Interaction between Vertical and Horizontal tax Competition: Theory and Evidence

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Abstract

We develop a model with two provinces, producing two goods: one mobile and the other not. The mobile good is taxed according to the destination principle by the local government; it is also federally taxed. People decide to buy the good at the most advantageous price. Namely they can buy bootlegged cigarettes and, if the price is very high in both provinces, they can decide to buy smuggled cigarettes, on which no tax is levied. The two provinces engage in tax competition. The province tax-reaction function are non linear because of scale economies in the cost of bootlegging. An increase in federal tax offsets the non linearity, because it decreases the magnitude of the horizontal externality. We test the theoretical results by using Canada-US data set from 1984-1994.

Keywords: horizontal externality, vertical externality, tax competition, tax rate.
JEL classification: H21.

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1 Introduction

Vertical and horizontal fiscal relations must be explored if European nations want to increase the size of EU budget, by giving more fiscal power to the European Parliament. Italy is also nowadays, facing a similar problem after the recent approval by the Parliament of the Constitutional reform about the relationship between central state and regions. The new Constitution calls for more fiscal power to the regions which can be obtained only by letting some tax bases overlap.

There are federal provinces like US and Canada, where many tax bases overlap without apparently big problems. This seems to contrast with traditional fiscal federalism literature (Musgrave (1959); Oates (1972)) which prescribes a fiscal imbalance between federal and local government. Decentralization of fiscal expenditure does not correspond to the same level of decentralization for the taxes necessary to finace it: many taxes cannot be decentralized because of the tax-base mobility threat, which could arise tax-competition phenomena, unabling the local authority to raise the revenue it need. Moreover, a progressive income tax should be centralized to preserve horizontal equity between individuals living in different states of the federation. These problems seem not to worry Canada, where the main provincial tax bases (like corporate and personal income or sales) are shared with the federal government. What drives the public finance Canadian system to work, given so big a tax decentralization on mobile tax bases? One simple explanation may be that the mobility effect is very small. Another, more appealing, is that the particular relation between vertical and horizontal externality mitigate the effect of the tax-base mobility threat.

We explore this issue by using a model with two provinces choosing taxes on a mobile tax base, which is also taxed by a federal state. People decide to buy the good at the better price. Important differences in province's taxes can cause relevant bootlegging phenomena. These, in the cigarette market, involve (Thursby and Thursby, 2000) the purchase of goods in low tax jurisdictions. The goods are then transported into high tax provinces, where counterfeit stamps are used to allow their sale along. In general bootlegging involves transporting cigarettes over relatively short distances. In this context a change in tax by one province affects the other province's tax base (horizontal externality), that responds by changing its tax. On the other end the so-called "wholesale smuggling" is a very big threat on the revenue of all provinces (Joossens et al., 1992) in a federal country, which does not depend on the relationship between provinces' taxes. In this case, in fact, smugglers do not pay taxes either in the selling, or in the purchasing province. This type of smuggling is a big problem for those goods with high federal taxes. A change in tax by the federal government affects all provinces' tax base (vertical externality), inducing an appropriate reply by every province. In our model the greater the total tax (federal + state tax), the bigger the quota of total consumers in the province who decide to buy the good in the "wholesale-smuggling" market, causing a decrease in the provinces's tax base. Notice that, since this does not correspond to an increase in the other provinces's tax base as in the bootlegging case, it causes an increase in each state tax in the attempt to recover the lost tax revenue. On the contrary the tax-competition process, due to bootlegging and cross-border shopping drives tax rates to the bottom: tax rates, for a given federal tax, are lower than they would be without tax-base mobility. We use a data set 1984-1994 for Canada and US and test the effect of an increase in federal tax on cigarettes on the horizontal tax-competition on cigarettes. We find that the federal tax rate affects the neighboring average tax rate in explaining the variance of the own tax rate. In fact it offsets the non linearity of the tax-reaction functions.

The remainder of the paper is organized as follows: in the next section we examine the related literature, in the third and forth section we develop the theoretical model. Section 5 tests the model and section 6 concludes.

2 Related literature

Johnson (1988) first, highlighted that state residents would prefer redistribution to be undertaken by state rather than federal government. This is because part of the increase in the use of redistributive income taxation is born indirectly by residents of other states by virtue of their being federal tax payers. The federal government would be in fact obliged to increase its federal tax if it wants to respect its public budget constraint, giving the depressing effect on the tax base of the state deciding to increase the use of redistributive income taxation. On the line of this work Boadway, Marchand, Vigneault (1998) studied the implication of this externality phenomenon for the optimality of resources allocation in a federation. They explored the externalities in the bottom-up and top-down direction: both types of exernalities are present if we assume that the federal and state government play a Nash game; only the bottom-up (state versus federal government) holds if we assume a Stackelberg game. Moreover if the federal state can implement contingent transfers, vertical and horizontal externalities will be nullified. Keen and Kotsogiannis (2002) study the vertical and horizontal externalities in a model with capital taxation, where capital is mobile. They also examine the welfare properties of a Nash and Stackelberg equilibrium, highlighting the case when the vertical externality prevails on the horizontal and vice-versa.

There are some empirical works on vertical externalities. Besley, Rosen (1998) estimate the existence of vertical fiscal externalities for cigarettes and gasoline in US, by relating the own state tax rate to the federal government tax rate. They find a positive link between state and federal tax rate on cigarette and gasoline with a US data set for the year 1975 to 1989. Esteller-Moré, Solé-Ollé (2001) find a positive sign for vertical externality by using US data for income tax during the period 1987-96. This sign is not very robust to comparative statics. In fact in Boadway and Keen (1996) an increase in the federal public expenditure due to a higher federal tax rate can induce the local government to react by lowering local public expenditure and indeed local income tax rate (public expenditure effect). Andersson et al.(2004) find a negative sign, exploring the relation between counties and municipal income tax rates for Sweden with a panel data 1981-1990.

Other empirical literature concentrates on estimating vertical and horizontal fiscal competition togheter. Goodspeed (2000) uses a data set with 13 OECD provinces for the period 1975-1984. A poverty index is used as a measure of intra-province mobility: the poorer the less mobile people are, the smaller the horizontal externality. He uses local income tax as dependent variable and finds negative sign for the federal tax rate and for the mobility index. Boadway and Hayashi (2001), using Canadian annual data 1963-1996, test horizontal and vertical tax competition by looking at corporate taxes on businesses. They find a negative sign for the vertical externality and positive for the horizontal externality. Each estimate is for a single province or an average province. Revelli (2003) studies the non-metropolitan two-tier system of local government in England - comprising 34 counties and 238 districts - using per capita current expenditure for the financial year 2000/2001, disaggregated in various functions of interest. He finds that horizontal externality disappears when a vertical externality coefficient is introduced, arguing that the relevant externality is just the last one. Interestingly, with tax variables Devereux, Lockwood and Redoano (2004) find the opposite for US by using a panel data 1977-1997: vertical externality for cigarettes and gasoline is not significant if they also test for horizontal externality, which is significant.

Goodspeed (2002), extending some results of Goodspeed (2000), finds that the vertical externality affects the horizontal externality (measured as in Goodspeed (2000)) in an income tax enviroment, by offsetting it. However, the paper does not present structural explanations of the result.

3 The model

Consider a federation with two provinces with equal populations. Consumers in the two provinces differ in their utility function for preference for the local public good. Two goods are produced: a mobile taxed good and an immobile good, whose price we take as numeraire. The two goods are produced, by using one input with constant returns to scale. Each resident can decide where to buy the consumption good, according to the post-tax price and the cost of bootlegging the good. Each province decides upon a local public good and a tax on the mobile good according to the destination principle. The good can be transported not for personal consumption, but to be resold, from the low tax province to the high tax province (bootlegging) and in this case a combination of transport cost and storage cost is incurred to buy the good (Scharf, 1999). This is the relevant empirical situation we focus on, for cigarette tax in Canada.

Let us index the two provinces as 1 and 2. Both have the same number of residents, normalized to 1 and uniformly distributed over $n \in [0, 1]$. We assume that the extremum 0 is the border of the province. Since the residents are uniformly distributed, the distance of each resident from the border is $d \in [0, 1]$, coinciding with the distribution of the residents. Assume that each consumer in province 1 has the following utility function:

$$U(x,y) = u(x) + y + \gamma_s \ln g + \Psi \ln G \qquad \text{with } s = 1, 2,$$

where $x \in \{0,1\}$ is the taxed good; y is the numeraire no-mobile good, g is the local public good, G is the federal public good, $\gamma_1 \neq \gamma_2 > 0$ is a parameter which determines the preference for the local public good respectively in province 1 and 2, Ψ is a parameter, determining the preference for the federal public good, which we is assumed identical in each province and $u(0) = 0$. The source of heterogeneity between the residents in the two provinces is the propensity to consume the local public good.[1] A symmetric equilibrium would make no sense in a federation, whose nature implicitly recognizes the existence of structural and tastes heterogeneity.

The ln function let us have a clear-cut FOC for the public good, but this does not affect the final results, which is affected by the quasilinear formulation of the utility function. This says that there is no link between public and private good. It seems reasonable that there is not any public good, which increases the utility due to one more cigarette.

It is more difficult to justify the perfect substitutability with the untaxed good. There is no reason why this should not be linked to the taxed good, but on the other side this assumption allows to get a constant marginal utility of income, since we have only two private goods. This let us underline the deadweightloss effect, due to the tax on the x-good (Besley, Rosen, 1998): the more the tax rate increases, the greater the loss in utility, because the more it costs to consume 1 unit of the x-good. Since y enters linearly in the primitive utility function, this last result does not depend on the level of income.

The mobile good is dichotomous following the Kanbur and Keen (1993) formulation. This is of great help in obtaining tractable reaction functions. In the cigarette case it is, moreover, reasonable to think of the demand for these goods, as to be very rigid. Finally it helps to isolate the role of mobility in determining the change in tax-base elesticity after a change in its own neighbor's tax rate: if the demand is rigid the only determinant of the change of the tax-base elesticity is mobility.

3.1 The third stage

The following assumptions are useful (Rizzo, 2002):

Assumption 1: *$u(1) - p > 0$, where $r = u(1) - p$ is the reservation price for the mobile good, net of production cost, of a consumer living either in 1 or 2.*

The meaning of this assumption is that it is always worth it for the consumer to buy the good x when it is not taxed.

[1] This will later allow us to skip out symmetric equilibria, for which static comparative results are note definite.

Assumption 2: *The cost of bootlegging per* consumption unit is given by:

$$\phi(d) = \frac{\ln(1+d)}{A} \tag{1}$$

where d is the distance of the consumer from the border and $A \geq 1$ is a fixed parameter.

