such bias against the vertical externalities hypothesis, we restrict the empirical analysis to municipalities that set taxes via direct-democratic political processes.

4. Taxation in a federation of federations: Switzerland as a “fiscal laboratory”

4.1. *The Swiss fiscal constitution*

Switzerland has a highly decentralized constitution featuring three jurisdictional levels (federal, cantonal and municipal) that account for roughly similar shares of the total tax take.[20] Cantons and municipalities raise taxes on four main bases: corporate income and capital, personal income, and wealth. Table 1 shows that personal income is by far the most important tax base, accounting for well over 70% of municipal tax revenue. Corporate taxes account for around 13%

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[19] Furthermore, one might suspect that the theoretical model warrants inclusion of an interaction term between T and N. This turns out not to be the case. In our model, the federation government will maximize W with respect to T to obtain

$$\begin{aligned} W_T|_{t_j=t} &= -\frac{K}{(1+\rho)} + \Gamma_g tK'\left(\frac{\partial p}{\partial t}+1\right) + \Gamma_G \frac{1}{N}\sum_j \left[K + TK'\left(\frac{\partial p}{\partial t}+1\right)\right] \\ &= -\frac{K}{(1+\rho)} + \Gamma_g tK'\left(\frac{\partial p}{\partial t}+1\right) + \Gamma_G \left[K + TK'\left(\frac{\partial p}{\partial t}+1\right)\right] = 0, \end{aligned}$$

which depends on N only via t (such that $t=f((T|t),N)$).

[20] According to the OECD, “the Swiss Confederation is more decentralized than any other OECD country” (Carey et al., 1999, p. 5). The revenue shares of the central, cantonal and municipal governments have remained at a stable 30, 40 and 30 percent respectively over the 1980s and 1990s (Feld et al., 2002).

of municipal tax revenue. Similar orders of magnitude apply for the allocation across tax bases of cantonal revenue (Table 1).

Five features of the Swiss fiscal constitution bear close resemblance to the theoretical setting within which we derived Proposition 1 and thereby make it a uniquely suited setting for an empirical test:

1. *Multiple comparable federations*. The three-tier Swiss fiscal hierarchy includes 26 federations (cantons) with different numbers of states (municipalities). Cantons and municipalities are relatively similar in many respects that affect their locational attractiveness – an implication of the smallness of Switzerland– and they tax almost perfectly identical bases. Furthermore, there is little spending specialization across municipalities: most municipalities are "general purpose" governments, with largely similar spending duties. Yet, cantons and municipalities differ significantly in terms of the tax rates and schedules they apply. The highest tax rate in our sample of municipal corporate income taxes is more than six times higher than the lowest comparable tax rate. At the cantonal level, the highest tax rate (Geneva) is more than seven times higher than the lowest one (Schwyz). For personal income taxes the range is somewhat narrower, but the highest rates still exceed the lowest rates by up to five times (see Fig. 4 for an illustration).
2. *Fiscal autonomy*. There are virtually no restrictions on the tax-setting powers of sub-national jurisdictions. Each of the 26 cantons has its own tax laws, defining 26 different sets of tax schedules. Based on the legally defined basic tax rates, cantonal and municipal authorities autonomously set multipliers that define effectively applied tax rates.[21]
3. *Small vertical and horizontal transfers among jurisdictions*. Federal statistics show that, summed across all jurisdictions and averaged over our sample years, net vertical transfers from cantons to municipalities constituted 1.9% of municipal revenue, while net horizontal transfers among municipalities corresponded to 3.6% of municipal revenue.
4. *Overlapping tax bases*. Within each canton, tax bases are identical for cantonal and municipal taxes, since they are defined by the cantonal tax laws. In addition, tax bases are very similar even across cantons, since the information used to calculate national taxes is taken from the tax forms filled in to report to the cantonal authorities, which imposes a certain degree of uniformity in the definition of tax bases. Since 2001, tax bases for direct taxes have been harmonized across cantons by federal law. Most municipalities set a single multiplier that shifts the cantonal tax schedule within and across all tax bases. Hence, the progressivity of tax schedules is the same for municipal and cantonal taxes in a majority of cases.[22] This arguably implies that municipal decision makers focus the choice of their multiplier on tax bases (and certain brackets thereof) with the largest impact on revenue, i.e. personal income taxes (see Table 1).
5. *Direct democracy*. Municipalities differ considerably in terms of the direct democratic constraints they impose on the fiscal discretion of their elected executives. A significant number of municipalities take decisions on tax rates through a vote of the entire citizenry. This institutional setting provides a close empirical counterpart to the social-welfare

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[21] The fiscal constitutions of some cantons constrain municipal tax-setting autonomy. We control for this in the estimations.

[22] To be precise, this system applies in 92 of our 103 sample municipalities. The remaining eleven municipalities enjoy some discretion over tax schedules across tax bases.

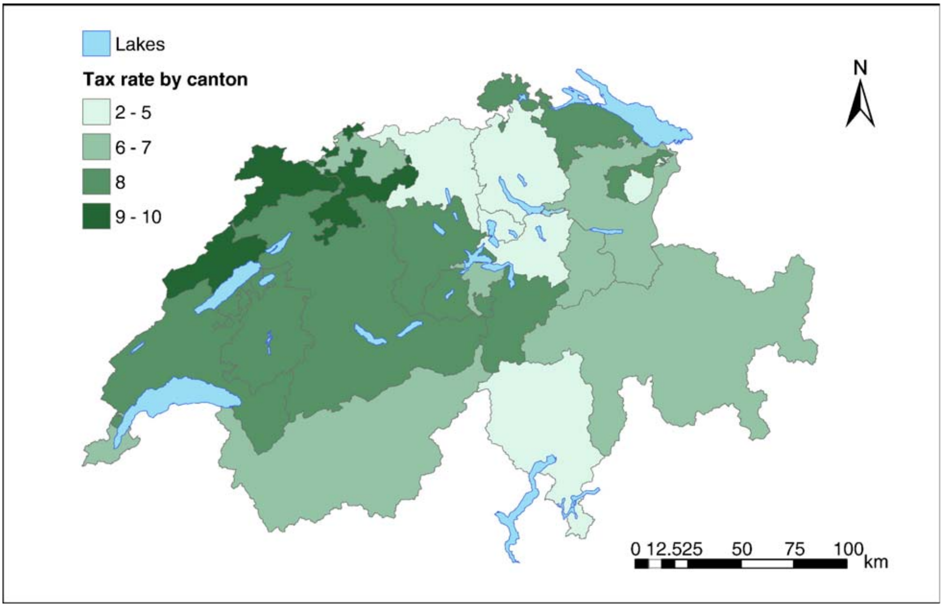

Fig. 4. Variation in sub-federal tax rates across Swiss cantons. Sum of cantonal and municipal tax rates on representative median-income household in 2001. Municipal tax rates are taken for capital town in each canton.

maximizing decision makers assumed in the underlying theory, and we therefore restrict the analysis to municipalities that feature direct-democratic fiscal decision making.

4.2. Data

One implication of the decentralized Swiss governance structure is that comparable data on municipalities are hard to come by. For the purpose of this study, we have assembled a panel data set of municipal and cantonal tax rates for the years 1985, 1991, 1995, 1998 and 2001. The "*assembly*" sample contains the 38 largest municipalities (distributed across 15 cantons) that set taxes via a show of hands at an annual assembly of all resident Swiss citizens. The "*referendum*" sample contains the 103 largest municipalities (distributed across 23 cantons) whose fiscal constitutions feature compulsory or voluntary referenda for decisions on tax rates. The assembly sample is contained in the referendum sample. All municipalities in our data set therefore feature direct-democratic controls on local tax decisions, and, for obvious reasons, direct democracy can be considered particularly strong in the assembly subsample.[23]

4.2.1. The dependent variable: sub-national tax rates

Our data set is unique in providing information on personal as well as corporate sub-national taxes. Since most municipalities do not decide their tax rates individually for different

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[23] We are grateful to Lars Feld for the generous provision of the data on municipal decision making. These data are based on a survey conducted in the mid-1990s.

tax bases, but instead set a single multiplier on the cantonal tax schedule, our main focus is on a revenue-weighted average of standardized versions of the nine tax variables. We refer to this aggregate as the "*tax index*".[24] Both municipal and cantonal tax indices have mean zero by construction.

