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 (2002), we derive a discriminating hypothesis to distinguish vertical and horizontal tax externalities based on observable 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 dominate - they are thus an observed empirical phenomenon as well as a notable extension to the theory of tax competition.

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<All tables and figures at end>

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1 Introduction

Tax 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.[2] Such externalities arise in federations of hierarchically nested but fiscally independent jurisdictions that tax the same base. 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.

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

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

[2] See Keen (1998) for an early survey.

[3] In the words of Oates (1999), "fiscal decentralization is in vogue". For a quantification of the global tendency toward fiscal decentratlisation, see Arzaghi and Henderson (2004).

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 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 competition analyzes fiscal externalities among different hierarchical layers of federations, and it identifies an incentive for lower-level jurisdictions to *over*tax relative to the social optimum, even if all tax setters are social-welfare maximizers.[5]

[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.

[5] Vertical externalities can yield inefficiently high tax rates also if sub-federal governments act as Leviathans (Keen and Kotsogiannis, 2003). We should note furthermore that federal political structures do not necessarily imply overtaxation, even if we abstract from horizontal tax competition as a potential counterweight. As shown by Boadway, Marchand and Vigneault (1998), it may be possible for the higher-level jurisdiction (the "federation") to correct for externalities that distort the tax decsions of lower-level jurisdictions ("states"), if the federal government acts as a Stackelberg leader. In a model with multiple tax bases,

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 with a number of theoretical explanations, of which horizontal tax competition is but one.[7] In our context, it is particularly interesting to note Revelli's (2003) finding that what could

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.

[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).

[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*.

appear to reflect horizontal fiscal interdependencies among sub-national jurisdictions may in fact to a large extent be driven by vertical externalities, i.e. common reactions to the fiscal policy of a higher-level fiscal authority. This strand of the literature 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, Lockwood and Redoano (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; and 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, Kirchgässner and Schaltegger, 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 government; and, in models featuring vertical externalities, the relationship between government size and decentralization 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.

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 $N \geq 1$ 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]

[8] Other prior research on Swiss data has 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

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, 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

$$\begin{aligned} g &= t_j K(\rho + \tau_j), \qquad (2) \\ G &= \frac{1}{N} \sum_j T K(\rho + \tau_j). \end{aligned}$$

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

capital but can stand for any mobile factor (and tax base).

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

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, 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:

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

where $u(\cdot)$ and $\Gamma(g_j; G)$ 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

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

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

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

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

[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.

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

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 (where $t_j = t, \forall j$), is given by

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

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

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

Setting equation (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 equation (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 ($\frac{\partial\rho}{\partial t}$), 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 state 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. Figure 1 illustrates these forces. The boundary for which $W_t=0$ is drawn in the space $(\frac{\varepsilon_g}{\varepsilon_G};-\frac{S_\rho}{K'})$. 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

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

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 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 extensive simulations, detailed in the Appendix, 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

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

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

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 Figures 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 the Appendix). In Figure 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 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. Figure 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

[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).

[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; Wilson, 1991).

relationship for different curvatures of the assumed state-level production function $F(K_j)$. Again, we observe that increases in N increase $|W_t|$, that is 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. 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 equation (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. However, cantons have different sizes, they set different tax rates, and they differ in numerous relevant respects other than size. Therefore, we estimate equation (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.

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. We thus 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:

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

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

[17] It would arguably have been more intuitive to treat any intra-federation variation in state tax rates as random noise, and to regress the *mean* state tax rate on a number that reflects the fragmentation of the federation and on federation-level averaged controls. However, such an empirical approach would be inefficient, as it would discard intra-federation information; and it would most likely yield biased coefficient estimates, as there is no reason to expect federation-level random components to be uncorrelated with fragmentation or with any other state-level regressor.

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 estimate equation (12) consistently without including T_i. We address the endogeneity of T_i via two-stage least squares estimation.[18]

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.

[18] 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

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

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

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.[19] 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 percent of municipal tax revenue. Corporate taxes account for around 13 percent 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 (i.e. cantons) with different numbers of states (i.e. 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 Figure 4 for an illustration).

[19] According to the OECD, "the Swiss Confederation is more decentralized than any other OECD country" (Carey, Gordon and Thalmann, 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).