Think of the cigarette bootlegger, that, for a given quantity to be provided, minimizes its cost during a certain time period. This implies that, the further from the border the market place, the lower the optimal number of trips and the greater the amount of good purchased in every trip.[2] This decreases the fixed transaction cost per unit of consumption, which, with a non increasing per unit storage cost, insures concavity of the unit cost of bootlegging in the distance from the border (Scharf, 1999). In a stylized model, such as the one presented here, this reasoning can be summarized by a cost of bootlegging concave in the distance from the border.

Notice that (1) is an increasing and concave function of d and $\phi(0) = 0$. When $A \to \infty$, we are in the perfect mobility case, in fact $\phi(d) = 0 \ \forall d$, and $A = 1$ implies the minimum mobility case and therefore the maximum possible unit cost of bootlegging. Notice that the intensity of the scale economies in the bootlegging technology is captured by A: the higher A, the lower the unit cost of bootlegging per unit of distance from the border. Finally, $0 \leq d \leq 1$ implies $0 \leq \phi(d) \leq \frac{\ln 2}{A}$. We use a logaritmic function, because it let us get some interesting explicit results, which would have not been possible with a more general form, because of the ambiguous sign of the third order derivatives. We are indeed assuming that the magnitude of the third order derivatives is not so big to overcome the effects due to the second and first order ones.

3.1.1 The shopping technology

Let us define t_2 as the specific unit tax on the mobile good in province 2. Assume that $t_1 > t_2$, if assumption 1 holds and $t_1 + T \in [0, r]$, the consumer in 1 decides where to buy the good by comparing its indirect utility derived from buying the legal or the bootlegged good. If it shops bootlegged goods from 2, it pays $\phi(k) + t_2 + T$. Therefore the consumer will shop bootlegged goods from 2 until:

$$\phi(k) = t_1 - t_2.$$

If we use (1):

$$k = [\phi(t_1 - t_2)]^{-1} = e^{A(t_1 - t_2)} - 1 \tag{2}$$

Notice that the level of T does not enter in determining k, because the federal tax is identical in both provinces.[3] The variable k is the distance from the border

[2] Fitz Gerald et al. (1995) show evidence of this. They analyzed two case-studies: Germany-Denmark and Ireland-Northern Ireland. In both cases the greater the distance from the border, the greater the amount of goods purchased and the fewer the trips in any given period.

[3] This has also been highlighted in Devereux, Lockwood, Redoano (2004). It is the reason why, in a model with zero demand-elasticity of the taxed good (Kanbur and Keen, 2003), they do not get any vertical externality, even if mobility is allowed.

of the consumer in province 1, who is indifferent between shopping legally in 1 or a bootlegged good from 2. Moreover, since consumers in 1 are uniformly distributed on $[0, 1]$, k is also the number of residents in 1, buying bootlegged goods, for a given $t_1 - t_2$. Note that k is convex in t_1. The higher t_1, the bigger the increase in the number of people buying from 2, for a given increase in t_1 ($\frac{\partial k}{\partial t_1} > 0$ and $\frac{\partial^2 k}{\partial t_1^2} > 0$). This is because the higher t_1, the further from the border the indifferent consumer is, the lower the increase in the bootlegging cost is ($\frac{\partial^2 \phi}{\partial d^2} < 0$).

If $t_1 \leq t_2$, we obtain an expression symmetric to (13), with opposite properties for the second order derivative of the bootlegging cost function: $l = e^{A(t_2 - t_1)} - 1$.

3.2 The second stage

If assumption 1 holds, $t_1 \in [0, r]$ and $t_2 \in [0, r]$, it will always be economic for consumers in 1 to buy good x. In this case, taking account of the initial assumption that the number of people is normalized to 1 and using the results from the third stage, we have that if $t_1 > t_2$, $B_1 = 1 - k(t_1, t_2)$ and if $t_1 \leq t_2$, $B_1 = 1 + l(t_1, t_2)$, where B_1 is the tax base faced by province 1. We can simplify the notation by defining:

$$n(t_1, t_2) = \begin{cases} -k(t_1, t_2) & \text{if } \; t_1 > t_2 \\ l(t_1, t_2) & \text{if } \; t_1 \leq t_2. \end{cases} \tag{3}$$

It follows that:

$$B_1 = 1 + n(t_1, t_2)$$

where n is the mobile tax-base quota coming in or going out depending on which tax regime we are dealing with.

The same reasoning applies to province 2.

$$g - B_1(t_1 + T) \leq 0. \tag{4}$$

3.2.1 Tax evasion

Price differentials among provinces create incentive for bootlegging, while high taxes create incentive for *wholesale smuggling*, from now on simply smuggling. As already discussed in the introduction smuggling occurs when cigarettes are sold without payment of tax or duties even in the province of origin and, more important, this is a long distance phenomenon. Therefore it affects the tax base in all the federation, without regards to the distance from the border of the provided consumer. We model the tax base loss due to smuggling as:

$$E_1 = \alpha B_1 \left(t_1 + T \right) \tag{5}$$

where E_1 is tax evasion in province 1 and α is a constant, which reflects the level of controls and corruption in the province. Tax evasion in province 1 is a characteristic positively linked to the number of individuals (B_1), legally shopping in their province, if $t_1 > t_2$, plus those living in 2 and shopping bootlegged goods from 1, if $.t_1 \leq t_2$.

It is reasonable to think that tax evasion, which is driven by the quota of B_1, shopping in the smuggling market, increases when the total tax rate $(t_1 + T)$ increases. Moreover since tax evasion is increasing in B_1 and $(t_1 + T)$, tax evasion is also increasing in $B_1 (t_1 + T)$ for a given α. In (5) we assume that tax evasion is linked to this last expression by a linear function. Notice that if both provinces increase their tax, t_1 and t_2, of the same amount, B_1 does not change, but E_1 increases via t_1: if the level of state taxes increases of the same level, a quota of people in both states switches to smuggled products. The same thing happens if T increases.

3.2.2 The local government problem

If $t_1+T \in [0, r]$ and $t_2+T \in [0, r]$, in the second stage, province 1 maximizes the indirect utility function of a representative resident shopping at home, subject to a budget constraint, by solving the following problem:

$$\underset{t_1,g,\mu}{Max}\ u(1) + m - (p + t_1 + T) + \gamma_1 \ln g_1 + \Psi \ln G \tag{6}$$

$$-\mu \{g - (B_1 t_1 - E_1)\}$$

The following assumptions are useful:

Assumption 3: $r < \frac{1}{A}$.

The meaning of assumption 3 is that, the bigger the scale economies (the greater A) in the bootlegging technology, the smaller the unit net reservation price can be. The greater A is, the less costly to buy the bootlegged good.

Assumption 4: $0 < \alpha < \frac{3-\sqrt{5}}{2}$.

We assume that the quota of revenue lost, because people go to the smuggling market is no more than 0.38 of the total revenue (provincial + federal), collected in the province. This assumption defines the $\alpha - set$ which, together with assumptions 1-3, allows us to prove the existence of a subgame perfect equilibrium in federal and local tax rates and public goods.

3.3 The first stage: the federal government problem

The federal government maximizes a function which is the sum of the welfare functions of the two provinces (Boadway, Marchand, Vigneault, 1998; Keen, Kotsogiannis, 2002). The federal government moves first, by choosing G and

T, that maximize its objective function. After that, at the second stage, local governments choose their local tax rates and public goods and therefore:

Proposition 1: *If assumptions 1-4 hold then the Stackelberg game where a central authority chooses a federal tax rate and a federal public good, by maximizing a its welfare function, subject to a budget constraint and the two provinces choose their tax rates and public goods by maximizing their welfare function, subject to a budget constraint, has a subgame perfect Nash equilibrium.*

Proof: *see appendix.*

The existence of a federal tax induces each province belonging to the federation to modify its tax-rate decision, taking into account the effect on the resident's tax base of the federal tax.

4 The federal tax and the slope of the province reaction functions

An increase in T (section 3.2.1), decreases the revenue in both provinces, because smuggling increases, making the provincial tax base decrease. In our setting the tax reply to a neighboring tax increase is linked to the amount of tax base coming in from the increasing tax province, which decreases because of the federal tax increase. Therefore the magnitude of the horizontal fiscal externality decreases.

It is useful to look at the anlytical formula of the impact on the horizontal fiscal externality of an increase in the federal tax: $\frac{\partial L_1}{\partial t_2 \partial T} = -\mu \left[\alpha \frac{\partial n}{\partial t_2} - \frac{\partial^2 n}{\partial t_2} \frac{\partial t_2}{\partial T} \left(t_1 - \alpha \left(t_1 + T \right) \right) \right]$. A quota of the tax base "going to province 1", because of the increase in tax in the other province, $\frac{\partial n}{\partial t_2}$, is offset by the increase in tax evasion, due to the increase in T,$-\alpha \frac{\partial n}{\partial t_2}$.[4] *An increase in the vertical externality, offsets part of the horizontal externality effect.*

Since we can test this, by using the slopes of the tax rate reaction function, we start by totally differentiating the FOC of (11), to derive the slope of tax-rate reaction function of province 1, for a given marginal cost of public funds:

$$\frac{dt_1}{dt_2} = -\frac{\frac{\partial^2 n}{\partial t_1 \partial t_2} \left(t_1 - \alpha \left(t_1 + T \right) \right) + \frac{\partial n}{\partial t_2} \left(1 - \alpha \right)}{\frac{\partial^2 n}{\partial t_1^2} \left(t_1 - \alpha \left(t_1 + T \right) \right) + 2 \frac{\partial n}{\partial t_1} \left(1 - \alpha \right)} \tag{7}$$

(22) catches only the so called deadweight loss effect (Besley, Rosen 1998). According to this, a tax increase in province 2 leads to an increase of the tax rate in province 1: the deadweight loss, for a given marginal cost of public funds, is minimized by increasing its own tax and therefore its own revenue. Another effect is not considered: the revenue effect (Smart, 1998). This leads

[4] Moreover this effect is stronger if $t_1 > t_2$, because in this case $\frac{\partial^2 n}{\partial t_2} < 0$, due to the concavity of the bootlegging cost function. Conversely the effect is milder if $t_1 < t_2$. In this case in fact $\frac{\partial^2 n}{\partial t_2} > 0$.

to a decrease in tax rate after an increase in the neighbor's rate, because the government need a lower tax rate to raise the same level of revenue, after the increase in t_2: the marginal cost of public funds decreases. The final effect on the tax rate is therefore ambiguous. If this last effect is not very high, as it seems to be from the flypaper literature[5] (Inman, 1971; Case, Hines and Rosen, 1993), (22) can be considered a good proxy of the reaction function slope, obtained by endogenizing the marginal cost of public funds.