The tax index is constructed on the base of effective cantonal and municipal tax rates for a set of representative tax payers. We chose a set that is small enough to be manageable but large enough to represent the progressivity of tax schedules. Using ANOVA, we found that a set of nine tax variables is sufficient to capture most of the variance in tax schedules across jurisdictions. These nine variables are as follows:

- *Personal income taxes* (3 variables). Personal income tax schedules are based on income and family status (single, married, number of children). We collected income tax rates for a median-income single household, for a median-income married household with two children, and for a high-income married household with two children. High income is defined as the average income of households in the highest reported statistical category, which is bounded below by a taxable annual income of 200,000 Swiss francs (≈140,000 U.S. dollars).
- *Personal wealth taxes* (2 variables). Personal wealth taxes follow a progressive schedule in most cantons. Therefore, we collected tax rates for a person with taxable wealth of 200,000 francs and of 5 million francs (≈3.6 million dollars), respectively.
- *Corporate income taxes* (3 variables). Swiss corporate income taxes are generally based on firms' profitability and capital. ANOVA showed that the main contribution to the variance in corporate income tax rates comes from profitability. We therefore collected tax rates for median-capital firms with profits amounting to 2%, 9% and 32%, respectively, of capital. The chosen profitability values represent first sextile, median and fifth sextile profitability values for Swiss firms over our sample period.
- *Corporate capital taxes* (1 variable). We included the corporate capital tax rate applicable to a firm with median capital stock, since most cantons levy proportional capital taxes.

Table 2 provides summary statistics for our sample tax rates. We can appreciate the considerable variance in tax rates across cantons and municipalities (see also Fig. 4). It is furthermore evident that the main tax schedules (on personal income and corporate income) exhibit significant progressivity.

4.2.2. Independent variables

The main variable for our discriminating hypothesis is *fragmentation*. As discussed above, the federation-specific N of the theoretical model with a single symmetric federation is represented by n_{ij} in the empirical model that features multiple federations composed of asymmetric states. We define the *smallness* of a municipality relative to its canton as $n_{ij} = 1 - \frac{P_{ij}}{P_i}$, where P_{ij} is the population of municipality j in canton i, and P_i is the respective cantonal population. For the population measures, we consider only residents with Swiss citizenship, since what we seek to represent is municipalities' political weight in the canton.

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[24] Standardization consists of mean-differencing and division by the sample standard deviation for each tax variable. Within each tax category, tax variables are weighted equally. Hence, for example, the three tax rates on personal income all enter the index with a weight of 1/3 times the share of personal income taxes in total tax revenue.

Table 2
Summary statistics (referendum sample)

Variable	Observations	Mean	S.D.	Municipal or cantonal with min.	Municipal or cantonal with max.
Municipality-level variables					
Tax index	507	0.00	0.86	Freienbach (SZ)	Le Locle (NE)
Personal income tax rate					
Single, median inc.	512	4.26	1.13	Freienbach (SZ)	Le Locle (NE)
Married, median inc.	512	3.68	1.18	Freienbach (SZ)	Le Locle (NE)
Married, high inc.	512	10.60	2.44	Freienbach (SZ)	Amriswil (TG)
Personal wealth tax rate					
*Wealth=CHF*200,000	512	0.13	0.07	Baar (ZG)	Glarus (GL)
*Wealth=CHF*5,000,000	512	0.31	0.06	Freienbach (SZ)	Solothurn (SO)
Corporate income tax rate					
2% profitability	507	3.67	1.60	Herisau (AR)	(*Several*)
9% profitability	507	5.06	1.81	Freienbach (SZ)	Porrentruy (JU)
32% profitability	507	7.35	2.44	Freienbach (SZ)	Solothurn (SO)
Corporate capital tax rate	507	0.20	0.09	Baar (ZG)	Glarus (GL)
Smallness	512	0.93	0.08	Schaffhausen (SH)	Nidau (BE)
Population	512	19,769	24,195	Appenzell (AI)	Genève (GE)
Share of population under 20	512	0.17	0.04	Renens (VD)	Einsiedeln (SZ)
Share of population over 65	512	0.19	0.03	Volketswil (ZH)	Zollikon (ZH)
Area (ha)	512	1927	2788	Nidau (BE)	Davos (GR)
Urban center dummy	512	0.40	0.49	(*Several*)	(*Several*)
Distance to freeway (km)	512	4.44	7.44	Morges (VD)	St. Moritz (GR)
Distance to airport (km)	512	50.66	32.39	Meyrin (GE)	St. Moritz (GR)
Lake shore (m)	512	2185	4503	(*Several*)	Einsiedeln (SZ)
Canton-level variables					
Tax index	512	0.00	0.88	Schwyz	Geneva
Latin dummy	512	0.27	0.45	(*Several*)	(*Several*)
Harmonized-tax dummy	512	0.21	0.41	(*Several*)	(*Several*)
Urbanized population	512	368,479	312,097	(*Several*)	Zürich
Area (ha)	512	228,616	200,429	Appenzell (AI)	Graubünden

Tax rates in percent. Municipalities in the canton of Appenzell Innerrhoden do not levy corporate taxes.

A range of control variables are included in all estimated equations (see Table 2 for summary statistics).

- As stipulated by our theoretical model, we have to control for the respective *cantonal tax rates*. These tax rates are instrumented via two-stage least squares with three identifying canton-level variables: the canton population living in urban areas, the area of the canton, and the total number of municipalities in the canton.
- Since the empirical model, unlike the theory, allows for heterogeneity at municipal level, and since municipal tax rates may therefore be interdependent in asymmetric fashion, we also run some estimations that include *canton-averaged municipal tax rates* (not counting the relevant municipality itself) as an additional regressor. These tax rates are instrumented via two-stage least squares using the averaged municipality-level exogenous variables as identifying instruments.
- A number of regressors are chosen to control for differences in municipalities' public revenue needs. *Municipal population* controls for potential increasing returns in public goods

production. A negative coefficient on this variable would be consistent with increasing returns. The share of *population over 20* and the share of *population over 65* are included as proxies of dependency ratios, and thus of demands on local budgets for education, health care and social security. In turn, a positive coefficient on municipal *area* might imply that public goods provision becomes costlier if required to cover a bigger area. Note that the area of municipalities in Switzerland is positively correlated with the mountainousness of their topography, which adds further demands on public infrastructure. Finally, we include a dummy for municipalities that represent *urban centers*, to account for the fact that these municipalities often supply particular center-related public goods such as cultural facilities or inner-city policing.

- Further variables are included to control for differences in municipalities' locational attractiveness, and thus their inherent appeal to potential tax payers. We include the following variables: *distance to the nearest freeway*, *distance to the nearest international airport*, *and length of lake shore within the municipality.*
- In keeping with existing empirical work on fiscal policy in Switzerland, a dummy for the *Latin* (i.e. French and Italian speaking) cantons picks up attitudinal differences between those cantons and the German speaking majority.
- Additional canton dummies are included to control for certain institutional idiosyncrasies. Although most municipalities enjoy complete autonomy in setting their tax rates, there are some exceptions. Five of the 26 cantons have *harmonized municipal tax rates* on corporate income and capital, whilst leaving municipalities' freedom to set personal taxes unconstrained. We therefore include a dummy that equals one for the relevant cantons and taxes.[25]

5. Empirical results: horizontal and vertical tax competition in Switzerland

5.1. Smallness and average tax rates

We estimate municipality-level regressions of Eq. (12) for the tax index. The results are presented in Table 3. In order to facilitate interpretation and comparison of estimated coefficients, all non-dichotomous variables are expressed in natural logs, and all parameter estimates are also reported as standardized (beta) coefficients. Standard errors are based on robust estimated covariance matrices, with municipality-level clustering to account for correlation within municipalities across time.[26]

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[25] We deliberately do not include canton fixed effects, since such fixed effects would pick up most of the variability in T_i and thus introduce endogeneity bias. However, some institutional idiosyncracies require additional controls. We include a dummy for the canton of Geneva, which features joint taxation and a special revenue sharing arrangement between cantonal and municipal authorities; for the canton of Uri, which is unique in featuring a proportional municipal personal income tax schedule; and for the canton of St. Gallen, which has a unique municipal corporate tax schedule. Since they only apply to corporate taxes, the dummy for cantons with harmonized municipal tax rates and the dummy for St. Gallen are dropped from the regressions for personal taxes. Conversely, the dummy for the canton of Uri is dropped from the regressions for corporate taxes. We include all these dummies in the regressions for the tax index.

[26] To ignore intertemporal correlation within municipalities results in considerably (but misleadingly) smaller estimated standard errors. It might be considered interesting to distinguish effects due to time variation from those due to cross-section variation in n_{ij}. The relatively small intertemporal variability of n_{ij}, however, makes it difficult to identify any statistically significant effects from the time variation in the data alone. More fundamentally, this distinction is unlikely to be of primary importance, because time-series and cross-section variability in smallness have qualitatively equivalent implications for the incentives faced by tax setters and thus for the identification of the parameter of interest.