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 defines effectively applied tax rates.[20]

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 percent of municipal revenue, while net horizontal transfers among municipalities corresponded to 3.6 percent 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.[21] 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 maximizing decision makers assumed in the underlying theory, and we therefore restrict the analysis to municipalities that feature direct-democratic fiscal

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

[21] 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.

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.[22]

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 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*".[23] 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:

[22] 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.

[23] 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 $\frac{1}{3}$ times the share of personal income taxes in total tax revenue.

- *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 percent 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 Figure 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.

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 two identifying canton-level variables: the canton population living in urban areas and the cantonal area.

- 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.[24]

5 Empirical Results: Horizontal and Vertical Tax Competition in Switzerland

5.1 Smallness and Average Tax Rates

We estimate municipality-level regressions of equation (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.[25]

Cantonal tax rates 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.[26] In addition, we report F statistics on the identifying instruments of the first-stage regressions as a test of instrument quality.

Column I of Table 3 presents results from the baseline regression in the *assembly sample*

[24] 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 of 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.

[25] To ignore intertemporal correlation within municipalities results in considerably (but misleadingly) smaller estimated standard errors.

[26] 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.

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 percent 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, although statistical significance now only obtains at the 90 percent confidence level. 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), but the result survives: vertical externalities dominate.

Can we have confidence in these results? Our estimations appear largely plausible, and, with R^2s of 0.79 and 0.64 respectively, 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 equation (11)). We find that the estimated coefficients on instrumented *cantonal* tax indices are positive in both samples. Statistical significance, however, is found only in the assembly sample. The related instrument diagnostic tests are broadly satisfactory. The J statistic is borderline significant (casting some doubt on the applicability of the orthogonality assumption) in the assembly sample, while, at 6.68, the first-stage F statistic for the referendum sample just satisfies the criterion reported by Stock and Yogo (2003, Table 1) for a two-stage least squares estimate that is allowed to exhibit at most 20 percent of the bias implied in its OLS counterpart.

Our findings thus suggest that municipal and cantonal taxes are complements rather than substitutes. One might suspect this result 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 *area* and *urban center* have the expected positive sign and are statistically significant in at least one of the two samples. The magnitudes are considerable. The coefficient on *urban center* in the referendum sample, for example, implies that city-center municipalities have tax rates that are 39 ($= 100 * (e^{0.33} - 1)$) percent higher than other municipalities, other things equal. Estimated coefficients on *population*, however, are negative, albeit not statistically significant.[27] Somewhat surprisingly, *population under 20* and *population over 65* do not seem important: the estimated coefficients are small, imprecisely measured and change signs across samples.

As for the three locational attractiveness variables, we find that average taxes rise significantly in *distance to the nearest international airport*, while there is some evidence that access to a lake shore has a weak negative impact on municipal taxes, and *distance to the nearest freeway* has no discernible effect. Peripherality thus appears as a particularly strong determinant of municipal tax rates: our estimates for example imply that doubling a municipality's distance to the nearest airport raises its tax rate by around one-half. 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.[28]

5.2 Robustness

We subject the baseline results of Table 3 to a number of robustness checks, which we present in Tables 4 and 5. The two tables report results of equivalent estimations based

[27] Our results therefore weakly support the Zax (1989) hypothesis of increasing returns of public goods provision. We also experimented with a quadratic *population* term, and found no economically larger or statistically significant effect.

[28] The relatively low tax 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.

on the assembly sample and on the referendum sample respectively. Our main finding, the positive coefficient on the *smallness* variable, turns out to be robust. We investigate three issues.

First, 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. While this effect has become appreciably stronger over time in the assembly sample (Table 4), the reverse time change appears in the referendum sample (Table 5). Our results must therefore be considered inconclusive as to whether the detected dominance of vertical externalities is becoming stronger or weaker with time. Our estimates for the remaining regressors are reassuringly similar across sample years.

Second, we take account of the possibility that municipal tax rates are spatially correlated for reasons that are not captured by the model - which of course features a number of spatially correlated regressors and thereby in itself explains spatial correlation in municipal tax rates. The first is to compute spatial autocorrelation tests, via Moran's I, on the regression residuals.[29] 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 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 kilometers, 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, in terms of both point estimates and inference, as our

[29] The verdict on spatial autocorrelation remained unchanged when we computed the Moran statistic with distance cutoff values larger than our default of 15 kilometers.

baseline 2SLS estimations.[30] Spatial error correlation therefore does not appear to affect our estimates and inference significantly.