We describe the reaction function's slope, for given marginal cost of public funds and derive all the propositions, which will follow, for a given marginal cost of public funds, because we assumed welfare maximizing provinces and therefore face a six-sumultaneous equation system with six unknowns $(t_1, g_1, \mu_1, t_2, g_2, \mu_2)$. It is theoretically possible to partially solve the six-equation system and get a reaction function linking t_1 to t_2, where μ_1 is endogenized. Unfortunately this function is not properly estimable, because it would be a structural equation estimate of the six-equation system with a missing variable, namely the endogenized μ_1. We estimate, in fact, a linear approximation of :

$$1 - \mu\left[(1 + n(t_1, t_2))(1 - \alpha) + [t_1 - \alpha(t_1 + T)]\,\frac{\partial n(t_1, t_2)}{\partial t_1}\right] = 0,$$

which is the first order condition with respect to t_1 from the maximization of the welfare function of province 1.

From (22) we get:

Proposition 2: *If assumption 1-4 hold then, for a given marginal cost of public funds and a fixed* t_2, $\frac{dt_1}{dt_2} > 0$.

Proof: *see appendix.*

This is because an increase in t_2, decreases the migrating tax-base quota, for a given t_1, if $t_1 > t_2$, or increases the migrating tax-base quota, for a given t_1, if $t_1 < t_2$. Therefore if t_2 increases, province 1 is induced to increase t_1, with respect to the situation before the increase in t_2, in the process of providing g by minimizing its deadweight loss, for a given marginal cost of public funds.

Proposition 3: *If assumptions 1-4 hold, then the slope of the tax-rate reaction function when* $t_1 > t_2$ *is greater than the slope of the tax-rate reaction function when* $t_1 < t_2$, *for a given marginal cost of public funds and a given* t_2.

Proof: *see appendix.*

This proposition comes from the the concavity assumption of the cost of bootlegging in the distance from the border, which implies that the further people are from the border, the less the bootlegging cost increases when that distance from the border increases. In fact if $t_1 > t_2$, for a given increase in t_2 (which means a decrease in the distance from the border of the consumer in 1, who is indifferent to buy legally in 1 or bootlegged goods from 2), the increase in the number of people willing to buy legally in 1 decreases with t_2, for a

[5] We can think of the tax base flow, due to the increase in t_2, as money transfer to province 1.

given t_1. If $t_1 < t_2$, for a given increase in t_2 (which means an increase of the distance from the border of the consumer in 2, who is indifferent to buy legally 2 or bootlegged good from 1), the increase in the number of people illegally shopping increases with t_2, for a given t_1 (see fig. 1). Therefore province 1, for a given increase in t_2, is induced to increase more t_1 in the former case than in the latter one. In the former case an increase in t_1 causes a loss in the benefit from the increase in t_2, lower than in the latter case.

Proposition 4: *If assumption 1-4 hold then (a) a unit increase in the federal tax decreases the tax-rate reaction function slope if $t_1 > t_2$, moreover (b) it increases the tax-rate reaction function slope if $t_1 < t_2$, for a given marginal cost of public funds and a given fixed t_2.*

Proof: *see appendix.*

As we have just seen, if $t_1 > t_2$, for a given increase in t_2, the increase in the number of people illegally shopping goods bootlegged from 2 decreases with t_2, for a given t_1. The decrease is smaller when the federal tax increases, because tax evasion increases and a quota of tax base disappears. Therefore the loss in benefit due to an increase in t_1 after the increase in t_2 is higher than before the increase in the federal tax. That is why the reaction of 1 to an increase in t_2 is smother when T increases.

If $t_1 < t_2$, for a given increase in t_2, the increase in the number of people illegally shopping goods bootlegged from 1, increases with t_2, for a given t_1. A quota of this increase will disappear if we introduce the federal tax and so tax evasion increases. Hence, the loss in benefit due to an increase in t_1, after the increase in t_2 is lower than before the increase in the federal tax. That is why the reaction of 1 to an increase in t_2 is stronger after an increase in T.

4.1 Testable theory

In the paper we focus on assumption 2, which we think is the most reasonable for cigarette bootlegging and test the following hypotheses:

1) $\frac{\partial t_1}{\partial t_2} > 0$

2) $\left.\frac{dt_1}{dt_2}\right|_{t_1>t_2} > \left.\frac{dt_1}{dt_2}\right|_{t_1<t_2}$

3) $\left[\left.\frac{dt_1}{dt_2}\right|_{T>0} - \left.\frac{dt_1}{dt_2}\right|_{T=0}\right]_{t_1>t_2} < 0$ and $\left[\left.\frac{dt_1}{dt_2}\right|_{T>0} - \left.\frac{dt_1}{dt_2}\right|_{T=0}\right]_{t_1<t_2} > 0$

Assumption 2 is indirectly tested, by veryfing its effect on the reaction function slope (inequality 2). After doing that, we test wheather the difference in slopes is affected by the existence of the federal tax (inequality 3).

5 The empirical test

Our main goal is to estimate if there is any significant strategic link between federal and provincial taxation, when tax is levied on the same tax base. In the literature this has been done by regressing local tax rate on federal tax rate

(Besley, Rosen, 1998). The method normally prevents from checking for year effects, because the federal tax rate in a panel-data set does not have the state dimension and the insertion of the year effects results into an insignificant coefficient for the federal tax rate. The typical objection in these works is that the federal tax-coefficient is significant because it picks up yearly macroeconomics shocks. A way out of this problem could be to estimate the effect of a change in federal tax on the tax-competition behaviour, which shows off when the tax base is mobile. If an increase in federal tax affects the tax-rate choice of a province, given the tax rate on the same mobile tax base of a neighboring province, it means that there is a link between the tax rate, chosen at federal and local level on the same tax base. This is also, what our theory shows: if a federal authority intervenes by introducing a central tax, it modifies the local tax base and increases the deadweight loss each local authority would bear with only its local tax; this implies that a local authority modifies the choice of its tax and so the tax-rate answer to an increase in tax rate from a neighboring state. We test this idea by using a Canada-US data set from 1984-1994.

In our case we argue that tax competition is due to bootlegging. This is likely to happen between border provinces: the further a province from the other, the more costly (in transport terms) is to bootleg. At a first glance bootlegging could not appear a relevant threat for the provincial tax base in the Canadian reality, where provinces are very big and densities very low. But at a further inspection, almost all the Canadian population lives near the US border. Notice that eight, out of the ten considered provinces,[6] border the US. This means that population in each of these provinces is concentrated along a line, which makes the bootlegging threat between provinces or the US a relevant problem. This is reinforced by the fact that in two, out of the eight provinces bordering the US (Nova Scotia, New Brunswick), bootlegging is a relevant issue, just because they are very small. The two provinces not bordering the US are P.E.I, which is very small and Newfoundland which is basically extended along the Quebec border: both characteristics play an important role for the relevance of bootlegging.[7]

In order to isolate the independent impact of the neighboring tax rates on the Canadian province tax, one must take into account other variables, that might affect the provinces tax rate. First of all we control for the US neighboring tax rates. Moreover the province's tax rate on commodities depends on several other types of variables. Province taxation can be influenced by economic and

[6] We excluded the three Territories Nunavut, Northwest Territories and Yukon because they represent a very small part of Canada in terms of population, income and tax base.

[7] How Canadian provinces relate their tax decisions on cigarettes seems to be an important issue, according to the provisional agenda on tobacco control of the World Health Organization meeting in 1999: "differentials in the price of tobacco....lead to both casual cross-border shopping and illegal bootlegging. Cross-border sales may occur within countries, such as Canada and United States, given the intracountry price differences among Canadian provinces and states within the United States". Moreover, this issue seems to worry also the national print: "Cigarettes are smuggled interprovincially by road, through mail-order operators, by commercial couriers ....The smugglers have little fear of the law." (Moon, The Globe and Mail, 28 June 1997)

demographic environment. We controlled for it by using many socio-economic variables (see data appendix). For all of them we computed the corresponding mean variables of the neighboring Canadian provinces and neighboring US states to each Canadian province. The political colour of the provincial government can also affect the tax-rate level: we divided the Canadian party system in three main groups: the conservative-progressive, which is right wing, the liberals, which is center, and left wing group, composed by the Democratic-Progressive, the Quebec party and the Social Credit party. We have then built dummies for the case when the premier belongs to one of the three groups. Finally we have dichotomous variables to control for province and year effects. We estimate the following equations:

$$t_{st} = \varsigma_s + \delta_1 h_{st} + \delta_2 v_t + \delta_4 EXPE_{st} + \delta_5 m_{st} + \vartheta x_{st} + \epsilon_{st} \tag{8}$$

$$t_{st} = \alpha_s + \beta_t + \lambda_1 h_{st} + \lambda_2 v_t * h_{st} + \lambda_3 EXPE_{st} + \lambda_4 m_{st} + \theta x_{st} + \epsilon_{st}, \tag{9}$$

where: t_{st} is the tax rate for province s and year t; α_s are province fixed effects; β_t are dummies variables that pick up for macro-shock and common change in fiscal policies; x_{st} is a vector of province specific time varying shocks; h_{st} is the tax-rate average of the neighboring provinces of province s in year t; v_t is the federal tax rate in year t; $EXPE_{st}$ is the ratio of the total expenditure on GDP for province s in year t; m_{st} is the tax-rate average of the neighboring US states of province s in year t; ϵ_{st} is the error term.

Equation (8) estimates the effect of an increase in federal tax, by omitting year effects and using some invariant year controls (federal GDP and federal unemployment). Equation (9) estimates the effect of an increase in federal tax through the tax-competition coefficient, controlling for year and province effects.

5.1 Hypotheses

Equation (8) estimates two parameters: δ_1, which is the tax-rate reaction coefficient to an increase in the tax-rate average of the neighboring provinces and δ_2, which is the tax-rate reaction coefficient to an increase in federal tax-rate. Here, we take the traditional approach, estimating the link between a federal tax and a local tax, levied on the same tax base.

Equation (9) does not include the federal tax, but the interaction term $v_t * h_{st}$ and controls for year effects. The interaction accounts for the change in tax-rate reaction to an increase in the tax-rate average of the neighboring provinces, after a change in federal tax. From our theory, δ_3 could be both positive, or negative, depending on the prevailing tax regime ($t_{st} > h_{st}$ or $t_{st} < h_{st}$).

We estimate $\lambda_1 = \gamma_1 + \gamma_2 \psi$ and $\lambda_2 = \gamma_3 \psi$, where ψ is a dummy which equals 1 for provinces where $t_{st} > h_{st}$. Therefore γ_1 is the slope of the tax-rate reaction function in the case $t_{st} < h_{st}$ and $\gamma_1 + \gamma_2 + \gamma_3 v_t$ is the slope of the tax-rate reaction function in the case $t_{st} > h_{st}$, for a given federal tax rate v_t. Proposition 3 predicts $\gamma_2 + \gamma_3 v_t > 0$: the slope of the tax-rate reaction function in the case $t_{st} > h_{st}$ is higher than in the case $t_{st} < h_{st}$. Moreover proposition 4 predicts $\gamma_3 < 0$: when $t_{st} > h_{st}$, an increase in the federal tax rate decreases the coefficient of the rate reaction function, due to an increase in the tax-rate average of the neighboring provinces.