Table 3
Tax index regressions, panel

Dependent variable= municipal tax index	Assembly sample	Referendum sample	Assembly sample	Referendum sample	Assembly sample (interior)	Referendum sample (interior)
Smallness	3.29 **	0.12	3.02 ***	0.26	7.74 *	0.28
	(0.24)	(0.01)	(0.22)	(0.03)	(0.61)	(0.03)
	1.55	0.44	0.98	0.23	4.53	0.47
Canton tax index (instrumented)	0.73 ***	0.63 ***	0.31 **	0.24 *	0.50 *	0.44 **
	(0.60)	(0.65)	(0.26)	(0.25)	(0.41)	(0.45)
	0.13	0.16	0.13	0.14	0.26	0.20
Avg. tax index of other municipalities in cantons (instrumented)	(*n.a.*)	(*n.a.*)	0.66 ***	0.78 ***	(*n.a.*)	(*n.a.*)
			(0.50)	(0.65)		
			0.20	0.12		
Population of municipality	−0.28	−0.23 **	−0.22 **	−0.10 *	−0.95 *	−0.22 *
	(−0.09)	(−0.17)	(−0.07)	(−0.07)	(−0.31)	(−0.17)
	0.21	0.11	0.13	0.06	0.56	0.12
Share of municipal population <20	0.41	−0.05	0.73 **	0.05	−0.08	−0.20
	(0.09)	(−0.01)	(0.15)	(0.01)	(−0.02)	(−0.05)
	0.42	0.25	0.32	0.18	0.43	0.25
Share of municipal population >65	−0.71 **	−0.28	−0.33	−0.32 *	−0.41	−0.06
	(−0.15)	(−0.06)	(−0.07)	(−0.07)	(−0.09)	(−0.01)
	0.34	0.28	0.27	0.20	0.35	0.31
Area of municipality	0.19 **	0.18 **	0.17 **	0.13 ***	0.27 ***	0.20 **
	(0.17)	(0.19)	(0.15)	(0.14)	(0.29)	(0.23)
	0.09	0.08	0.07	0.05	0.09	0.08
Urban center dummy	0.65 ***	0.46 ***	0.45 ***	0.25 ***	0.93 ***	0.43 ***
	(0.36)	(0.26)	(0.25)	(0.14)	(0.54)	(0.24)
	0.15	0.11	0.11	0.08	0.19	0.13
Distance to freeway	0.11	−0.05	0.08	−0.01	0.08	−0.07
	(0.08)	(−0.05)	(0.06)	(−0.01)	(0.06)	(−0.08)
	0.14	0.05	0.11	0.03	0.18	0.06
Distance to airport	0.58 ***	0.37 ***	0.18	0.09	0.50 **	0.29 ***
	(0.48)	(0.36)	(0.15)	(0.08)	(0.43)	(0.29)
	0.14	0.09	0.18	0.07	0.24	0.09
Lake shore	−0.01	−0.02 *	−0.02	−0.01	−0.05 *	−0.04 **
	(−0.05)	(−0.09)	(−0.10)	(−0.05)	(−0.26)	(−0.17)
	0.02	0.01	0.02	0.01	0.03	0.01
Latin dummy	−1.91 ***	−0.57 ***	−1.13 ***	−0.17	−1.72 ***	−0.37 **
	(−0.36)	(−0.30)	(−0.21)	(−0.09)	(−0.40)	(−0.20)
	0.26	0.18	0.27	0.13	0.31	0.18
Harmonized-tax dummy	0.06	−0.86 ***	0.03	−0.34 ***	−0.20	−0.91 ***
	(0.03)	(−0.40)	(0.01)	(−0.16)	(−0.10)	(−0.40)
	0.19	0.15	0.09	0.10	0.19	0.17
Geneva dummy	(*n.a.*)	−1.68 ***	(*n.a.*)	−0.53	(*n.a.*)	−1.60 ***
		(−0.53)		(−0.16)		(−0.52)
		0.36		0.36		0.41
Uri dummy	−1.41 ***	−1.06 ***	−0.31	−0.24	−0.18	−0.85 ***
	(−0.26)	(−0.12)	(−0.06)	(−0.03)	(−0.04)	(−0.11)
	0.41	0.24	0.43	0.23	0.92	0.27
St. Gallen dummy	0.37 **	1.52 ***	−0.04	0.53 **	0.17	1.62 ***
	(0.14)	(0.48)	(−0.01)	(0.17)	(0.06)	(0.41)
	0.18	0.19	0.19	0.22	0.33	0.26
Number of observations	185	507	185	507	130	392
R^2	0.79	0.73	0.80	0.82	0.77	0.73

Table 3 (*continued*)

Dependent variable= municipal tax index	Assembly sample	Referendum sample	Assembly sample	Referendum sample	Assembly sample (interior)	Referendum sample (interior)
Hansen *J* statistic	3.58	3.86	6.55	17.43	5.71	2.97
	0.17	0.15	0.59	0.04	0.06	0.23
1st-stage *F* for cantonal tax	17.73	19.16	97.57	45.69	12.76	19.18
1st-stage *F* for municipal tax	(*n.a.*)	(*n.a.*)	637.95	102.58	(*n.a.*)	(*n.a.*)

Beta coefficients in parentheses, standard errors below. Year dummies and intercept included in all regressions. All non-dichotomous variables are in natural logs. Two-stage least squares regressions, with cantonal tax indices instrumented using as instruments all exogenous regressors, plus canton population living in urban areas, canton area, canton number of municipalities, and (for the regressions 3 and 4) canton averages of all municipality-specific variables. Standard errors and first-stage *F* statistics based on robust covariance matrices, clustered by municipality. Hansen *J* statistics calculated without Uri (both samples) and Latin (assembly sample) dummies due to insufficient degrees of freedom; *P* values below.

* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

Tax rates on the right-hand side of the regression model are instrumented via two-stage least squares. We report Hansen's *J* statistic for overidentifying restrictions (Sargan test). Rejection of the null hypothesis through this test suggests misspecification – most likely due to violation of the orthogonality condition for the chosen instruments.[27] In addition, we report *F* statistics on the identifying instruments of the first-stage regressions as a test of instrument quality.

The first data column of Table 3 presents results from the baseline regression in the *assembly sample* of municipalities (i.e. those featuring the most direct system of citizen participation in tax setting). The estimated coefficient on *smallness* is positive and statistically significant at the 95% confidence level. This, our main result, supports the vertical-externalities hypothesis: municipalities that account for a smaller share of cantonal population have higher tax rates, other things equal.

The second data column of Table 3 reports results for an equivalent regression in the larger *referendum sample* of municipalities. Again we find a positive coefficient on smallness, but this coefficient is by an order of magnitude smaller and no longer statistically significant. Conforming with our priors, the dominance of vertical externalities is weakened as we incorporate municipalities with less immediate forms of direct democracy (and hence greater scope for a self-inflating public sector).

An augmented version of the baseline model, including also the average tax rate of other municipalities in the same canton, yields the same finding: *smallness* raises municipal taxes in the assembly sample but has no statistically significant effect in the referendum sample (see the middle two columns of Table 3).[28]

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[27] We have also run every regression using the two-step efficient generalized method of moments estimator. Since our findings remained substantially unaffected, we chose to report standard instrumental variables regressions. All results mentioned but not shown are of course available on request.

[28] Our results differ significantly from those found by Devereux et al. (2004). Estimating the determinants of cigarette and gasoline taxes across US states, they observe that the national tax rate loses most of its "explanatory power" once the tax rate of neighboring states is introduced as an (instrumented) control. This suggests that vertical tax externalities are particularly strong in Switzerland.

Can we have confidence in these results? Our estimations appear largely plausible, and, with R^2 values ranging from 0.73 to 0.82, the model succeeds in explaining a large share of the variation in municipal tax rates.

The theory explicitly suggests inclusion of the federation tax rate as an explanatory variable, even though it gives us no prior on the sign of the coefficient (see Eq. (11)). We find that the estimated coefficients on instrumented *cantonal* tax indices are statistically significantly positive in both samples. The related instrument diagnostic tests are satisfactory. Inclusion of neighboring municipalities' tax rates reduces the estimated impact of cantonal tax rates, but does not render them statistically insignificant. The coefficients on neighboring municipalities' tax rates are positive and significant as well. Our findings thus suggest that municipal and cantonal taxes, and municipal taxes among each other, are strategic complements – in line with the bulk of existing results on fiscal reaction functions.

One might suspect the apparent complementarity of municipal and cantonal taxes to be driven by an omitted variable, municipal income. Indeed, if tax authorities target a certain level of revenue per capita, then municipal and cantonal tax rates will co-move in opposite direction to cantonal incomes. We have explored this issue by including cantonal income as an additional regressor. Our verdict from this was not to include cantonal income for the remainder of the analysis, because (i) inclusion of cantonal income in principle raises additional concerns about simultaneity issues, because (ii) the coefficient on this variable was never found to be significant, and because (iii) the estimated coefficients on any of the remaining regressors were not affected significantly.

Of the regressors that we include to control for municipalities'. revenue needs, we find that coefficients on *area* and *urban center* have the expected positive sign and are statistically significant throughout. The magnitudes are considerable. The coefficient on *urban center* in the referendum sample in the baseline specification, for example, implies that city-center municipalities have tax rates that are 58% ($=100*(e^{0.46}-1)$) higher than other municipalities, other things equal. Estimated coefficients on *population*, however, are negative. This lends some support to the hypothesis of increasing returns of public goods provision formulated e.g. by Zax (1989).[29] Whilst there is some evidence that the share of *population under 20* raises municipal tax rates, the estimated impact of *population over 65* is negative. It thus seems that the net effect on municipal finances of population above retirement age is positive.