Third, 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 the assembly sample (Table 4), we find that the OLS estimates are virtually identical to the 2SLS estimates, even concerning the coefficient on cantonal tax rates. In the referendum sample (Table 5), the OLS coefficients on the cantonal tax rate are significantly larger than their 2SLS counterparts. 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 coefficient 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 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 percent of municipal tax revenue (Table 2), 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).[31] R^2s remain high

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

[31] In order not to overload the tables, we do not report results on control variables other than the in-

(particularly for personal income taxes), 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 most of the 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. Seven of the eight corporate-tax regressions in Tables 6 and 7 yield negative coefficients on *smallness* (and the one positive coefficient is not statistically significant). These results must be treated with some caution, since, of the seven 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, and that the dominance of vertical externalities applies only to personal taxes. Given the imprecision of the estimates and the particular institutional setting in which municipalities decide on a unique multiplier, our result cannot be more than a loose conjecture, which it would be interesting to investigate 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 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

strumented cantonal tax rates in Tables 6 and 7. Coefficient estimates on most controls are stable across individual tax instruments.

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: taking 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, sub-federal tax revenue on average corresponds to around 70 percent of federal 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 "vertical" tax externalities 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 (2001). 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 set suboptimally high taxes. It is straightforward to extend this example: such externalities 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.[32] The logic of "vertical" tax externalities thus extends well beyond the case of fiscal federations.

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

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A Appendix: 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

$$\begin{aligned} K(\rho+\tau_j) &= \left(\frac{\alpha A}{\rho+\tau_j}\right)^{1/(1-\alpha)}, \\ K'(\rho+\tau_j) &= -\frac{K_j}{(1-\alpha)(\rho+\tau_j)}. \end{aligned}$$

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:

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

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

$$\begin{aligned} S_\rho &= \frac{K}{(1+\rho)} + \frac{\pi}{(1+\rho)^2}, \\ S_\tau &= \frac{K}{(1+\rho)}. \end{aligned}$$

Finally, joining these expressions, we obtain

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

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

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

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

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

where

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

and

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

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.

Run	Loop start for α, δ, γ	Start. val. 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	3,050
4	2/100	0	13,686	0	2,718
5	3/100	0	13,735	0	2,523
6	4/100	0	13,762	0	2,343
7	5/100	0	13,770	0	2,163
8	6/100	0	13,747	0	2,015
9	7/100	0	13,706	0	1,875
10	8/100	0	13,657	0	1,764
11	9/100	0	13,598	0	1,638
12	10/100	0	13,309	29	1,700
13	11/100	0	13,476	0	1,454
14	12/100	0	13,342	0	1,354
15	13/100	0	13,212	0	1,276
16	14/100	0	13,053	0	1,171
17	15/100	0	12,324	34	1,213
18	16/100	0	12,728	0	1,007
19	17/100	0	12,430	0	926
20	19/100	0	10,831	0	807
Total			260,629	63	32,612