We then estimate $\lambda_1 = \varphi_1 + \varphi_2 (1 - \psi)$ and $\lambda_2 = \varphi_3 (1 - \psi)$, where φ_1 is the slope of the tax-rate reaction function in the case $t_{st} > h_{st}$ and $\varphi_1 + \varphi_2 + \varphi_3 v_t$ is the slope of the tax-rate reaction function in the case $t_{st} < h_{st}$, for a given federal tax rate v_t. Proposition 3 predicts $\varphi_2 + \varphi_3 v_t < 0$: the slope of the tax-rate reaction function in the case $t_{st} < h_{st}$ is lower than in the case $t_{st} > h_{st}$. Proposition 4 says that $\varphi_3 > 0$: when $t_{st} < h_{st}$, an increase in the federal tax rate increases the coefficient of the tax-rate reaction function, after an increase in the average rate of the neighboring provinces.

5.2 Estimation Strategy

In theoretical section we describe a two stage game a la Stackelberg. We are empirically interested in the second stage where we face a system of six simultaneous equations: three from the solution of the optimal tax problem of province 1, which determines t_1, g_1 and μ_1, for a given t_2; and three from the symmetric tax problem solved by province 2, which determines t_2, g_2 and μ_2, for a given t_1. In the empirical specification we can think of t_1 as the Canadian province tax rate (t_{st}) and t_2 as the mean of the neighboring province tax rates (h_{st}). By using not all the neighboring variables but just the mean, we reduce the empirical situation to a two-province problem: each province competes with one fictitious (average) neighboring province. This is quite a usual procedure in the literature (Hines et al. 1993; Besley, Rosen 1998; Brueckner, Saavedra 2001; Esteller-Moré, Sollé-Ollé, 2001), especially when the spatial dimension must be emphasized.

Like all studies of social interactions, this economic framework suffers from an identification problem of the model's structural equations and a simultaneity bias of the standard errors of the equation estimated. The issues arise because tax-rate interactions are symmetric, in the sense that each province's behavior affects that of its neighbors in the same way, the neighboring provinces behavior affects the province's own behavior, which feeds back again on the neighbors.

We tackle these two problems firstly by identifying one of these six equations, the first order condition with respect to the tax choice of province 1; and secondly, by instrumenting the endogenous variables to cope with the endogeneity bias. We have two endogenous variables, if we assume a Stackelberg model: the average neighboring tax rate, t_2, and the marginal cost of public funds, μ_1. In a model of simultaneous equations, the federal tax rate is also endogenous. If we want to correctly identify the estimated equation, we need variables which are correlated with t_2, $\mu_1$and T (if we use a simultaneous decision model), but not to t_1.

Equation (9) can be written as follows:

$$t_{st} = \alpha_s + \beta_t + \gamma_1 h_{st} + \gamma_2 \psi h_{st} + \gamma_3 \psi v_t h_{st} + \gamma_4 EXPE_{st} + \gamma_5 m_{st} + \theta x_{st} + \epsilon_{st} \quad (10)$$

The vector x is composed by 23 variables: INC_{st} and its square, $GRANT_{st}$, $UNEMP_{st}$, GDP_{st} (per-capita GDP), POP_{st}, $AGED_{st}$, $CHILD_{st}$ and $DENS_{st}$;

the neighboring Canadian variables for INC_{st} and its square, $GRANT_{st}$, $UNEMP_{st}$, GDP_{st}, $DENS_{st}$ and symmetric variables for the neighboring US provinces, two dummies for the political colour of the premier. Moreover macroeconomic shocks and province fixed effects are controlled through 10 dummies for year effects and 9 dummies for province effects.

5.2.1 Instrumentation

The mean Canadian neighboring tax rate and its interactions are endogenous, because they can also be influenced by the Canadian province. The marginal cost of public funds (endogenous from the theoretical model) is proxied with total government expenditure over GDP ($EXPE_{st}$), using the first order condition of the theoretical model relative to the optimal choice of the public good.[8] The mean neighboring US tax rate, m_{st} could clearly be endogenous: the US rate mean can also be influenced by the Canadian province.

If this is the structural model, a simple OLS estimate of (10) would suffer from endogeneity and measurement error bias: the error term ϵ_{st} would be correlated with the error terms of the other simultaneous equations of the system. The endogeneity bias comes from the fact that we are dealing with simultaneous equations; the measurement error bias is because we have no exact measure of the marginal cost of public funds, μ, that we have had to proxy. We use the two-stage least squares method: first we estimate the reduced forms of the six endogenous variables and then we substitute their fitted values into (10). The residuals of this last equation are corrected by using the actual values of the endogenous variables.[9]

We define a vector of instruments, composed by 10 variables: $GRANT, INCTAX$,and the mean Canadian and US neighboring variables for $POP, AGED, CHILD$ and $INCTAX$. We argue that these variables, not appearing in (10), affect $h_{st}, \psi h_{st}, \psi v_t h_{st}$, $EXPE_{st}$ and m_{st}, but are uncorrelated with t_{st}. The vector allows us to identify equation (10), which has five endogenous variables.

We instrumented the mean Canadian neighboring tax rate $h_{st}, \gamma\psi h_{st}, \psi v_t h_{st}$ with the neighboring Canadian variables for POP_{st}, $AGED_{st}$, $CHILD_{st}$ $INCTAX_{st}$.

The level of taxation, and in a reduced form equation also the tax rate on cigarettes, is in fact normally linked to the size of population: these variable influence the available tax base and the cost of public goods. Moreover age structure influences taxation, according to the relative preference for social policies. It is reasonable to think of these neighboring variables not affectinng the

[8] The first order condition with respect to g is:

$$\frac{\partial L}{\partial g} = \frac{\gamma_1}{g} - \mu = 0.$$

For more analytical details see appendix.

[9] The two-stage least square strategy would deliver residuals using the fitted values of the endogenous variables. Since we are estimating the structural model, we are interested in the residuals using the actual values of the endogenous variables.

We execute the procedure, by using the *ivreg* command of STATA, which already gives the corrected residuals with the actual values of the endogenous variables.

province' s tax rate on cigarettes. The inclusion of $INCTAX_{st}$ is explained by the fact that the federal income tax can influence the provincial tax and therefore provincial taxes on cigarettes in a reduced form equation (Besley, Rosen, 1998).

We instrumented the mean US neighboring state tax rate with the same corresponding variables.

Spatial error dependence can arise when the error includes some omitted variables not captured in the covariates, which are themselves spatially dependent. If the spatial dependence is ignored, estimation may be bayesed (Brueckner, 2001; Brueckner and Saavedra, 2001). We sort out this problem by controlling for more than one variable, giving reason of the neighboring economic enviroment: the neighboring Canadian variables for INC_{st} and its square, $GRANT_{st}$,$UNEMP_{st}$, GDP_{st} and symmetric variables for the neighboring US provinces. These variables, if omitted, can generate a spurious correlation between its own tax and the neighboring tax or other exogenous covariates.

Finally, we instrumented also $EXPE_{st}$ with $GRANT_{st}$ and $INCTAX_{st}$. These two variables are all important in determining the tax rate on cigarette not directly, but indirectly trough the level of public expenditure. The more grant a province receives, the higher its public expenditure for a given level of taxation. The inclusion of $INCTAX_{st}$ is explained by the fact that the federal income tax, can influence the provincial income tax and therefore the provincial total revenue. (Besley, Rosen, 1998)

It is important to notice that $GRANT_{st}$ and $INCTAX_{st}$ can also proxy time-varying provincial shocks (business cycle) and so result in missing variables in the second stage equation. We control for this in the second stage equation, using $UNEMP_{st}$, INC_{st} and its square, and GDP_{st}.

Moreover, in the second stage equation we also control for POP_{st} and its square, $CHILD_{st}$, $AGED_{st}$ and $DENS_{st}$. We control finally for the effect of politics on the tax-rate choice, by using two dummies accounting for the governor progressive-conservative and liberal. We also control for year and province effects. We reply the same estimate for the complementary tax regime $t_{st} < h_{st}$.

After performing the two-stage least square regressions we test the validity of the instruments, regressing the residuals from the second stage equation on the instruments and all the exogenous variables, running an F-test on the joint significance of the instruments.

We also estimate (9), where the federal tax-rate is in, instrumenting it with the federal deficit (therefore the instruments variables become 11), when we test for the simultaeous decision model: it is reasonable that the federal deficit influences the choice of the federal tax, but not the choice of the local tax. In this case, since we do not have fixed year effects, we control for cyclical macroeconomics shocks with federal GDP and federal unemployment. The estimated equation is identified because the endogenous variables are four (h_{st}, v_t, m_{st}, μ_{st}) and the instruments eleven.

5.3 Results

We start, by testing for vertical externality only (table 2, column 1), controlling for socio-eonomic characteristics, province effects and yearly macroeconomic shocks. The coefficient of the federal tax turns out to be 0.82 and significant at 1%. In the second column we add the neighboring tax variables for Canada and US: the coefficient decreases of more than 100% (0.39) and it becomes significant at 5%. If then we control for the neighboring economic enviroment, by adding some neighboring socio-economic variables, the mean of the Canadian neighboring tax rates remain almost the same, whereas the federal tax rate coefficient decreases of almost 50% and is no more significant.

In table 3 column 1 we run a two stage least square regression, where, according to our theory (Stackelberg model), we instrument the mean Canadian neighboring tax rate. We get a significant horizontal tax-competition coefficient, and again not significant vertical tax competition coefficient, but with a much lower t-statistics than before.[10] This regression performs a very bad overidentification test (p-value=0.04). It means that the instruments are not good, or that the specification is not correct because some variable, correlated with the instuments is missing.[11]

In column 2 we try a specification, where the federal tax is instrumented (simultaneous tax decision between different government levels). The federal tax coefficient becomes bigger, but still not significant. The overidentification test is better (0.19), but still not satisfactory at all. We, therefore, estimate (column 3) a new regression, where we add an interaction of the neighboring tax with a dummy accounting for the case when $t_{st} < h_{st}$, and do not instrument the federal tax: we get a coefficient for the federal tax very similar to that of column 2 and the neighboring tax coefficient a bit bigger, but interestingly the overidentification test jumps to 0.45. This is still not satisfactory, but it gives a hint that the previous specification (column 1, table 3) was not correct and that the problem was not the endogeneity of the federal tax, but the missing interaction.