As for the three locational attractiveness variables, we find some evidence that average taxes rise in *distance to the nearest international airport*, while *lake shore* and *distance to the nearest freeway* have no discernible effect. Finally, where the coefficient estimates are precisely measured, our evidence suggests that municipalities in *Latin* cantons, and those in cantons with *harmonized municipal tax rates*, apply lower average tax rates.[30] The finding that harmonization of municipal tax rates has a rate-lowering impact may be considered as further corroboration of the vertical-externalities hypothesis.

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[29] We also experimented with a quadratic *population* term, and found no economically larger or statistically significant effect.

[30] The relatively low tax rates found for municipalities in Latin cantons may seem surprising, given that the Latin cantons on average have larger public sectors than their German-speaking counterparts. The main explanation is that Latin cantons on average have a lower ratio of municipal to cantonal tax burdens.

5.2. Robustness

We subject the baseline results of Table 3 to a number of robustness checks, which we present in the last two columns of Table 3, and in Tables 4 and 5. Our main finding, the positive coefficient on the *smallness* variable in the assembly sample, turns out to be robust. We investigate four issues.

First, we address the fact that our baseline specification, just like the theoretical model, considers horizontal tax interactions solely within the federation (i.e. within cantons), thus assuming implicitly that externalities from fiscal decisions taken outside the federation are identical across the federation. This ignores intra-cantonal geography. Cross-canton externalities will likely be particularly strong for those municipalities that border another canton, if the border in question crosses a functional economic region. Hence, we re-run the estimations only on those municipalities that we define as "interior". Interior municipalities are defined as those that do not share a land border with any municipality that lies in another canton but belongs to the same functional economic area (as defined by the Swiss Federal Statistical Office on the basis mainly of commuting patterns and the contiguity of built-up areas).[31] Concentrating on interior municipalities reduces the size of the assembly sample by 30% and that of the referendum sample by 23%. The results are reported in the last two columns of Table 3. The qualitative findings do not change: the coefficients on smallness remain positive for both the assembly and the referendum sample, suggesting dominant vertical externalities, and all other statistically significant coefficients retain their signs. The coefficients on smallness are larger in the "interior" sub-samples than in the baseline estimations, which is consistent with the view that horizontal interactions are stronger for border municipalities. Conversely, one might expect the effect of the cantonal tax rate to be stronger for interior municipalities, but we in fact observe it to be somewhat weaker. We cannot, therefore, claim to have fully controlled for municipalities'. different sensitivity to conditions in other cantons, but to the extent that concentration on interior municipalities does reduce the importance of cross-canton externalities, it confirms the robustness of our baseline results.

Second, we estimate the model separately for each year. To convey a representative impression of those estimations, we report results for our first and last sample year (1985 and 2001) in Tables 4 and 5. We find that the positive coefficient on smallness applies throughout our sample period and in fact has become appreciably stronger over time. Our results therefore suggest that the dominance of vertical externalities became stronger over our sample period. Our estimates for the remaining regressors are reassuringly similar across sample years.

Third, we take account of the possibility that municipal tax rates are spatially correlated for reasons that are not captured by the model (which features a number of spatially correlated regressors and thereby in itself explains spatial correlation in municipal tax rates). The first step is to compute spatial autocorrelation tests, via Moran's I, on the regression residuals.[32] While we cannot reject the null hypothesis of zero spatial autocorrelation of the residuals in the assembly sample, this is not true for the referendum sample. We thus seek to reestimate the model in a way

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[31] The Swiss Federal Statistical Office identifies 48 functional economic areas consisting of multiple municipalities ("agglomerations"). It is interesting to note that the political boundaries of cantons cross the boundaries of those functional areas relatively rarely. For instance, only 10% of the municipalities in the referendum sample belong to a functional economic area whose urban center is in another canton. Cantons and functional economic areas therefore largely overlap, which offers some justification for focusing on intra-cantonal tax externalities.

[32] The verdict on spatial autocorrelation remains unchanged when we compute the Moran statistic with distance cutoff values larger than our default of 15 km.

Table 4
Tax-index regressions for individual years: assembly sample

Dependent variable = municipal tax index	2SLS		Spatial GMM		OLS	
	1985	2001	1985	2001	1985	2001
Smallness	1.24	5.67**	1.26	6.04***	1.36	5.65**
	(0.12)	(0.32)	(0.12)	(0.34)	(0.13)	(0.32)
	1.75	2.52	1.24	1.83	1.47	2.27
Cantonal tax index (instrumented)	0.55***	0.84***	0.55***	0.76***	0.53***	0.84***
	(0.54)	(0.64)	(0.54)	(0.59)	(0.52)	(0.65)
	0.13	0.29	0.09	0.17	0.14	0.23
Population of municipality	−0.06	−0.50	−0.05	−0.47*	−0.06	−0.50
	(−0.02)	(−0.12)	(−0.02)	(−0.11)	(−0.03)	(−0.12)
	0.25	0.36	0.17	0.25	0.23	0.35
Share of municipal population under 20	0.64	0.40	0.70**	0.52	0.63	0.40
	(0.21)	(0.05)	(0.23)	(0.07)	(0.21)	(0.05)
	0.43	0.96	0.28	0.67	0.42	0.96
Share of municipal population over 65	−0.86**	−0.77	−0.81***	−0.68**	−0.84**	−0.78
	(−0.19)	(−0.14)	(−0.18)	(−0.13)	(−0.18)	(−0.14)
	0.39	0.54	0.24	0.32	0.39	0.54
Area of municipality	0.02	0.39**	0.02	0.36***	0.02	0.39**
	(0.02)	(0.27)	(0.02)	(0.25)	(0.02)	(0.27)
	0.10	0.14	0.07	0.10	0.10	0.16
Urban center dummy	0.49**	0.77**	0.51***	0.77***	0.49***	0.77**
	(0.36)	(0.33)	(0.38)	(0.33)	(0.36)	(0.33)
	0.17	0.32	0.12	0.19	0.17	0.33
Distance to freeway	0.02	0.25	0.02	0.25	0.02	0.25
	(0.02)	(0.14)	(0.02)	(0.15)	(0.02)	(0.14)
	0.17	0.28	0.12	0.17	0.17	0.28
Distance to airport	0.63***	0.52*	0.60***	0.52***	0.63***	0.52*
	(0.70)	(0.33)	(0.67)	(0.33)	(0.70)	(0.33)
	0.16	0.25	0.11	0.19	0.15	0.26
Lake shore	−0.01	−0.03	−0.01	−0.04	−0.01	−0.03
	(−0.05)	(−0.13)	(−0.05)	(−0.14)	(−0.06)	(−0.13)
	0.02	0.04	0.01	0.03	0.02	0.04
Latin dummy	−1.46***	−2.17***	−1.44***	−2.16***	−1.46***	−2.17***
	(−0.37)	(−0.31)	(−0.36)	(−0.31)	(−0.36)	(−0.31)
	0.22	0.53	0.17	0.42	0.23	0.52
Harmonized-tax dummy	0.17	−0.10	0.16	−0.07	0.17	−0.10
	(0.11)	(−0.04)	(0.10)	(−0.03)	(0.11)	(−0.04)
	0.21	0.33	0.16	0.25	0.21	0.33
Uri dummy	−1.86***	−0.21	−1.83***	−0.10	−1.83***	−0.21
	(−0.47)	(−0.03)	(−0.46)	(−0.01)	(−0.46)	(−0.03)
	0.44	0.79	0.34	0.55	0.41	0.71
St. Gallen dummy	0.00	0.51	0.00	0.43	−0.01	0.51
	(0.00)	(0.15)	(0.00)	(0.13)	(−0.01)	(0.15)
	0.18	0.37	0.13	0.27	0.15	0.37
Number of observations	37	37	37	37	37	37
R^2	0.84	0.77	0.83	0.78	0.84	0.77
Hansen *J* statistic	5.49	0.94	0.78	1.43		
	0.06	0.63	0.64	0.49		

Table 4 (*continued*)

Dependent variable= municipal tax index	2SLS		Spatial GMM		OLS	
	1985	2001	1985	2001	1985	2001
F statistic of 1st-stage regression	10.58	17.98	15.75	36.52		
Moran *I* statistic of residuals	0.04	0.06			0.03	0.06
	0.33	0.25			0.34	0.25

Beta coefficients in parentheses, standard errors below. Intercept included in all regressions. All non-dichotomous variables are in natural logs. 2SLS and spatial GMM: cantonal tax indices are instrumented using all exogenous regressors, plus canton population living in urban areas, canton area and canton number of municipalities as instruments. Spatial GMM: based on Conley (1999), with neighborhood distance cutoff of 15 km. Standard errors and first-stage *F* statistics based on robust covariance matrices. Hansen *J* statistics calculated without Uri and Latin dummies due to insufficient degrees of freedom; *P* values below. Moran *I* statistic calculated using 15 km distance bands and a binary distance weighting matrix; *P* values below.

* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

that is consistent and efficient also in the presence of spatial error correlation. Since we do not want to forego instrumenting the cantonal tax rate, we apply the spatial GMM estimator proposed by Conley (1999), which permits structural estimation with a covariance matrix that implies a distance weighting within a certain neighborhood. Neighborhood in turn is defined as applying to all municipalities located within a certain radius of the municipality in question. Distances are Euclidean, and municipalities' centroids are taken as the "steeple" definition from the Swiss statistical office. We report results for neighborhood distance cutoffs of 15 km, but we found them to be very robust to changing this threshold. Our findings, given in the fourth and fifth columns of Tables 4 and 5, are easily summarized: estimation via spatial GMM returns essentially the same results, as our baseline 2SLS estimations, with somewhat larger estimated coefficients on *smallness*.[33] Spatial error correlation therefore does not appear to affect our estimates and inference fundamentally, and taking it into account strengthens our main result.

Fourth, we estimate our structural model with OLS, thereby ignoring the potential endogeneity of cantonal tax rates. The results are presented in the final two columns of Tables 4 and 5. In both samples we find that the OLS estimates are very similar to the 2SLS estimates, even concerning the coefficient on cantonal tax rates. This suggests that the strategic complementarity of municipal and cantonal tax rates is two-directional: municipalities on average react to higher cantonal tax rates by raising their own tax rate, and cantonal governments react to higher municipal tax rates by raising the cantonal tax rate. We note that, even in the referendum sample, OLS estimation yields estimated coefficients on *smallness* that are positive, although not statistically significant. The finding that municipal tax rates increase in *smallness* is not therefore driven by the model we adopt to instrument for the cantonal tax rate (but obvious concerns over the endogeneity of cantonal tax rates lead us to prefer the 2SLS estimates).

5.3. Smallness and tax rates on different tax bases

We find robustly positive coefficients on smallness in our regressions of the *tax index*, which is a revenue-weighted average of tax rates on a set of representative tax bases. Even though the

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[33] This finding also applies to the panel regressions of Table 3.

Table 5
Tax-index regressions for individual years: referendum sample

Dependent variable= municipal tax index	2SLS		Spatial GMM		OLS	
	1985	2001	1985	2001	1985	2001
Smallness	0.62	0.19	0.70	1.39 *	0.11	0.24
	(0.80)	(0.02)	(0.06)	(0.14)	(0.01)	(0.02)
	0.45	0.51	0.46	0.76	0.55	0.52
Cantonal tax index (instrumented)	0.28 *	0.92 ***	0.30	0.55	0.51 ***	0.87 ***
	(0.32)	(0.83)	(0.25)	(0.50)	(0.58)	(0.79)
	0.15	0.24	0.16	0.37	0.10	0.23
Population of municipality	−0.02	−0.34 ***	−0.06	0.00	−0.10	−0.32 ***
	(−0.02)	(−0.22)	(−0.02)	(0.00)	(−0.09)	(−0.21)
	0.13	0.11	0.14	0.28	0.13	0.11
Share of municipal population under 20	0.01	0.06	−0.13	−0.60	0.13	0.03
	(0.00)	(0.01)	(−0.04)	(−0.16)	(0.04)	(0.01)
	0.26	0.33	0.25	0.48	0.25	0.33
Share of municipal population over 65	−0.34	−0.30	−0.50	−0.28	−0.51	−0.24
	(−0.07)	(−0.06)	(−0.09)	(−0.05)−	(−0.11)	(−0.05)
	0.39	0.35	0.40	0.80	0.36	0.35
Area of municipality	0.11	0.25 **	0.18 **	0.25 ***	0.12	0.25 **
	(0.12)	(0.23)	(0.18)	(0.23)	(0.14)	(0.23)
	0.10	0.10	0.09	0.09	0.10	0.10
Urban center dummy	0.31 **	0.55 ***	0.30 **	0.32	0.37 ***	0.53 ***
	(0.19)	(0.28)	(0.19)	(0.16)	(0.23)	(0.27)
	0.12	0.14	0.13	0.21	0.11	0.14
Distance to freeway	−0.08	−0.04	−0.08	−0.02	−0.07	−0.04
	(−0.10)	(−0.04)	(−0.06)	(−0.02)	(−0.08)	(−0.04)
	0.07	0.06	0.06	0.06	0.07	0.06
Distance to airport	0.46 ***	0.31 ***	0.48 ***	0.49 ***	0.43 ***	0.32 ***
	(0.48)	(0.27)	(0.45)	(0.42)	(0.45)	(0.27)
	0.10	0.12	0.11	0.16	0.10	0.12
Lake shore	−0.02 *	−0.02	−0.02	−0.04 *	−0.02	−0.02
	(−0.12)	(−0.07)	(−0.11)	(−0.16)	(−0.09)	(−0.08)
	0.01	0.02	0.01	0.02	0.01	0.01
Latin dummy	−0.31	−0.73 ***	−0.37 *	−0.47	−0.48 ***	−0.69 ***
	(−0.18)	(−0.34)	(−0.08)	(−0.22)	(−0.27)	(−0.32)
	0.19	0.22	0.20	0.31	0.18	0.21
Harmonized-tax dummy	−0.76 ***	−0.93 ***	−0.71 ***	−0.91 ***	−0.77 ***	−0.93 ***
	(−0.39)	(−0.39)	(−0.38)	(−0.38)	(−0.40)	(−0.39)
	0.18	0.19	0.20	0.18	0.17	0.18
Geneva dummy	−1.27 ***	−1.82 ***	−1.18	−1.33 **	−1.65 ***	−1.77 **
	(−0.44)	(−0.51)	(0.00)	(−0.37)	(−0.57)	(−0.49)
	0.34	0.40	0.33	0.44	0.34	0.40
Uri dummy	−0.86 ***	−0.54	−0.90 ***	0.04	−1.13 ***	−0.51
	(−0.11)	(−0.06)	(−0.19)	(0.00)	(−0.14)	(−0.05)
	0.30	0.36	0.32	0.49	0.27	0.35
St. Gallen dummy	0.91 ***	1.71 ***	0.84 ***	1.60 ***	1.14 ***	1.70 ***
	(0.31)	(0.48)	(0.37)	(0.44)	(0.39)	(0.48)
	0.24	0.21	0.27	0.23	0.24	0.21
Number of observations	102	101	102	101	102	101
R^2	0.71	0.73	0.70	0.73	0.73	0.73
Hansen *J* statistic	6.66	4.13	3.65	0.22		
	0.04	0.13	0.16	0.90		
F statistic of 1st-stage regression	39.08	8.91	40.60	9.23		

Table 5 (*continued*)

Dependent variable= municipal tax index	2SLS		Spatial GMM		OLS	
	1985	2001	1985	2001	1985	2001
Moran *I* statistic of residuals	0.23	0.14			0.23	0.13
	0.00	0.03			0.00	0.03

Beta coefficients in parentheses, standard errors below. Intercept included in all regressions. All non-dichotomous variables are in natural logs. 2SLS and spatial GMM: cantonal tax indices are instrumented using all exogenous regressors, plus canton population in urban areas, canton area and canton number of municipalities as instruments. Spatial GMM: based on Conley (1999), with neighborhood distance cutoff of 15 km. Standard errors and first-stage *F* statistics based on robust covariance matrices. Hansen *J* statistics calculated without Uri dummy due to insufficient degrees of freedom; *P* values below. Moran *I* statistic calculated using 15 km distance bands and a binary distance weighting matrix; *P* values below.

* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

municipal tax decision in almost all cases concerns but a single number, i.e. the multiplier applied to cantonal tax rates across the entire schedule, it might be interesting to estimate our model separately for tax rates on individual representative tax bases. Given that personal income taxes contribute over 70% of municipal tax revenue (Table 1), we naturally assume that municipalities' tax decisions focus most strongly on the rates they imply for personal income taxes. Hence, it is the municipal tax rates on personal income that are *a priori* expected to be most sensitive to economic and political incentives.

Our estimation results for tax rates on individual tax bases are reported in Table 6 (for the assembly sample) and Table 7 (for the referendum sample).[34] R^2 values remain high, the strategic complementarity of municipal and cantonal tax remains the dominant result, and the instrument tests are satisfactory in a majority of cases (although our instruments appear to be too weak in the majority of estimations for taxes other than personal income).

Most importantly, the estimations confirm that vertical externalities dominate for the tax rates that we assume to be most sensitive to the cost–benefit calculations of the voting citizens: with respect to personal income taxes, the estimated coefficients on smallness are all positive. The fact that this effect is found to be stronger in the assembly sample than in the referendum sample mirrors the equivalent result found already in our regressions for the tax index.

Finally, an intriguing pattern emerges in the regressions for corporate taxes. Six of the eight corporate-tax regressions in Tables 6 and 7 yield negative coefficients on *smallness* (and the two positive coefficients are not statistically significant). These results must be treated with some caution, since, of the six negative coefficients, only one is statistically significantly different from zero. Nonetheless, they invite the conjecture that horizontal externalities dominate in the setting of corporate taxes, while the dominance of vertical externalities applies primarily to personal taxes. This might be taken as indirect evidence in support of a theoretical literature on horizontal tax interdependencies which has stressed that, unlike the taxation of capital, the decentralized taxation of personal income need not lead to inefficiently low provision of public goods, given certain conditions on the mobility and homogeneity of households (Boadway, 1982; Myers, 1990; Kessler et al., 2002). In light of the imprecision of our tax-base specific estimates and of the particular institutional setting whereby municipalities

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[34] In order not to overload the tables, we do not report results on control variables other than the instrumented cantonal tax rates in Tables 6 and 7. Coefficient estimates on most controls are stable across individual tax instruments.