Table A1: Simulation results

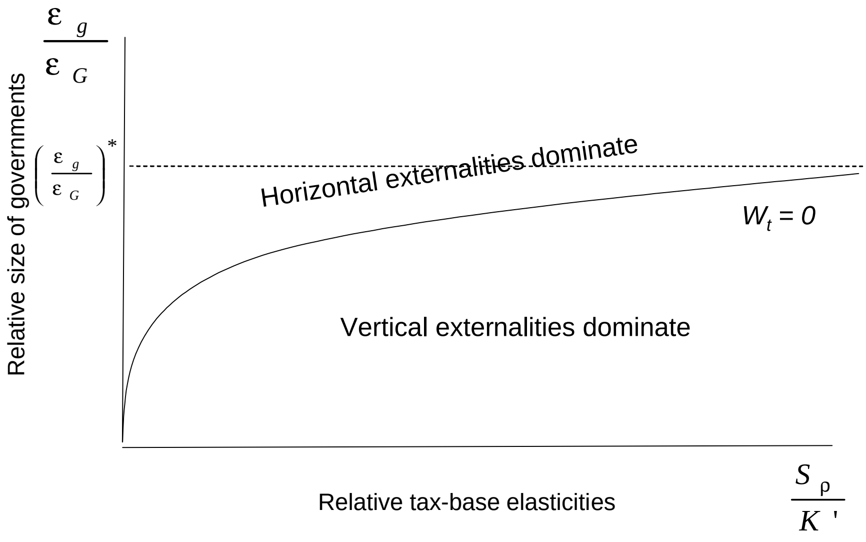

Figure 1: Parameter ranges for dominance of vertical/horizontal externalities.

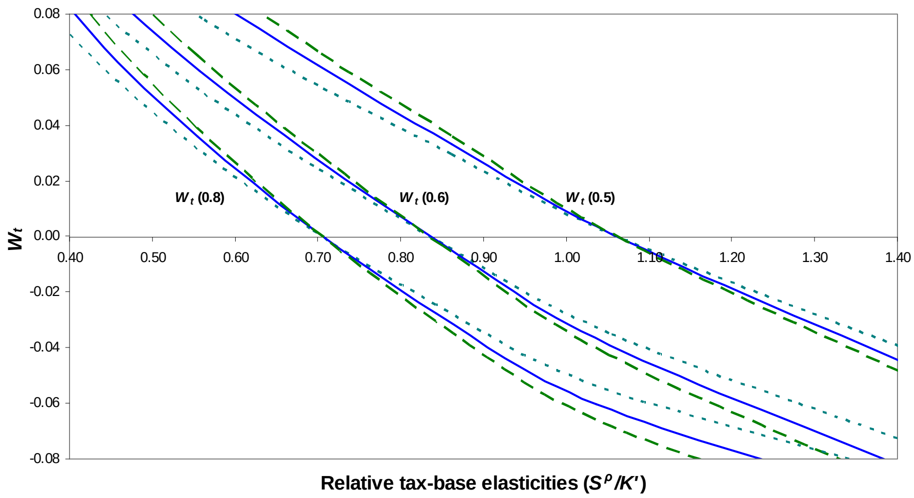

Figure 2: Relative tax-base elasticities, tax distortions, and fragmentation

Assumed functional forms are described in the Appendix. Parameter values are: $A = B = 5$, ε_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: $N = 50$.

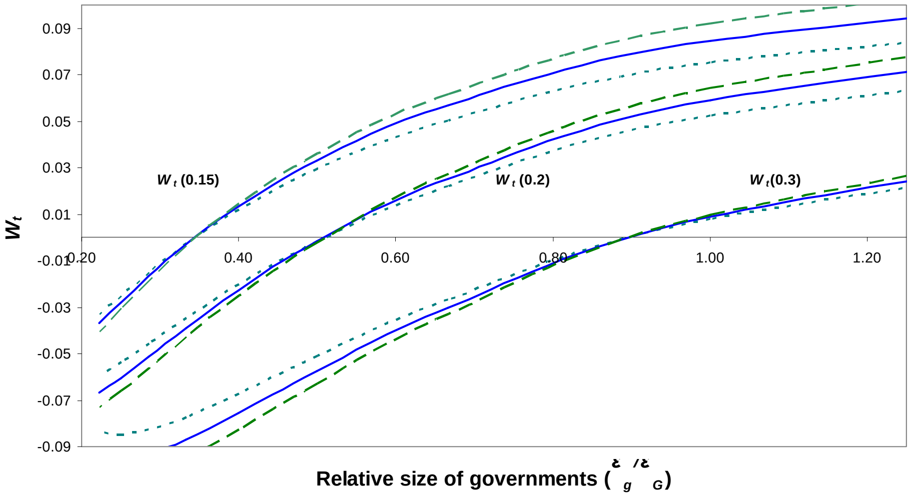

Figure 3: Relative government sizes, tax distortions, and fragmentation

Assumed functional forms are described in the Appendix. 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: $N = 50$.