However in the regression of column 3, we do not obtain significant t-statistics for both the interaction term and the federal tax-rate coefficient. In this regression, even if we do not use year effects, we control for macroeconomic shocks, by using federal GDP and federal unemployment, which are very collinear to the federal tax, a province invariant variable. This, with the inclusion of the mean neighboring rate, which, if a vertical tax externality holds (Besley and Rosen, 1998 for US cigarette and gasoline tax), could cause the low

[10] Note the interesting difference with the opposite result in Revelli (2003), where the decision variable is public expenditure: the introduction of a control for expenditure from a higher government layer makes the horizontal externality disappear. On the converse this result is confirmed by Devereux, Lockwood and Redoano (2004) findings.

[11] The residuals could include this variable, which, if related with the instruments, will also be reflected in the coefficients of the instruments, when we regress the residuals on all the covariates plus the instruments to test the null hypothesis that the instruments are jointly different from 0. It follows that the test is weakened by the correlation between the instruments and the missing variable which is included in the residuals.

t-statistic for the federal tax coefficient and the interaction term. A way out from this puzzle is to estimate a fixed-effect model, dropping the federal tax coefficient. We also adopt a more accurate specification of the interaction term, according to the tax regime, which follows our theoretical model.

Specifically, we look at the interaction of the federal tax with the tax-competition coefficient. We (column 1, table 4) estimate the horizontal tax-competition coefficient for a given v_t, when $t_{st} < h_{st}$, $\varphi_1 + (\varphi_2 + \varphi_3 v_t)$, and the effect on this coefficient of an increase in the federal tax: φ_3. In a second regression (table 4, column 2), we repeat the same test for the case $t_{st} > h_{st}$, estimating the coefficient $\gamma_1 + (\gamma_2 + \gamma_3 v_t)$ and the effect on the coefficient of an increase in the federal tax: γ_3. The direct federal tax effect is accounted for in the year effects. We used the same instruments as before. In the first regression (column 1) $\varphi_2 = -2.994$ with not very high t-statistics (this can be due to correlation with the other tax-rate terms) and $\varphi_3 = 1.547$ and more than 5% significant. It means that if $t_{st} < h_{st}$ then the tax-rate slope decreases with respect to the other complementary tax regime (proposition 3). This trend is counteracted by φ_3, which is positive (proposition 4): the greater the increase in the federal tax, the bigger the tax-rate slope. Notice that the overidentification test (F>0.8) increases considerably with respect to the previous regression in column 3, table 3: the added variables, related to the tax regime were really missing in the previous regression. When we estimate the second regression (column 2) we get $\gamma_2 = 3.061$ and $\gamma_3 = -1.61$; both coefficients are more than 5% significant: if $t_{st} > h_{st}$, then the tax-rate slope increases with respect to the other complementary tax-regime (proposition 3). This trend is contrasted by γ_3, which is negative (proposition 4): the bigger the increase in the federal tax-rate, the smaller the tax-rate slope. Also in this case the overidentification (F >0.86) btest is much higher than in that of column 4, table 2.

The reason why we use two regressions to estimate the effect of an increase in federal tax on tax competition in the two different tax regimes, is that the tax rates in the two tax regimes are quite correlated (correlation index:-0.54). In fact, if we put them together (column 3, table 3), the t-statistics become very low, but interestingly the coefficients do not change a lot. The coefficients of the neighboring tax (computed as function of the federal tax, when it is set equal to 1) for the case $t_{st} > h_{st}$ is downward biased (3.061-1.610-0.162= 1.289 instead of 3.014-0.119-1.381= 1.514). This is because the interaction in column 3 is positive (1.442) and the correlation between the interactions relative to the two regimes is negative. There is a very slightly positive bayes in the coefficient of the neighboring tax (computed as function of the federal tax, when it is set equal to 1) for the case $t_{st} < h_{st}$ (-2.994+1.547+1.529= 0.082 instead of 1.442-1.381= 0.061). Analogously the reason for the bias is that the interaction in column 3 is negative (-0.119) and the correlation between the interactions relative to the two regimes is negative.

Notice that in both regimes the coefficients of the neighboring taxes interacted with the federal taxes in column 1 and 2 of table 4 mantain the signs they have in column 3 of table 4, which are those predicted by the theoretical model: -0.119 (column 3), -1.610 (column 2) and 1.442 (column 3), 1.547 (column 1).

6 Conclusions

We theoretically assess the effect of federal and local tax base overlapping, when the tax base is mobile and rection functions are non linear, because the cost of moving the tax base from one province to another is non linear in the distance from the border. The introduction of a federal tax decreases the fiscal externality due to tax base mobility. In our model, this means partial offsetting of the non linearity of the reaction functions.

We test whether the provincial governments of Canada are aware of this mechanism, by looking at provinces changes of tax rates if neighboring provinces change theirs and so the federal government. We derive the reaction function slopes according to two different complementary tax-rate regimes, which are also function of the federal tax.

The paper develops a test of the theoretical result by using a data set for Canada and US running from 1984 to 1994, with sales taxes and specific cigarette taxes.

We show evidence that an increase in the federal tax decreases tax competition due to tax-base mobility, by offsetting the non-linearity of the reaction functions. This result has a fiscal policy relevance: tax-base overlapping could also have some beneficial effect, when tax bases are mobile. Namely if a federal tax is implemented on a mobile tax base, there would be less need for inter-state or provincial compensating transfers. Notice that the vertical externality has always been seen as source of inefficiency in tax decisions; Keen, Kotsogiannis (2002); Boadway, Marchand, Vigneault (1998); Goodspeed (2002)).

Several extensions of this work are possible. On the empirical side, it would be useful to collect data on border densities and border lengths. It is reasonable to think that each state fixes its tax rate, being aware of the neighboring rates, where population density near the border and the length of the border are greater. On the theoretical side it would be interesting to explore the political economy reasons, which could determine the ambiguous sign of the vertical externality found in previous literature: friendly provinces could decide to sustain the federal authority willing to increase the federal tax, by decreasing theirs, others, not friendly, could do the opposite.

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7 Data Appendix

t_{st} is the Canadian cigarette tax rate, inclusive of general sales tax, for province s in year t, divided by the CPI and PPP index. These rates are from the National Clearinghouse on Tobacco and Health for Canada: the tax rates are already provided as the sum of the unit tax-equivalent of the general sales tax plus the unit tax rate. They are expressed in Canadian dollars per pack of 20.

7.1 Endogenous variables

v_t federal Canadian cigarette tax rate, inclusive of general sales tax. This is also from the National Clearinghouse on Tobacco and Health for Canada.

h_{st} is the mean of the tax rates in year t of the Canadian provinces neighboring on province s, divided by the CPI and PPP index.

m_{st} is the mean of the tax rates of the US states neighboring province s in year t. The tax rates on cigarettes for the United States are taken from www.library. unt.edu/gpo/acir/acir.html: they are expressed in US dollars per pack of 20 cigarettes. Tax rates on sales are also taken from www.library.unt.edu/ gpo/acir/acir.html: they are expressed in percentage of the price. The final tax rate is calculated by taking the unit-tax equivalent of the general sales tax (which is obtained multiplying the general sales tax-rate by the price), adding this to the unit tax-rate.

$EXPE_{st}$ is the total province expenditure divided by the GDP for province s in year t. Total province expenditure comes from www.statcan.ca for Canada.

7.2 Demographic and economic variables

POP_{st} is the number of persons in province s in year t. It comes from www.statcan.ca for Canada and www.census.gov for the United States.

$DENS_{st}$ is calculated as the total population (POP_{st}) divided by the area for province s in year t. Areas are expressed in square miles: for Canada from www.statcan.ca/english/Pgdb/Land/Geography/phys01.htm and for the US from http://quickfacts.census.gov/qfd/index.html.

$CHILD$ ratio of individuals who between 5-17 to the total population of province s in year t. The number of individuals who are between 5-17 comes from www.statcan.ca for Canada and www.census.gov for the United States.

$AGED_{st}$ ratio of individuals who are over 65 to the total population of province s in year t. The number of individuals who are over 65 comes from www.statcan.ca for Canada and www.census.gov for the United States.

$UNEMP_{st}$ unemployment rate for province s in year t. From www.statcan.ca for Canada and from www.stats.bls.gov for the US.

INC_{st} per-capita income for province s in year t divided by the CPI and PPP index. Income comes from www.statcan.ca for Canada and from www.bea.doc.gov for the US.

$GRANT_{st}$ federal grant-in-aid over GDP for province s in year t. Federal grant-in-aid comes for the US from "Federal Expenditures by State" which is part of the Consolidated Federal Funds Reports program from US Census Bureau and for Canada from www.statcan.ca.

GDP_{st} per-capita GDP for province s in year t. GDP comes from www.statcan.ca for Canada and www.bea.doc.gov for the US.

$INCTAX_{st}$ federal tax revenue over GDP for province s in year t. Federal tax-revenue comes from www.statcan.ca for Canada and from www.bea.doc.gov for the US.

We computed two dichotomous variables to account for the party of the premier (Progressive Conservative and Liberal).

From http://www.swishweb.com/Politics/Canada.

The PPP (Parity Purchasing Power) index for Canada-US was downloaded by the OECD web site.

US cigarettes price per pack comes from The Federal Tax Burden on Cigarettes, Vol. 27, 1996.

The CPI comes from the Statistical Abstracts of the United States (2000).

8 Appendix

Recall that the provincial government solves the following problem:

$$\underset{t_1,g,\mu}{Max}\ u(1) + m - (p + t_1 + T) + \gamma_1 \ln g_1 + \Psi \ln G. \tag{11}$$

The federal government, given the second stage equilibrium tax rates of the local governments, solves the following problem:

$$\underset{T,G,\Omega}{Max} 2u(1) + 2m - 2p - 2T - t_1 - t_2 + 2\Psi \ln G + \gamma_1 \ln g_1 + \gamma_2 \ln g_2 \tag{12}$$

$$-\Omega \left[G - (2T - E_1 - E_2)\right]$$

where Ω is the marginal cost of federal public funds, $E_1 = \alpha (t_1 + T) B_1$ is province 1's government estimate of the revenue loss due to tax evasion linked to the sum of local and federal revenue raised from the same tax base, $B_1 = 1 + n(t_1(T), t_2(T))$, and $E_2 = \alpha (t_2(T) + T) B_2$ is province 2's government estimate of the revenue loss due to tax evasion linked to the sum of local and federal revenue raised from the same tax base, $B_2 = 1 - n(t_1(T), t_2(T))$; $n(t_1(T), t_2(T))$ represents mobile people, affecting local tax bases: this depens on T through $t_1(T)$ and $t_2(T)$,which are the second stage Nash-equilibrium tax-rates. Therefore the federal budget constraint can be written as: $G - 2T +$
$\alpha [t_1(T) + T][1 + n(t_1(T), t_2(T))] + \alpha [t_2(T) + T][1 - n(t_1(T), t_2(T))] \geq 0.$

8.1 Some results from the paper

If $t_1 > t_2$:

$$k = [\phi(t_1 - t_2)]^{-1} = e^{A(t_1 - t_2)} - 1 \tag{13}$$

where k is the distance from the border of the consumer in province 1, who is indifferent between shopping legally in 1 or a bootlegged good from 2. Moreover, since consumers in 1 are uniformly distributed on $[0, 1]$, k is also the number of residents in 1, buying bootlegged goods, for a given $t_1 - t_2$.