Table 6
Regressions for individual tax instruments: panel, assembly sample

Dependent variable	Smallness	Cantonal tax rate (instrumented)	No. of observations	R^2	Hansen J statistics	First-stage F statistics
Personal income						
Single median inc.	1.00*** (0.30) 0.29	0.58*** (0.45) 0.15	190	0.77	2.30 0.32	19.13
Married median inc.	1.00*** (0.25) 0.27	0.69*** (0.58) 0.11	190	0.83	1.30 0.52	11.29
Married high inc.	1.19*** (0.31) 0.32	0.66*** (0.56) 0.11	190	0.80	4.92 0.09	47.64
Wealth						
200,000	−0.30 (−0.03) 0.82	0.80*** (0.70) 0.23	190	0.90	3.44 0.18	2.39
5,000,000	0.97*** (0.31) 0.24	0.91*** (1.11) 0.11	190	0.72	2.79 0.25	9.65
Corporate income						
2%	−0.80 (−0.11) 0.81	0.47 (0.44) 0.29	185	0.80	3.03 0.22	4.33
9%	−1.28 (−0.27) 1.24	0.95** (0.80) 0.41	185	0.67	2.97 0.23	1.81
32%	1.45 (0.26) 1.20	0.26 (0.29) 0.33	185	0.50	4.58 0.10	8.79
Capital	−6.85*** (−0.88) 1.37	1.88*** (1.59) 0.32	185	0.51	7.64 0.02	12.86

***Significant at 1%. **Significant at 5%. *Significant at 10%.
Beta coefficients in parentheses, standard errors below. Intercept included in all regressions. All non-dichotomous variables are in natural logs. Non-reported controls are identical to Table 5; except St. Gallen and harmonized-tax dummies, which are not included for corporate taxes, and Uri dummy, which is not included for wealth and corporate taxes. Cantonal tax rates are instrumented using all exogenous regressors, plus canton population in urban areas, canton area and canton number of municipalities as instruments. Standard errors and first-stage F statistics based on robust covariance matrices. Hansen J statistics calculated without Uri and Latin dummies due to insufficient degrees of freedom; P values below.

decide on a unique multiplier, our result cannot, however, be more than a loose conjecture. It would be interesting to investigate this further in an empirical setting of jurisdictions that decide separately on tax rates for different tax bases.

6. Conclusions

We test for the dominance of horizontal or vertical tax externalities in a federation of independent benevolent tax-setting authorities. An empirically testable discriminating criterion is

Table 7
Regressions for individual tax instruments: panel, referendum sample

Dependent variable	Smallness	Cantonal tax rate (instrumented)	No. of observations	R^2	Hansen J statistics	First-stage F statistics
Personal income						
Single median inc.	0.02	0.08	512	0.48	3.13	21.17
	(0.01)	(0.09)			0.21	
	0.13	0.24				
Married median inc.	0.08	0.24	512	0.64	1.86	18.18
	(0.02)	(0.22)			0.39	
	0.14	0.21				
Married high inc.	0.25**	0.37**	512	0.66	4.13	28.81
	(0.09)	(0.38)			0.13	
	0.12	0.16				
Wealth						
200,000	−0.43	0.69***	512	0.88	10.50	7.57
	(−0.05)	(0.66)			0.01	
	0.53	0.17				
5,000,000	0.25**	0.53***	512	0.54	5.19	19.00
	(0.11)	(0.86)			0.07	
	0.11	0.12				
Corporate income						
2%	−0.31	0.23	507	0.65	2.36	6.71
	(−0.07)	(0.21)			0.31	
	0.32	0.26				
9%	−0.25	0.16	507	0.68	2.72	12.01
	(−0.06)	(0.13)			0.26	
	0.35	0.23				
32%	0.37	−0.02	507	0.57	1.68	4.66
	(0.10)	(−0.02)			0.43	
	0.40	0.38				
Capital	−0.59	−0.11	507	0.34	9.31	41.62
	(−0.13)	(−0.11)			0.01	
	0.51	0.32				

***Significant at 1%. **Significant at 5%. *Significant at 10%.
Beta coefficients in parentheses, standard errors below. Intercept included in all regressions. All non-dichotomous variables are in natural logs. Non-reported controls are identical to Table 5; except St. Gallen and harmonized-tax dummies, which are not included for corporate taxes, and Uri dummy, which is not included for wealth and corporate taxes. Cantonal tax rates are instrumented using all exogenous regressors, plus canton population in urban areas, canton area and canton number of municipalities as instruments. Standard errors and first-stage F statistics based on robust covariance matrices. Hansen J statistics calculated without Uri dummy due to insufficient degrees of freedom; P values below.

derived, building on the model by Keen and Kotsogiannis (2002). Theory predicts that state tax rates *decrease* with the fragmentation of a federation (and hence the relative smallness of states) if horizontal externalities dominate but increase with fragmentation if vertical externalities dominate.

Exploiting the institutional variety of the Swiss multi-federation system of fiscally autonomous cantons and municipalities, we estimate the discriminatory relationship empirically. Each of the 26 cantons is taken to represent a federation, while the municipalities correspond to sub-federal “states”. Swiss cantons provide a close approximation of the federal fiscal structures that characterize the relevant theoretical model. While tax schedules vary widely across cantons and tax rates vary similarly widely across both cantons and municipalities, the tax bases of hierarchically nested governments are virtually identical. Since the theory in addition crucially depends on the assumption that lower-level governments are benevolent, we apply our estimations to a sample of municipalities featuring a high degree of direct-democratic participation in the setting of local taxes.

We find that, on average, municipal tax rates increase in the relative smallness of municipalities. Hence, vertical externalities are found to dominate overall. Our evidence thus supports the existence of vertical tax externalities among states with benevolent tax setting: vertical tax externalities that dominate the effects of horizontal externalities are more than a theoretical curiosity.

This finding naturally raises two questions: are local taxes in Switzerland too high? and: is our result likely to extend to other countries?

The answer to the first question is "not necessarily". The theory features a two-level jurisdictional hierarchy and for welfare calculations considers only the utility of federation residents. Hence, to transpose the welfare result from the theory to our empirical context is to narrow the normative focus to individual cantons: adopting the point of view of citizens'. welfare in a particular canton, taking taxes in the entire rest of the world including the other cantons as given, our result indeed implies that average municipal tax rates are too high. However, allowing for further interdependencies, this result no longer necessarily holds, since it may be that average municipal taxes are too low for Switzerland as a whole (if horizontal tax externalities among cantons are so strong as to offset the vertical externalities inside of cantons). This normative indeterminacy extends *a fortiori* to a welfare calculus that encompasses tax interactions beyond the national borders.

As for the generality of our finding, we deem it useful in itself that a novel theoretical result with considerable policy implications can be shown to hold empirically *somewhere*. If we are to speculate nonetheless on whether our specific empirical setting is more propitious to vertical externalities than other real-world federations, there is one clear reason to think this not to be the case. The model shows the relative weight of vertical externalities to increase with the size of the federal relative to the sub-federal public sector. In our empirical setting, municipal tax revenue on average corresponds to around 70% of cantonal revenue (see Table 1). In many federations, the sub-federal fiscal share is considerably lower, and the associated scope for vertical externalities thus correspondingly higher, than this. Conversely, however, the benevolent-government model is unlikely to correspond as well to other empirical settings as to the one analyzed in this paper, which might make other federations relatively less susceptible to vertical externalities. Empirical research on the three-way interaction among tax externalities, fiscal decentralization and government objective functions would thus be useful.

By way of a concluding conjecture, we note that tax externalities of a very similar nature to the "common-pool vertical" externalities analyzed in this paper can arise also among jurisdictions that are not linked through a higher layer of government. What matters is that, *for a given size* of the tax base in jurisdiction *A*, the size of the tax base in some jurisdiction *B* affects the welfare of residents in jurisdiction *A*. One example is provided by Haufler and Wooton (2006). In their model, three countries compete through profit taxation to host a globally mobile firm. Hosting the firm benefits a country's residents because it saves them trade costs on the goods they purchase from that firm. Two of the three countries form a customs union and each union member is better off if the firm locates in the other union country rather than outside the union. In the absence of intra-union coordination, each union country internalizes only its own share of the (potential) benefit of attracting the firm to the union, and hence the union countries may set suboptimally high taxes. It is straightforward to extend this example: such outcomes can arise in the presence of any type of spatial externalities, such as input–output linkages among firms, knowledge spillovers, labor-market spillovers or environmental externalities.[35] The logic of "vertical" tax externalities thus extends well beyond the case of fiscal federations.