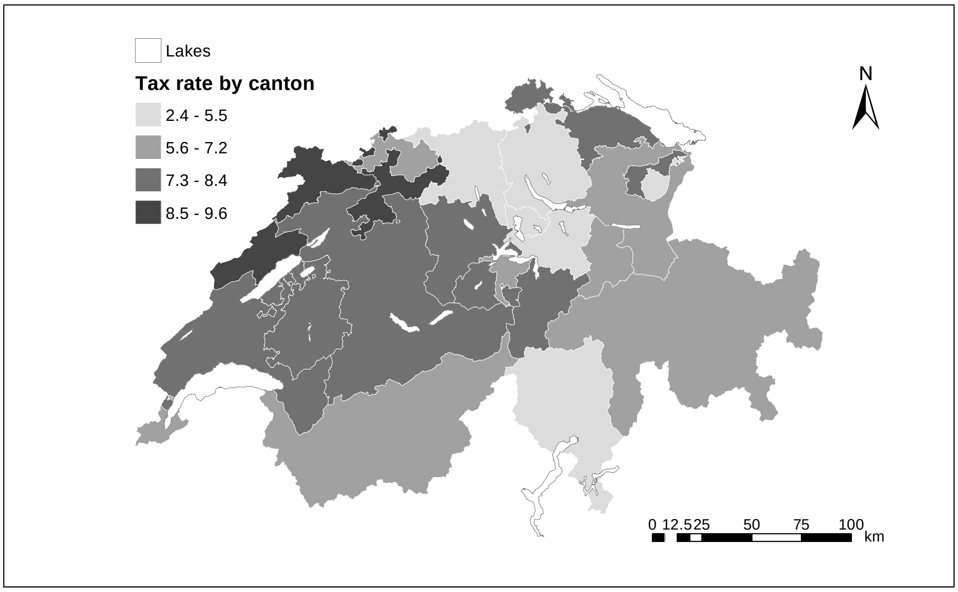

Figure 4: Variation in sub-federal tax rates across Swiss cantons

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.

Tax base	Municipalities 1985 Revenue	%	Municipalities 2000 Revenue	%	Cantons 1985 Revenue	%	Cantons 2000 Revenue	%
Private income	8,296	73.9	14,283	70.6	10,418	64.2		
Wealth	690	6.1	1,723	8.5	895	5.5	19,536	68.5
Corporate inc.	1,122	10.0	2,378	11.8	1,767	10.9		
Capital	350	3.1	458	2.3	547	3.4	4,742	16.6
Other taxes	764	6.8	1,384	6.8	2,640	16.1	4,234	14.8
Total	11,222	100.0	20,226	100.0	16,237	100.0	28,512	100.0

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

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.

Variable	Obs.	Mean	Std. dev.	Mun. or cant. with min.	Mun. or cant. 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 = CHF200,000	512	0.13	0.07	Baar (ZG)	Glarus (GL)
wealth = CHF5,000,000	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)
`Corp. 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 pop. under 20	512	0.17	0.04	Renens (VD)	Einsiedeln (SZ)
Share of pop. over 65	512	0.19	0.03	Volketswil (ZH)	Zollikon (ZH)
Area (hectares)	512	1,927	2,788	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 (meters)	512	2,185	4,503	(*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 (hectares)	512	228,616	200,429	Appenzell (AI)	Graubünden

Table 2: Summary statistics (referendum sample)

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

dep. var. = municipal tax index	assembly sample	referendum sample
Smallness	3.42** (0.25) 1.62	0.85* (0.09) 0.51
Cantonal tax index (instrumented)	0.70*** (0.58) 0.14	0.12 (0.13) 0.33
Population of municipality	−0.29 (−0.09) 0.21	−0.08 (−0.06) 0.15
Share of mun. pop. under 20	0.40 (0.08) 0.41	−0.35 (−0.09) 0.29
Share of mun. pop. over 65	−0.68* (−0.14) 0.36	0.20 (0.04) 0.42
Area of municipality	0.19** (0.17) 0.09	0.14 (0.14) 0.09
Urban center dummy	0.64*** (0.35) 0.16	0.33** (0.19) 0.17
Distance to freeway	0.11 (0.08) 0.14	−0.05 (−0.05) 0.06
Distance to airport	0.59*** (0.48) 0.14	0.46*** (0.44) 0.10
Lake shore	−0.01 (−0.06) 0.02	−0.04** (−0.17) 0.02
Latin dummy	−1.91*** (−0.35) 0.26	−0.19 (−0.10) 0.27
Harmonized-tax dummy	0.06 (0.03) 0.18	−0.80*** (−0.38) 0.16
Geneva dummy	(*n.a.*)	−0.79 (−0.25) 0.58
Uri dummy	−1.38*** (−0.26) 0.42	−0.71** (−0.08) 0.29
St. Gallen dummy	0.36* (0.14) 0.18	1.20*** (0.37) 0.28
Number of observations	185	507
R^2	0.79	0.65
Hansen J statistic	3.00 0.08	0.07 0.79
F statistic of first-stage regression	17.33	6.60