If $t_1 \leq t_2$:

$$l = [\phi(t_2 - t_1)]^{-1} = e^{A(t_2 - t_1)} - 1 \tag{14}$$

where l is the distance from the border of the consumer in province 2 who is indifferent between shopping legally in 2 or bootlegged goods from 1. l is also the number of residents in 2, buying bootlegged goods, for a given $t_2 - t_1$. Finally:

$$n(t_1, t_2) = \begin{cases} -k(t_1, t_2) & \text{if } t_1 > t_2 \\ l(t_1, t_2) & \text{if } t_1 \leq t_2. \end{cases} \tag{15}$$

8.2 Proofs

Lemma 1: *If assumptions 1-2 hold, the second stage subgame tax-rate equilibrium strategies must necessarily belong to* $t_1 \in \left[\frac{\alpha}{1-\alpha}T, r - T\right]$ *and* $t_2 \in \left[\frac{\alpha}{1-\alpha}T, r - T\right]$.

Proof: Assume that at the second stage $t_1^* \in \left[0, \frac{\alpha}{1-\alpha}T\right[\,]r - T, +\infty[$ is a feasible strategy for some t_2, then $W(t_1^*, t_2, T) > W(t_1^{**}, t_2, T)$, where $t_1^{**} \in \left[\frac{\alpha}{1-\alpha}T, r - T\right]$.

This is a contradiction because $t_1^* \in \left[0, \frac{\alpha}{1-\alpha}T\right[$ implies $g < 0$, which cannot hold, because one of the constraints of the local government problem is $g \geq 0$. Moreover if $t_1 + T > r$, then $g = -k(t_1, t_2)\left[t_1 - \alpha\left(t_1 + T\right)\right] < 0$, when $t_1 > t_2$ and $g = 0\left[t_1 - \alpha\left(t_1 + T\right)\right]$, when $t_1 < t_2$. The former case cannot hold for the reason just discussed and the latter case would imply $W = -\infty$ and so, if we use assumption 2, $W(t_1^*, t_2, T, G) = m + \gamma_1 \ln(0) \leq W(t_1^{**}, t_2, T, G) = u(1) - p - t_1^{**} - T + m + \gamma_1 \ln\left\{(1+n)\left[t_1^{**} - \alpha\left(t_1^{**} + T\right)\right] + \Psi_1 \ln G\right\}$ This proves the lemma.

Lemma 2: *If assumptions 1-3 , 4 and $T > \frac{\alpha}{1-\alpha}r$ holds, then the the subgame-perfect-equilibrium federal tax rate must necessarily belong to $T \in \left[\frac{\alpha}{1-\alpha}r, (1-\alpha)r\right]$.*

Proof: Remember $W\left(T, G\right) = 2u(1) + 2m - 2p - 2T - t_1(T) - t_2(T) + \gamma_1 \ln g_1(T) + \gamma_2 \ln g_2(T) + \Psi_1 \ln G + \Psi_2 \ln G$. Note that from the second stage $g_1 = \left[1 + n\left(t_1\left(T\right), t_2\left(T\right)\right)\right] t_1 - \alpha\left[t_1\left(T\right) + T\right]\left[1 + n\left(t_1\left(T\right), t_2\left(T\right)\right)\right]$ and $g_2 = \left[1 - n\left(t_1\left(T\right), t_2\left(T\right)\right)\right] t_2 - \alpha\left[t_2\left(T\right) + T\right]\left[1 - n\left(t_1\left(T\right), t_2\left(T\right)\right)\right]$ and that $G = 2T - \alpha\left[t_1\left(T\right) + T\right]\left[1 + n\left(t_1\left(T\right), t_2\left(T\right)\right)\right] - \alpha\left[t_2\left(T\right) + T\right]\left[1 - n\left(t_1\left(T\right), t_2\left(T\right)\right)\right]$.

If $T \geq \frac{\alpha}{1-\alpha}r$, which implies $T(1-\alpha) \geq \alpha r$, we can write:

$$2T(1-\alpha) \geq 2\alpha r \geq 2\alpha \max\left[t_1, t_2\right] \geq \alpha\left[t_1\left(1+n\right) + t_2\left(1-n\right)\right]$$

which is:

$$2T(1-\alpha) - \alpha\left[t_1\left(1+n\right) + t_2\left(1-n\right)\right] \geq 0,$$

This says that the budget constraint is non negative.

We have seen that at the second stage, if assumption 2 holds the provinces always choose $t_1 \in \left[\frac{\alpha}{1-\alpha}T, r - T\right]$ and $t_2 \in \left[\frac{\alpha}{1-\alpha}T, r - T\right]$. This let us state that the condition which guarantees a subgame perfect equilibrium is: $T \leq (1-\alpha)r$. Only in this case the previous two sets are not empty. Suppose the condition does not hold and let us assume that the federal government chooses a $T > (1-\alpha)r$, it means $t_s \in [0, r - T] \left[\frac{\alpha}{1-\alpha}T, +\infty\right[$. This would imply a negative revenue for province s when $t_s \in [0, r - T]$, but this choice cannot belong to the strategy set because the provinces maximize their welfare function under a non-negative revenue constraint. So the strategy choice of province s (s=1,2) restricts to $t_s \in \left]\frac{\alpha}{1-\alpha}T, +\infty\right[$, which means that the tax base is always 0 in both provinces. This implies that the federal revenue is also 0, which means $W\left(T, G(T)\right) = -\infty$. Since lemma 1 ($t_s \leq r - T$, with $s = 1, 2$) insures that $2u(1) + 2m - 2p - 2T - t_1 - t_2 > 0$, we can state $W\left(T^*, G(T^*)\right) \geq W\left(T^{**}, G(T^{**})\right)$ where $T^* \in \left[\frac{\alpha}{1-\alpha}r, (1-\alpha)r\right]$ and $T^{**} \in \left[0, \frac{\alpha}{1-\alpha}r\right] [(1-\alpha)r, r]$

Note that, since $0 < \alpha < \frac{3-\sqrt{5}}{2}$, the set $T^* \in \left[\frac{\alpha}{1-\alpha}r, (1-\alpha)r\right]$, is not empty.

Proposition 1: *If assumptions 1-4 hold then the Stackelberg game where a central authority chooses a federal tax rate and a federal public good, by maximizing its welfare function, subject to a budget constraint and the two provinces* *choose their tax rates and public goods by maximizing their welfare function, subject to a budget constraint, has a subgame perfect Nash equilibrium.*

Proof: Since assumption 2 holds, we can apply lemma 1 and define the following strategy sets for each province of the federation at the second stage of the game:

$$\frac{\alpha}{1-\alpha}T \leq t_1 \leq r - T$$

$$\frac{\alpha}{1-\alpha}T \leq t_2 \leq r - T$$

These two sets are compact, non-empty and convex.

The pay-off function of province 1 is:

$$W(t_1,t_2) = u(1) + m_1 - (p + t_1 + T) + \gamma_1 \ln\left\{(1+n)\left(t_1 - \alpha\left(t_1+T\right)\right)\right\} + \Psi_1 \ln G \tag{16}$$

(16) is the welfare function of province 1 with the budget constraint fitted in. This function is continuous in $\forall t_1 \in \left[\frac{\alpha}{1-\alpha}T, r-T\right]$. It is easy to verify the continuity in $t_1 > t_2$ and $t_1 < t_2$. Moreover the limit of the function when $t_1 \to t_2$ coincides in the two regimes ($t_1 > t_2$ and $t_1 \leq t_2$): $\lim\limits_{t_1 \to t_2^+} W(t_1,t_2) = \lim\limits_{t_1 \to t_2^-} W(t_1,t_2) = u(1) + m - (p + t_1 + T) - f + \gamma_1 \ln\left(t_1 - \alpha\left(t_1+T\right)\right) + \Psi \ln G$. This proves the continuity also when $t_1 = t_2$. Taking the derivative of (16):

$$\frac{\partial W}{\partial t_1} = -1 + \frac{\gamma_1}{g}\left[\frac{\partial n}{\partial t_1}\left(t_1 - \alpha\left(t_1+T\right)\right) + (1+n)(1-\alpha)\right]. \tag{17}$$

The first order derivative of the pay-off function is a continuous function in $t_1 = t_2$. In fact its limit when $t_1 \to t_2$ coincides in the two regimes: $\lim\limits_{t_1 \to t_2^+} \frac{\partial W}{\partial t_1} = \lim\limits_{t_1 \to t_2^-} \frac{\partial W}{\partial t_1} = -1 + \gamma_1 \frac{-A[t_1 - \alpha(t_1+T)] + 1 - \alpha}{t_1 - \alpha(t_1+T)}$.

Take the derivative of (17):

$$\frac{\partial^2 W(t_1,t_2)}{\partial t_1^2} = \frac{\gamma_1}{g^2}\left[\left(\left(t_1 - \alpha\left(t_1+T\right)\right)\frac{\partial^2 n}{\partial t_1^2} + 2\frac{\partial n}{\partial t_1}(1-\alpha)\right)g - \left(\frac{\partial g}{\partial t_1}\right)^2\right] \tag{18}$$

if we use (15) and (13), when $t_1 > t_2$:

$$\frac{\partial^2 W(t_1,t_2)}{\partial t_1^2} = \frac{\gamma_1}{g^2}\left[-Ae^{A(t_1-t_2)}\left[A\left(t_1 - \alpha\left(t_1+T\right)\right) + 2(1-\alpha)\right]g - \left(\frac{\partial g}{\partial t_1}\right)^2\right]. \tag{19}$$

Notice that assumption 5 and lemma 1 imply:

$$\frac{\partial^2 W(t_1,t_2)}{\partial t_1^2} < 0.$$

If we use (15) and (14), when $t_1 < t_2$:

$$\frac{\partial^2 W(t_1,t_2)}{\partial t_1^2} = \frac{\gamma}{g^2}\left[Ae^{A(t_1-t_2)}\left[A\left(t_1-\alpha\left(t_1+T\right)\right)-2\left(1-\alpha\right)\right]g-\left(\frac{\partial g}{\partial t_1}\right)^2\right]. \tag{20}$$

Assumption 3 and 4 imply:

$$t_1 \leq r \leq \frac{1}{A} < \frac{1}{A}+\frac{\alpha}{1-\alpha}T$$

which means that:

$$\frac{\partial^2 W(t_1,t_2)}{\partial t_1^2} < 0.$$

The first-order derivative of the pay-off function has a kink in $t_1 = t_2$. In fact if we take the limit of the second-order derivative when $t_1 \to t_2$ in the two regimes: $\lim\limits_{t_1\to t_2^+}\frac{\partial^2 W}{\partial t_1^2} \neq \lim\limits_{t_1\to t_2^-}\frac{\partial^2 W}{\partial t_1^2}$. But since the pay-off function is continuous and differentiable in $t_1 = t_2$ and concave in $t_1 < t_2$ and $t_1 > t_2$, it must be concave $\forall t_1 \in \left[\frac{\alpha}{1-\alpha}T, r-T\right]$, whatever $t_2 \in \left[\frac{\alpha}{1-\alpha}T, r-T\right]$.