Appendix A. Simulations

For Proposition 1 to be valid, we need E_t to be negative for all possible parameter values. However, the sign of E_t in (9), cannot be determined without further assumptions or resorting to simulations. We explore this issue via simulations, which we summarize here. We choose the following production function:

$$F(K_j) = AK_j^{\alpha}.$$

Profit maximization then implies

$$K(\rho + \tau_j) = \left(\frac{\alpha A}{\rho + \tau_j}\right)^{1/(1-\alpha)},$$

$$K'(\rho + \tau_j) = -\frac{K_j}{(1-\alpha)(\rho + \tau_j)}.$$

Similarly, using the FOC of profit maximization, the rent function becomes

$$\pi(\rho + \tau_j) = (1-\alpha)AK_j^{\alpha}.$$

In addition, we posit the following indirect utility function:

$$U_j = (e - S_j) + B\ln[(1+\rho)S_j + \pi(\rho + \tau_j)] + g_j^{\delta}G^{\gamma}.$$

Thus, we have $\varepsilon_g = \delta$ and $\varepsilon_G = \gamma$. Utility maximization implies the following expression for savings:

$$S(\rho;\tau_j) = B - \frac{\pi(\rho + \tau_j)}{(1+\rho)},$$

with

$$S_{\rho} = \frac{K}{(1+\rho)} + \frac{\pi}{(1+\rho)^2},$$

$$S_{\tau} = \frac{K}{(1+\rho)}.$$

Finally, joining these expressions, we obtain

$$W_j = (e - S(\rho,\tau_j)) + B\ln\left[(1+\rho)S(\rho,\tau_j) + \pi(\rho + \tau_j)\right] + (t_j K(\rho + \tau_j))^{\delta} \times \left(\frac{1}{N}\sum_j TK(\rho + \tau_j)\right)^{\gamma}.$$

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[35] In the case of negative spillovers, e.g. in the form of pollution, the vertical externality would of course induce suboptimally low tax rates.

The equilibrium condition for state taxes (6) is now given by

$$\begin{aligned} E \equiv \left.\frac{\partial W_j}{\partial t_j}\right|_{t_j=1} = & -\frac{K}{(1+\rho)} + \delta (tK)^{\delta-1}(TK)^{\gamma}\left[K + tK'\left(\frac{1}{N}\frac{\partial \rho}{\partial t}+1\right)\right] + \gamma (tK)^{\delta}(TK)^{\gamma-1} \\ & \times \left[\frac{T}{N}K'\frac{\partial \rho}{\partial t}K'\right] = 0. \end{aligned}$$

We are interested in signing the derivative of the above condition with respect to *t* (evaluated at the symmetric equilibrium):

$$\begin{aligned} E_t = & -\frac{K'}{(1+\rho)} + \frac{K\dfrac{\partial \rho}{\partial t}}{(1+\rho)^2} + \delta(\delta-1)(tK)^{\delta-2}(TK)^{\gamma}\left(K + tK'\left(\frac{1}{N}\frac{\partial \rho}{\partial t}+1\right)\right) \\ & \times \left(K + tK'\left(\frac{\partial \rho}{\partial t}+1\right)\right) + \delta\gamma(tK)^{\delta-1}(TK)^{\gamma-1}\left(K + tK'\left(\frac{1}{N}\frac{\partial \rho}{\partial t}+1\right)\right) \\ & \times TK'\left(\frac{\partial \rho}{\partial t}+1\right) + \delta(tK)^{\delta-1}(TK)^{\gamma}K'\left(\frac{\partial \rho}{\partial t}+1\right) + \delta(tK)^{\delta-1}(TK)^{\gamma} \\ & \times K'\left(\frac{1}{N}\frac{\partial \rho}{\partial t}+1\right) + \delta(tK)^{\delta-1}(TK)^{\gamma}tK''\left(\frac{1}{N}\frac{\partial \rho}{\partial t}+1\right)\left(\frac{\partial \rho}{\partial t}+1\right) \\ & + \delta(tK)^{\delta-1}(TK)^{\gamma}\frac{t}{N}K'\frac{\partial^2 \rho}{\partial t^2} + \delta\gamma(tK)^{\delta-1}(TK)^{\gamma-1}\frac{T}{N}K'\left(\frac{\partial \rho}{\partial t}+1\right) \\ & \times \left(K + tK'\left(\frac{\partial \rho}{\partial t}+1\right)\right) + \gamma(\gamma-1)(tK)^{\delta}(TK)^{\gamma-2}\frac{T^2}{N}(K')^2\left(\frac{\partial \rho}{\partial t}+1\right)^2 \\ & + \gamma(tK)^{\delta}(TK)^{\delta-1}\frac{T}{N}K''\left(\frac{\partial \rho}{\partial t}+1\right)^2 + \gamma(tK)^{\delta}(TK)^{\gamma-1}\frac{1}{N}K'\frac{\partial^2 \rho}{\partial t^2} \end{aligned}$$

where

$$K'' = \frac{K(2-\alpha)}{(\rho+\tau)^2(1-\alpha)^2} > 0,$$

and

$$\begin{aligned} \frac{\partial^2 \rho}{\partial t^2} = & \left[\frac{K\left(\dfrac{\partial \rho}{\partial t}+1\right)}{(\partial+\tau)^2(1-\alpha)^2} + \frac{K\left(\dfrac{\partial \rho}{\partial t}+1\right)}{(\rho+\tau)^2(1-\alpha)} + \frac{K\left(\dfrac{\partial \rho}{\partial t}+1\right)}{(\rho+\tau)(1-\alpha)(1+\rho)} + \frac{K\dfrac{\partial \rho}{\partial t}}{(1+\rho)^2}\right] \\ & \Bigg/ \left[\frac{K}{(1+\rho)} + \frac{\pi}{(1+\rho)^2} + \frac{K}{(\rho+\tau)(1-\alpha)}\right] + K\left(\frac{1}{(\rho+\tau)(1-\alpha)} + \frac{1}{(1+\rho)}\right) \\ & \times \left[-\frac{K\left(\dfrac{\partial \rho}{\partial t}+1\right)}{(\rho+\tau)(1-\alpha)(1+\rho)} - \frac{K\dfrac{\partial \rho}{\partial t}}{(1+\partial)^2} - \frac{\alpha\pi\left(\dfrac{\partial \rho}{\partial t}+1\right)}{(\rho+\tau)(1-\alpha)(1+\rho)^2} - \frac{2\pi\dfrac{\partial \rho}{\partial t}}{(1+\rho)^3}\right. \\ & \left. -\frac{K\left(\dfrac{\partial \rho}{\rho t}+1\right)}{(\rho+\tau)^2(1-\alpha)}\right] \Bigg/ \left(\frac{K}{(1+\rho)} + \frac{\pi}{(1+\rho)^2} + \frac{K}{(\rho+\tau)(1-\alpha)}\right)^2. \end{aligned}$$

In order to determine the sign E_t, we perform a grid search across a range of parameter values via a simulation program in Maple. The parameters in the model are A, B, α, δ,γ and T. We simulate all possible permutations for five different and even spaced values of every parameter. This implies a maximum of 15,625 observations. Note that, by definition, α, δ, and γ range between zero and one. The program solves, in each loop, for the equilibrium values of the state tax rate t and the rate of return in the federation ρ and then evaluates E_t (and K, π and W_t) at this solution.

For the parameters A and B we choose the values 0.1, 1.1, 2.1, 3.1 and 4.1; whereas T takes on the values 0.01, 0.11, 0.21, 0.31 and 0.41. As for the remaining parameters (α, δ and γ), the loops start at different values with four increments of 0.2 in different simulation runs. Not all parameter combinations yield a solution for state tax rates. Conversely, in some cases, multiple solutions can be obtained, depending on starting values fed into the solution algorithm. Hence, we impose $\rho=0$ as the starting value for the solution algorithm in runs 3 to 20. This may be considered a natural starting point, as it implies that the federation rate of return equals that in the Rest of the World.

Table A1 reports the main results. Our simulations are quite conclusive. E_t is negative in 260,566 cases out of the 260,629 parameter configurations for which a solution for ρ and t exists. The 63 cases yielding a positive E_t all obtain for two particular values of α, and further experimentation shows that an infinitesimal deviation from these values again results in either no solution or strictly negative simulated values for E_t.

As a by-product Table A1 reports the number of observations for which the equilibrium implies the dominance of vertical externalities ($W_t<0$). Significant numbers of solutions corresponding to dominant vertical externalities are found in all simulation runs.