Table 3: Tax index regressions, panel

Beta coefficients in parentheses, standard errors below. *** significant at 1%, ** at 5% and * at 10%. 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 all exogenous regressors plus cantonal agglomeration population and cantonal area as instruments. 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.

dep. var. = munic. tax index	2SLS		spatial GMM		OLS	
	1985	2001	1985	2001	1985	2001
Smallness	1.25 (0.12) 1.70	5.06* (0.29) 2.85	1.15 (0.11) 1.26	5.16** (0.29) 2.05	1.36 (0.13) 1.47	5.65** (0.32) 2.27
Cantonal tax index (instr.)	0.55*** (0.54) 0.13	0.94*** (0.72) 0.30	0.55*** (0.54) 0.09	0.90*** (0.69) 0.23	0.53*** (0.52) 0.14	0.84*** (0.65) 0.23
Population of municipality	−0.06 (−0.02) 0.25	−0.48 (−0.12) 0.37	−0.04 (−0.02) 0.19	−0.47* (−0.11) 0.25	−0.06 (−0.03) 0.23	−0.50 (−0.12) 0.35
Share of mun. pop. under 20	0.64 (0.21) 0.42	0.42 (0.06) 0.98	0.72** (0.24) 0.29	0.22 (0.03) 0.74	0.63 (0.21) 0.42	0.40 (0.05) 0.96
Share of mun. pop. over 65	−0.86** (−0.19) 0.40	−0.90 (−0.17) 0.70	−0.80*** (−0.17) 0.27	−1.02** (−0.19) 0.47	−0.84** (−0.18) 0.39	−0.78 (−0.14) 0.54
Area of municipality	0.02 (0.02) 0.10	0.43** (0.30) 0.18	0.01 (0.02) 0.07	0.44*** (0.30) 0.12	0.02 (0.02) 0.10	0.39** (0.27) 0.16
Urban center dummy	0.49** (0.36) 0.18	0.81** (0.35) 0.36	0.52*** (0.38) 0.11	0.89*** (0.38) 0.22	0.49*** (0.36) 0.17	0.77** (0.33) 0.33
Distance to freeway	0.02 (0.02) 0.17	0.25 (0.14) 0.29	0.04 (0.04) 0.13	0.15 (0.09) 0.20	0.02 (0.02) 0.17	0.25 (0.14) 0.28
Distance to airport	0.63*** (0.70) 0.16	0.50* (0.32) 0.26	0.59*** (0.65) 0.12	0.52*** (0.33) 0.19	0.63*** (0.70) 0.15	0.52* (0.33) 0.26
Lake shore	−0.01 (−0.05) 0.02	−0.02 (−0.09) 0.05	−0.01 (−0.05) 0.01	−0.02 (−0.07) 0.03	−0.01 (−0.06) 0.02	−0.03 (−0.13) 0.04
Latin dummy	−1.46*** (−0.37) 0.22	−2.22*** (−0.32) 0.57	−1.43*** (−0.36) 0.18	−2.28*** (−0.33) 0.44	−1.46*** (−0.36) 0.23	−2.17*** (−0.31) 0.52
Harmonized-tax dummy	0.17 (0.11) 0.21	−0.10 (−0.04) 0.35	0.18 (0.11) 0.17	−0.14 (−0.05) 0.26	0.17 (0.11) 0.21	−0.10 (−0.04) 0.33
Uri dummy	−1.86*** (−0.47) 0.43	−0.35 (−0.05) 0.80	−1.85*** (−0.46) 0.33	−0.25 (−0.04) 0.58	−1.83*** (−0.46) 0.41	−0.21 (−0.03) 0.71
St. Gallen dummy	−0.00 (0.00) 0.18	0.51 (0.15) 0.37	−0.01 (−0.00) 0.14	0.41 (0.13) 0.27	−0.01 (0.01) 0.15	0.51 (0.15) 0.37
Number of observations	37	37	37	37	37	37
R^2	0.84	0.77	0.84	0.76	0.84	0.77
Hansen J statistic	5.63 0.02	0.65 0.42	0.82 0.37	0.49 0.48		
F statistic of 1st-st. regression	14.25	4.65	20.52	8.91		
Moran I statistic of residuals	0.03 0.33	0.07 0.22			0.03 0.34	0.06 0.25