Notice that the set of maximizers $t_1(t_2)$ is non-empty and compact since the pay-off function is continuous and the strategy set, where t_1 is chosen, ($\frac{\alpha}{1-\alpha}T \leq t_1 \leq r$) is non-empty and compact. The set of maximizers $t_1(t_2)$ is also convex since the pay-off function is concave in t_1 and the strategy set is convex. The above properties ensures that the reaction function $t_1(t_2)$ is continuous and convex-valued. The same reasoning applies to province 2. We can therefore apply Kakutani fixed point theorem and say that the game, where the two provinces choose their own tax-rate and local public good by maximizing their welfare function, has a Nash equilibrium.

We have proved the existence and uniqueness of the second stage sub-game equilibrium.

The first-stage federal welfare function $W\left(T,G(T)\right) = 2u(1)+2m-2p-2T-t_1(T)-t_2(T)+\gamma_1\ln g_1(T)+\gamma_2\ln g_2(T)+\Psi\ln G(T)+\Psi\ln G(T)$. Note that from the second stage $g_1 = \left[1+n\left(t_1\left(T\right),t_2\left(T\right)\right)\right]t_1-\alpha\left[1+n\left(t_1\left(T\right),t_2\left(T\right)\right)\right]\left(t_1+T\right)$ and $g_2 = \left[1+n\left(t_1\left(T\right),t_2\left(T\right)\right)\right]t_2-\alpha\left[1+n\left(t_1\left(T\right),t_2\left(T\right)\right)\right]\left(t_2+T\right)$ and that $G = 2T-\alpha\left[t_1\left(T\right)+T\right]\left[1+n\left(t_1\left(T\right),t_2\left(T\right)\right)\right]-\alpha\left[t_2\left(T\right)+T\right]\left[1-n\left(t_1\left(T\right),t_2\left(T\right)\right)\right]$.

Since (17) is a continuous function in t_1 and T, $\frac{\partial t_1}{\partial T}$ exists for $\forall T \in \left[\frac{\alpha}{1-\alpha}r,(1-\alpha)r\right]$ and therefore $t_1(T)$ is continuous for $\forall\left[\frac{\alpha}{1-\alpha}r,\left(1-\alpha\right)r\right]$. Of course the same holds for $t_2(T)$. Moreover since $n(t_1,t_2) = \begin{cases} -\left[e^{A(t_1-t_2)}-1\right] \text{if } t_1>t_2 \\ e^{A(t_2-t_1)}-1 \quad \text{if } t_1\leq t_2. \end{cases}$ is also continuous for $\forall t_1 \in \left[\frac{\alpha}{1-\alpha}T, r-T\right]$, we can say that $W\left(T,G(T)\right)$ *is continuous in* T.

Finally, since, at the first stage, the federal state maximize $W\left(T,G(T)\right)$, by choosing T, which by lemma 2 belongs to the compact set $T \in \left[\frac{\alpha}{1-\alpha}r,\left(1-\alpha\right)r\right]$,we can apply the Weierstrass Theorem and establish that a subgame-perfect equilibrium exists.

Proposition 1a: *If assumptions 1-4 hold, an increase in the federal tax, for given marginal cost of public funds, μ, implies for each province a higher tax rate, given the tax rate of the other province fixed.*

Proof: Sove problem (11), for a given μ and g:

$$\frac{\partial L}{\partial t_1} = -1 - \mu \left[-\frac{\partial n}{\partial t_1} \left[t_1 - \alpha \left(t_1 + T \right) \right] - (1+n)(1-\alpha) \right] = 0 \qquad (21)$$

by totally differentiating (21) with respect to t_1 and T:

$$\frac{dt_1}{dT} = \frac{\alpha \frac{\partial n}{\partial t_1}}{2\frac{\partial n}{\partial t_1} + \frac{\partial^2 n}{\partial t_1^2} \left(t_1 - \alpha \left(t_1 + T \right) \right)}$$

when $t_1 > t_2$, by using (13) and (15): $\frac{dt_1}{dT} = \frac{\alpha}{2+A[t_1-\alpha(t_1+T)]}$, which, by lemma 1, is positive. When $t_1 < t_2$, by using (14) and (15): $\frac{dt_1}{dT} = \frac{\alpha}{2-A[t_1-\alpha(t_1+T)]}$. Notice that this last expression is always positive because by assumptions 3 and 4 $t_1 \leq r < \frac{1}{A} < \frac{2}{A(1-\alpha)} + \frac{\alpha}{1-\alpha}T$.

We can rule out the case $t_1 = t_2$, in fact since $\gamma_1 \neq \gamma_2$, $t_1 = t_2$ cannot be an equilibrium.

Notice that if we differentiate with respect to t_1 and t_2, we obtain:

$$\frac{dt_1}{dt_2} = -\frac{\frac{\partial^2 n}{\partial t_1 \partial t_2} \left(t_1 - \alpha \left(t_1 + T \right) \right) + \frac{\partial n}{\partial t_2} (1-\alpha)}{\frac{\partial^2 n}{\partial t_1^2} \left(t_1 - \alpha \left(t_1 + T \right) \right) + 2\frac{\partial n}{\partial t_1} (1-\alpha)} \qquad (22)$$

Proposition 2: *If assumption 1-4 hold then, for a given marginal cost of public funds and a fixed t_2, $\frac{dt_1}{dt_2} > 0$.*

Proof: When $t_1 > t_2$, by using (13) and (15): $\frac{dt_1}{dt_2} = \frac{(1-\alpha)+A(t_1-\alpha(t_1+T))}{2(1-\alpha)+A(t_1-\alpha(t_1+T))}$. Notice that $(1-\alpha) + A\left(t_1 - \alpha\left(t_1+T\right)\right) \geq 0$. In fact $1-\alpha > 0$, by assumption 4 and $A\left(t_1 - \alpha\left(t_1+T\right)\right) \geq 0$, by lemma 1. This implies that the denominator is positive.

When $t_1 \leq t_2$,by using (14) and (15): $\frac{dt_1}{dt_2} = \frac{(1-\alpha)-A(t_1-\alpha(t_1+T))}{2(1-\alpha)-A(t_1-\alpha(t_1+T))}$. Since the numerator is positive if $t_1 \leq r < \frac{1}{A} < \frac{\alpha}{1-\alpha}T + \frac{2}{A}$ which is always true by assumptions 3 and 4. If the numerator is positive, the denominator is also positive.

We can rule out the case $t_1 = t_2$, in fact since $\gamma_1 \neq \gamma_2$, $t_1 = t_2$ cannot be an equilibrium.

Proposition 2a: *If assumptions 1-4 hold, an increase in the federal tax T, decreases the horizontal fiscal externality, for a given t_1 and marginal cost of public funds.*

Proof: Notice that the analytical expression for the horizontal externality is: $\frac{\partial L}{\partial t_2} = \mu \frac{\partial n}{\partial t_2} \left(t_1 - \alpha \left(t_1 + T \right) \right)$. Taking the derivative of this last expression with respect to T, for a given $t_1$and given 2's optimal choice, $t_2(T)$, at the second stage:

$$\frac{\partial L}{\partial t_2 \partial T} = -\mu\left[\alpha\frac{\partial n}{\partial t_2} - \frac{\partial^2 n}{\partial t_2}\frac{\partial t_2}{\partial T}\left(t_1 - \alpha\left(t_1 + T\right)\right)\right]$$

When $t_1 > t_2$, if we use (13) and (15), we get $\frac{\partial L}{\partial t_2 \partial T} = -\mu\alpha A e^{A(t_1 - t_2)}\left[\frac{2+A(1-\alpha)(t_2-t_1)}{2+A(t_2-\alpha(t_2+T))}\right]$. The denominator is positive by lemma 1. Moreover $2 + A\left(1-\alpha\right)\left(t_2 - t_1\right) > 2 + A\left(1-\alpha\right)\left(\min t_2 - \max t_1\right) = 2 - A\left(1-\alpha\right)r$; notice that assumption 3 ($r < \frac{1}{A}$) implies $2 - A\left(1-\alpha\right)r > 2 - \left(1-\alpha\right)$, which by using assumption 4 ($0 < \alpha < \frac{3-\sqrt{5}}{2}$) and the previous inequality leads to $2 + A\left(1-\alpha\right)\left(t_2 - t_1\right) > 0$. This shows that the numerator of the fraction in square barackets is positive. All this implies $\frac{\partial L}{\partial t_2 \partial T} < 0$.

When $t_1 < t_2$, if we use (14) and (15), we get $\frac{\partial W}{\partial t_2 \partial T} = -\mu\alpha A e^{A(t_2 - t_1)}\left[\frac{2-A(1-\alpha)(t_2+t_1)+2\alpha AT}{2-A(t_1-\alpha(t_1+T))}\right]$. The denominator is positive by assumptions 3 and 4: $t_1 \leq r < \frac{1}{A} < \frac{\alpha}{1-\alpha}T + \frac{2}{A}$; the numerator is positive, in fact $2 - A\left(1-\alpha\right)\left(t_2 + t_1\right) + 2\alpha AT > 2 - A\left(1-\alpha\right)2r + 2\alpha AT$, morever assumption 3 ($r < \frac{1}{A}$) implies $2 - A\left(1-\alpha\right)2r + 2\alpha AT > 2 - \left(1-\alpha\right)2 + 2\alpha AT$, which, by using the previous inequality and assumption 4, ($0 < \alpha < \frac{3-\sqrt{5}}{2}$), gives $2 - A\left(1-\alpha\right)\left(t_2 + t_1\right) + 2\alpha AT > 0$, namely $\frac{\partial L}{\partial t_2 \partial T} < 0$. The symmetric case $t_1 = t_2$ is ruled out by assumption 1: $\gamma_1 \neq \gamma_2$.