Table A1
Simulation results

Run	Loop start for α, δ, γ	Starting values for ρ	# of solutions	# where $E_t>0$	# where $W_t<0$
1	19/100	(Automated)	11,301	0	808
2	19/100	2	11,390	0	807
3	1/100	0	13,572	0	3050
4	2/100	0	13,686	0	2718
5	3/100	0	13,735	0	2523
6	4/100	0	13,762	0	2343
7	5/100	0	13,770	0	2163
8	6/100	0	13,747	0	2015
9	7/100	0	13,706	0	1875
10	8/100	0	13,657	0	1764
11	9/100	0	13,598	0	1638
12	10/100	0	13,309	29	1700
13	11/100	0	13,476	0	1454
14	12/100	0	13,342	0	1354
15	13/100	0	13,212	0	1276
16	14/100	0	13,053	0	1171
17	15/100	0	12,324	34	1213
18	16/100	0	12,728	0	1007
19	17/100	0	12,430	0	926
20	19/100	0	10,831	0	807
Total			260,629	63	32,612

Appendix B. Smallness

The number of states (N) of a federation takes center stage in the theoretical model underlying our analysis. For the empirical analysis, we employ the corresponding measure of "smallness". This appendix shows how the two concepts are linked.

The empirical model defines the smallness of state j as

$$n_j = 1 - s_j \qquad \text{if } s_j > 0.$$[36]

By the definition of n_j we have

$$\sum_j n_j = N - 1,$$

and

$$\mathrm{d}N = \sum_j \mathrm{d}n_j.$$

In particular, for a change $\mathrm{d}N > 0$ in the number of states (*ceteris paribus*, and treating N as a continuous variable) we have

$$\mathrm{d}n_j \geq 0 \quad \forall j,$$

i.e. a marginal increase in the number of states implies that smallness (weakly) increases for all states in the federation.

A simple example might be illustrative. Assume a federation consisting of 10 individuals divided up equally into two states, 1 and 2. Given that each state includes 50% of population, smallness is $n_j = 1/2$ for $j = 1, 2$. If an additional state joins the federation with a population of 5, each state includes one third of the population and $n_k = 2/3$ for $k = j, 3$. Hence $\mathrm{d}n_l > 0\ \forall j$. Similarly, take the same federation with 10 individuals, divided equally between two states. If state 2 is divided into two states, 2a and 2b, we have $\mathrm{d}n_1 = 0$ and $\mathrm{d}n_l > 0$ for $l =$ 2a, 2b.

Assume, now, that the change in N affects the value of smallness in only one state. Then $\mathrm{d}_N = \mathrm{d}n_j$ and our qualitative results, in particular $\frac{\partial t}{\partial N} = \frac{\partial t}{\partial n_j} = -\frac{E_N}{Et}$, go through.

There is thus a non-negative mapping from $\mathrm{d}N$ to $\mathrm{d}n_j$, *ceteris paribus*. In general, an increase in one particular n_j (or in a subset of n_js) could coincide with a decrease in N. In that sense, $\mathrm{d}n_j$ must be considered a noisy measure of $\mathrm{d}N$. Yet, in general (i.e. if we drop the *ceteris paribus* restriction), $\mathrm{d}N > 0 \Rightarrow \mathrm{E}(\mathrm{d}n_j) > 0$. Hence, $\mathrm{d}n_j$ is at least positively correlated with $\mathrm{d}N$, and is thus a valid proxy for $\mathrm{d}N$.

References

Arzaghi, Mohammad, Henderson, J. Vernon, 2005. Why are countries fiscally decentralizing? Journal of Public Economics 89 (7), 1157–1189.

Besley, Timothy J., Case, Anne, 1995. Incumbent behavior: vote-seeking, tax-setting, and yardstick competition. American Economic Review 85, 25–45.

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[36] We assume implicitly that there exists a set of states J, with $j \in J$, that encompasses all possible states of the federation, even those that are not currently part of the federation.

Besley, Timothy J., Rosen, Harvey S., 1998. Vertical externalities in tax setting: evidence from gasoline and cigarettes. Journal of Public Economics 70 (3), 383–398.

Boadway, Robin, 1982. On the method of taxation and the provision of local public goods: comment. American Economic Review 72 (4), 846–851.

Boadway, Robin, Marchand, Maurice, Vigneault, Marianne, 1998. The consequences of overlapping tax bases for redistribution and public spending in a federation. Journal of Public Economics 68, 453–478.

Brennan, Geoffrey, Buchanan, James M., 1980. The Power to Tax: Analytical Foundations of a Fiscal Constitution. Cambridge University Press.

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

Bucovetsky, Sam, 1991. Asymmetric tax competition. Journal of Urban Economics 30, 167–181.

Bucovetsky, Sam, 2004. Tax bloc formation among Leviathans. Mimeo, York University, Toronto.

Büttner, Thiess, 2003. Tax base effects and fiscal externalities of local capital taxation: evidence from a panel of German jurisdictions. Journal of Urban Economics 54 (1), 110–128.

Carey, David, Gordon, Kathryn, Thalmann, Philippe, 1999. Tax reform in Switzerland. OECD Economics Department Working Paper #222.

Conley, Timothy G., 1999. GMM estimation with cross sectional dependence. Journal of Econometrics 92, 1–45.

Dahlby, Bev, Wilson, Leonard S., 2003. Vertical fiscal externalities in a federation. Journal of Public Economics 87, 917–930.

Devereux, Michael P., Lockwood, Ben, Redoano, Michela, 2004. Horizontal and vertical indirect tax competition: theory and some evidence from the USA. CEPR Discussion Paper #4470.

Esteller-Moré, Alejandro, Solé-Ollé, Albert, 2001. Vertical income tax externalities and fiscal interdependence: evidence from the US. Regional Science and Urban Economics 31, 247–272.

Esteller-Moré, Alejandro, Solé-Ollé, Albert, 2002. Tax setting in a federal system: the case of personal income taxation in Canada. International Tax and Public Finance 9, 235–257.

Feld, Lars P., Kirchgässner, Gebhard, 2001. Income tax competition at the state and local level in Switzerland. Regional Science and Urban Economics 31, 181–213.

Feld, Lars P., Kirchgässner, Gebhard, 2003. The impact of corporate and personal income taxes on the location of firms and on employment: some panel evidence for the Swiss cantons. Journal of Public Economics 87 (1), 129–155.

Feld, Lars P., Matsusaka, John G., 2003. Budget referendums and government spending: evidence from Swiss cantons. Journal of Public Economics 87 (12), 2703–2724.

Feld, Lars P., Kirchgässner, Gebhard, Schaltegger, Christoph A., 2002. Decentralized taxation and the size of government: evidence from Swiss state and local governments. Mimeo, University of St. Gallen.

Goodspeed, Timothy J., 2000. Tax structure in a federation. Journal of Public Economics 75, 493–506.

Haufler, Andreas, Wooton, Ian, 2006. The effects of regional tax and subsidy coordination on foreign direct investment. European Economic Review 50 (2), 285–305.

Hayashi, Masayoshi, Boadway, Robin, 2001. An empirical analysis of intergovernmental tax interaction: the case of business income taxes in Canada. Canadian Journal of Economics 34 (2), 481–503.

Hoyt, William H., 2001. Tax policy coordination, vertical externalities, and optimal taxation in a system of hierarchical governments. Journal of Urban Economics 50, 491–516.

Keen, Michael J., 1998. Vertical tax externalities in the theory of fiscal federalism. IMF Staff Papers 45 (3), 454–485.

Keen, Michael J., Kotsogiannis, Christos, 2002. Does federalism lead to excessively high taxes? American Economic Review 92 (1), 363–370.

Keen, Michael J., Kotsogiannis, Christos, 2003. Leviathan and capital tax competition in federations. Journal of Public Economic Theory 5 (2), 177–199.

Keen, Michael J., Kotsogiannis, Christo, 2004. Tax competition in federations and the welfare consequences of decentralization. Journal of Urban Economics 56 (3), 397–407.

Kessler, Anke S., Lülfesmann, Christoph, Myers, Gordon M., 2002. Redistribution, fiscal competition, and the politics of economic integration. Review of Economic Studies 69 (4), 899–923.

Kirchgässner, Gebhard, Pommerehne, Werner W., 1996. Tax harmonization and tax competition in the European Union: lessons from Switzerland. Journal of Public Economics 60 (3), 351–371.

Myers, Gordon M., 1990. Optimality, free mobility, and the regional authority in a federation. Journal of Public Economics 43 (1), 107–121.

Oates, Wallace E., 1985. Searching for Leviathan: an empirical study. American Economic Review 75 (4), 748–757.

Oates, Wallace E., 1999. An essay on fiscal federalism. Journal of Economic Literature 27, 1120–1149.

Revelli, Federico, 2003. Reaction or interaction? Spatial process identification in multi-tiered government structures. Journal of Urban Economics 53, 29–53.

Sato, Motohiro, 2003. Tax competition, rent-seeking and fiscal decentralization. European Economic Review 47, 19–40.

Wilson, John D., 1986. A theory of interregional tax competition. Journal of Urban Economics 19, 296–315.

Wilson, John D., 1991. Tax competition with interregional differences in factor endowments. Regional Science and Urban Economics 21, 423–452.

Zax, Jeffrey S., 1989. Is there a Leviathan in your neighborhood? American Economic Review 79 (3), 560–567.

Zodrow, George R., Mieszkowski, Peter, 1986. Pigou, Tiebout, property taxation, and the underprovision of local public goods. Journal of Urban Economics 19, 356–370.