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

Beta coefficients in parentheses, standard errors below. *** significant at 1%, ** at 5% and * at 10%. 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 cantonal agglomeration population and cantonal area 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.

dep. var. = munic. tax index	2SLS		spatial GMM		OLS	
	1985	2001	1985	2001	1985	2001
Smallness	1.16** (0.15) 0.56	0.88 (0.08) 0.73	1.19** (0.15) 0.54	0.91 (0.09) 0.60	0.11 (0.01) 0.55	0.24 (0.02) 0.52
Cantonal tax index (instr.)	0.04 (0.04) 0.22	0.24 (0.22) 0.68	0.08 (0.09) 0.22	0.55 (0.50) 0.61	0.51*** (0.58) 0.10	0.87*** (0.79) 0.23
Population of municipality	0.06 (0.05) 0.15	−0.12 (−0.08) 0.27	0.02 (0.02) 0.15	−0.21 (−0.14) 0.24	−0.10 (−0.09) 0.13	−0.32*** (−0.21) 0.11
Share of mun. pop. under 20	−0.13 (−0.04) 0.28	−0.27 (0.05) 0.47	−0.19 (−0.06) 0.25	−0.22 (−0.04) 0.40	0.13 (0.04) 0.25	0.03 (0.01) 0.33
Share of mun. pop. over 65	−0.17 (−0.04) 0.45	0.43 (0.09) 0.80	−0.16 (−0.03) 0.44	0.41 (0.09) 0.75	−0.51 (−0.11) 0.36	−0.24 (−0.05) 0.35
Area of municipality	0.09 (0.11) 0.10	0.15 (0.14) 0.14	0.13 (0.14) 0.09	0.24** (0.22) 0.12	0.12 (0.14) 0.10	0.25** (0.23) 0.10
Urban center dummy	0.24* (0.15) 0.14	0.37 (0.19) 0.31	0.25* (0.16) 0.15	0.39 (0.20) 0.28	0.38*** (0.23) 0.11	0.53*** (0.27) 0.14
Distance to freeway	−0.09 (−0.11) 0.07	−0.02 (−0.01) 0.07	−0.08 (−0.09) 0.06	−0.01 (−0.01) 0.07	−0.07 (−0.08) 0.07	−0.04 (−0.04) 0.06
Distance to airport	0.49*** (0.52) 0.11	0.42*** (0.36) 0.16	0.47*** (0.50) 0.11	0.37** (0.31) 0.15	0.43*** (0.45) 0.10	0.32*** (0.27) 0.12
Lake shore	−0.03** (−0.15) 0.01	−0.04 (−0.19) 0.04	−0.02* (−0.13) 0.01	−0.04 (−0.16) 0.03	−0.02 (−0.09) 0.01	−0.02 (−0.08) 0.01
Latin dummy	−0.14 (−0.08) 0.22	−0.08 (−0.04) 0.64	−0.18 (−0.10) 0.22	−0.31 (−0.15) 0.60	−0.48*** (−0.27) 0.18	−0.69*** (−0.32) 0.21
Harmonized-tax dummy	−0.74*** (−0.38) 0.19	−0.90*** (−0.38) 0.19	−0.75*** (−0.39) 0.20	−0.86*** (−0.36) 0.18	−0.77*** (−0.40) 0.17	−0.93*** (−0.39) 0.18
Geneva dummy	−0.87** (−0.30) 0.41	−1.00 (−0.28) 0.81	−0.91** (−0.31) 0.42	−1.29** (−0.36) 0.74	−1.65*** (−0.57) 0.34	−1.77*** (−0.49) 0.40
Uri dummy	−0.57 (−0.07) 0.36	−0.00 (−0.00) 0.51	−0.57 (−0.07) 0.37	−0.22 (−0.02) 0.49	−1.13*** (−0.14) 0.27	−0.51* (−0.05) 0.35
St. Gallen dummy	0.67** (0.23) 0.29	1.53*** (0.43) 0.27	0.72** (0.25) 0.31	1.64*** (0.46) 0.27	1.14*** (0.39) 0.24	1.70*** (0.48) 0.21
Number of observations	102	101	102	101	102	101
R^2	0.66	0.63	0.67	0.69	0.73	0.73
Hansen J statistic	0.00 0.95	1.24 0.26	0.63 0.43	1.72 0.19		
F statistic of 1st-st. regression	15.14	1.41	15.90	1.28		
Moran I statistic of residuals	0.24 0.00	0.14 0.03			0.23 0.00	0.13 0.03

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

Beta coefficients in parentheses, standard errors below. *** significant at 1%, ** at 5% and * at 10%. 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 cantonal agglomeration population and cantonal area 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.

dep. var.	**Smallness**	Cant. tax rate (instrumented)	N° of obs.	R^2	Hansen J stat	First stage F stat
Personal Income						
single med. inc.	1.00*** (0.30) 0.30	0.57*** (0.45) 0.18	190	0.77	2.15 0.14	14.45
married med. inc.	1.01*** (0.25) 0.29	0.68*** (0.56) 0.14	190	0.83	1.19 0.27	8.06
married high inc.	1.38*** (0.36) 0.43	0.51*** (0.43) 0.19	190	0.80	3.56 0.06	13.70
Wealth						
200k	−0.31 (−0.03) 0.82	0.81*** (0.71) 0.23	190	0.90	2.63 0.10	3.46
5m	0.94*** (0.30) 0.27	0.97*** (1.17) 0.14	190	0.71	1.88 0.17	4.75
Corporate Income						
2%	−0.41 (−0.06) 1.09	0.27 (0.26) 0.42	185	0.75	1.60 0.21	5.31
9%	−1.62 (−0.34) 1.52	1.13* (0.95) 0.58	185	0.65	3.04 0.08	1.34
32%	1.44 (0.26) 1.26	0.28 (0.31) 0.37	185	0.51	4.59 0.03	8.61
Capital	−6.88*** (−0.88) 1.37	1.89*** (1.60) 0.31	185	0.51	6.05 0.01	17.93

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

Beta coefficients in parentheses, standard errors below. *** significant at 1%, ** at 5% and * at 10%. 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 cantonal agglomeration population and cantonal area 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.

dep. var.	**Smallness**	Cant. tax rate (instrumented)	N° of obs.	R^2	Hansen J stat	First stage F stat
Personal Income						
single med. inc.	0.07 (0.03) 0.17	−0.27 (−0.29) 0.54	512	0.30	1.06 0.30	6.33
married med. inc.	0.11 (0.03) 0.15	0.11 (0.10) 0.36	512	0.60	1.22 0.27	6.72
married high inc.	0.47** (0.17) 0.22	−0.02 (−0.02) 0.32	512	0.60	1.45 0.23	10.71
Wealth						
200k	−1.47 (−0.18) 2.83	1.77 (1.70) 2.19	512	0.51	2.80 0.09	0.34
5m	0.52** (0.23) 0.22	0.13 (0.21) 0.22	512	0.46	1.22 0.27	9.91
Corporate Income						
2%	0.26 (0.05) 0.93	−1.73 (−1.60) 1.48	507		0.46 0.50	0.65
9%	−0.38 (−0.09) 0.40	0.82* (0.66) 0.46	507	0.78	1.76 0.18	1.82
32%	−0.04 (−0.01) 0.46	0.82 (0.97) 0.67	507	0.64	2.60 0.11	1.83
Capital	−0.55 (−0.12) 0.53	−0.22 (0.21) 0.45	507	0.27	10.26 0.00	7.27

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

Beta coefficients in parentheses, standard errors below. *** significant at 1%, ** at 5% and * at 10%. 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 cantonal agglomeration population and cantonal area 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.