Proposition 3: *If assumptions 1-4 hold, then the slope of the tax-rate reaction function when $t_1 > t_2$ is greater than the slope of the tax-rate reaction function when $t_1 < t_2$, for a given marginal cost of public funds and a given fixed tax rate.*

Proof : When $t_1 > t_2$, by using (13) and (15): $\frac{dt_1}{dt_2} = \frac{(1-\alpha)+A(t_1-\alpha(t_1+T))}{2(1-\alpha)+A(t_1-\alpha(t_1+T))}$. Notice that assumptions 1, 3, 4 and lemma 1 insures that $\frac{dt_1}{dt_2} = \frac{(1-\alpha)+A(t_1-\alpha(t_1+T))}{2(1-\alpha)+A(t_1-\alpha(t_1+T))} > \frac{1}{2}$. When $t_1 < t_2$, by using (14) and (15): $\frac{dt_1}{dt_2} = \frac{(1-\alpha)-A(t_1-\alpha(t_1+T))}{2(1-\alpha)-A(t_1-\alpha(t_1+T))}$. Assumptions 1, 3, 4 and lemma 1 insures that $\frac{dt_1}{dt_2} = \frac{(1-\alpha)-A(t_1-\alpha(t_1+T))}{2(1-\alpha)-A(t_1-\alpha(t_1+T))} \leq \frac{1}{2}$. Notice that the case $\frac{dt_1}{dt_2} = \frac{1}{2}$ can happen only in the $t_1 < t_2$ regime, in fact $\frac{dt_1}{dt_2} = \frac{1}{2}$ if and only if $t_1 = \frac{\alpha}{1-\alpha}T$, which is not feasible in the regime $t_1 > t_2$. In fact in this last case we should have $t_2 < \frac{\alpha}{1-\alpha}T$, which contradicts lemma 1.

This shows that $\left.\frac{dt_1}{dt_2}\right|_{t_1 > t_2} > \left.\frac{dt_1}{dt_2}\right|_{t_1 < t_2}$

We can rule out the case $t_1 = t_2$, in fact since $\gamma_1 \neq \gamma_2$, $t_1 = t_2$ cannot be an equilibrium.

Proposition 4: *If assumption 1-4 hold then (a) a unit increase in the federal tax decreases the tax-rate reaction function slope if $t_1 > t_2$, moreover (b) it increases the tax-rate reaction function slope if $t_1 < t_2$, for a given marginal cost of public funds and a given fixed t_2.*

Proof: Take $t_1 > t_2$, use (13) and (15) and take the derivative of (22) with respect to T:

$$\frac{\partial t_1}{\partial t_2 \partial T} = -\frac{A\left(1-\alpha\right)^2\left(\frac{\alpha}{1-\alpha} - \frac{\partial t_1}{\partial T}\right)}{\left[2\left(1-\alpha\right) + A\left(t_1 - \alpha\left(t_1 + T\right)\right)\right]^2} \tag{23}$$

Suppose that $\frac{\partial t_1}{\partial t_2 \partial T} > 0$. This would imply: $\frac{\partial t_1}{\partial T} = \frac{\alpha}{2+A[t_1-\alpha(t_1+T)]} > \frac{\alpha}{1-\alpha}$. This last inequality would imply $(1+\alpha) + A\left(t_1 - \alpha\left(t_1+T\right)\right) < 0$, which, given lemma 2 and assumption 4, is impossible. Therefore if $t_1 > t_2$, then: $\frac{\partial t_1}{\partial t_2 \partial T} < 0$.

Take $t_1 < t_2$, use (14) and (15) and take the derivative of (22) with respect to T:

$$\frac{\partial t_1}{\partial t_2 \partial T} = \frac{A\left(1-\alpha\right)^2\left(\frac{\alpha}{1-\alpha} - \frac{\partial t_1}{\partial T}\right)}{\left[2\left(1-\alpha\right) + A\left(t_1 - \alpha\left(t_1 + T\right)\right)\right]^2} \tag{24}$$

Suppose that $\frac{\partial t_1}{\partial t_2 \partial T} < 0$ which implies$\frac{dt_1}{dT} = \frac{\alpha}{2-A[t_1-\alpha(t_1+T)]} > \frac{\alpha}{1-\alpha}$. This also implies $(1+\alpha) - A\left(t_1 - \alpha\left(t_1+T\right)\right) < 0$, which means $t_1 > \frac{1+\alpha}{1-\alpha} + \frac{\alpha}{1-\alpha}T$, which contradicts assumption 4 ($t_1 \leq r < \frac{1}{A}$), given assumption 3 ($A \geq 1$). Therefore if $t_1 < t_2$, then $\frac{\partial t_1}{\partial t_2 \partial T} > 0$. Finally $\gamma_1 \neq \gamma_2$ rules out the $t_1 = t_2$ case.

Table 1: Summary Statistics

Variable		
TAX (province unit cigarette tax, inclusive of general sales tax, 1989 US$)	0.9311	(0.3705)
C NEIGH TAX (neighboring Canadian province average unit cigarette tax, inclusive of general sales tax, 1989 US$)	0.8882	(0.3138)
Federal tax	0.8601	(0.3254)
US NEIGH TAX (neighboring US state unit cigarette tax, inclusive of general sales tax, 1989 US$)	0.2485	(0.1452)
EXPE (total province public expenditure divided by provincial gdp)	0.6184	(0.1510)
POP $*10^{-7}$ (province population)	0.2718	(0.3110)
DENS$*10^{-3}$ (population density: population divided by area)	12.7921	(11.2883)
UNEMP (unemployment rate)	11.4873	(3.7240)
AGED (proportion of population over 65)	0.1147	(0.0163)
CHILD (proportion of population between 5-17)	0.1920	(0.0171)
INC$*10^{-3}$ (province income per capita in 1989 US$)	13.2187	(1.9920)
GRANT (federal grants divided by provincial population)	0.0011	(0.0005)
GDP (province gdp per-capita in 1989 US million $)	0.1385	0.0309
INCTAX (federal income tax divided by provincial gdp)	0.0825	(0.0131)
C NEIGH DENS$*10^{-3}$ (neighboring Canadian province average population density)	12.5121	(8.2137)
US NEIGH DENS$*10^{-3}$ (neighboring US state average population density)	52.9159	(71.4226)
C NEIGH UNEMP (neighboring Canadian province average unemployment rate)	10.9308	(2.4546)
US NEIGH UNEMP (neighboring US state average unemployment rate)	4.8178	(2.6718)
C NEIGH INC$*10^{-3}$ (neighboring Canadian province average population per-capita income in 1989	13.4088	(1.3908)
US NEIGH INC$*10^{-3}$ (neighboring US state average per-capita income in 1989 US$)	12.7175	(6.5527)
C NEIGH GRANT (neighboring Canadian province average federal grant on provincial pop.)	0.0010	(0.0003)
US NEIGH GRANT (neighboring US state average federal grant on state pop.)	0.0005	(0.0003)
US NEIGH INCTAX (neighboring US state average federal income tax on state gdp)	0.0806	(0.0104)
C NEIGH INCTAX (neighboring Canadian province average federal income tax on provincial gdp)	0.0710	(0.0361)
C NEIGH GDP (neighboring Canadian province average gdp per-capita in 1989 US million $)	0.0143	(0.0028)
US NEIGH GDP (neighboring US state average gdp per-capita in 1989 US million $)	0.0146	(0.0075)
C NEIGH POP (neighboring Canadian province average population)	3060374	(1942044)
US NEIGH POP (neighboring US state average population)	2474501	(3165001)
C NEIGH AGED (neighboring Canadian province average proportion of population over 65)	0.1133	(0.0131)
US NEIGH AGED (neighboring US state average proportion of population over 65)	0.1034	(0.0522)
C NEIGH CHILD (neighboring Canadian province average proportion of population between 5-17)	0.1899	(0.009)
US NEIGH CHILD (neighboring US state average proportion of population beteween 5-17)	0.1540	(0.0779)
Federal GDP (Federal GDP in 1989 million $)	476244.3	(30030.71)
Federal unemployment rate	9.7272	(1.3761)
Deficit (federal deficit over federal gdp)	-0.0496	(0.0093)

Notes: Figures are means, with standard deviations in parenthesis, based on annual data for the years 1984-1994, inclusive, for the following ten Canadian provinces: Alberta, Ontario, British Columbia Saskatchewan, Newfoundland, Prince Edward Island, Nova Scotia, New Brunsweek, Quebec, Manitoba (110 observations).

Table 2: The impact of federal tax on provincial tax

Dependent Variable	TAX: province cig. tax rate (sales tax + specific unit tax)	TAX: province cig. tax rate (sales tax + specific unit tax)	TAX: province cig. tax rate (sales tax + specific unit tax)
Federal tax-rate on cigarettes+federal sale tax	0.822 (3.54)**	0.390 (2.08)*	0.226 (1.55)
C NEIGH TAX		0.615 (3.49)**	0.567 (2.85)*
US NEIGH TAX		0.328 (0.50)	0.583 (0.63)
EXPE	-0.105 (0.08)	-0.356 (0.23)	0.568 (0.25)
dummy when equalization holds	0.159 (1.10)	0.123 (1.02)	0.193 (1.14)
dummy when TAX higher than C NEIGH TAX	0.131 (2.26)*	0.172 (2.83)*	0.165 (2.85)*
DENS	0.040 (0.22)	-0.141 (0.87)	0.067 (0.21)
CHILD	-6.203 (0.63)	-10.654 (1.13)	-10.345 (1.37)
AGED	-12.152 (0.48)	-23.510 (0.99)	-17.430 (0.82)
POP $*10^7$	-3.732 (0.82)	-0.893 (0.19)	-5.229 (0.66)
UNEMP	0.008 (0.16)	0.016 (0.34)	0.056 (2.34)*
INC$*10^3$	-0.741 (1.10)	-0.647 (0.89)	-0.789 (1.56)
$INC^2 *10^8$	2.690 (1.02)	2.479 (0.86)	3.236 (1.56)
GDP	-14.272 (0.45)	-30.363 (0.86)	2.763 (0.08)
Dummy=1 if the premier of the Government belongs to the Liberals	0.020 (0.25)	-0.011 (0.14)	0.005 (0.03)
Dummy=1 if the premier of the Government belongs to the Progressive Conserv.	-0.049 (0.90)	-0.084 (1.56)	-0.068 (0.39)
C NEIGH UNEMP			-0.007 (0.17)
US NEIGH UNEMP			0.094 (1.72)

C NEIGH INC*10^3			-1.435 (2.42)*
C NEIGH INC^2 *10^8			5.271 (2.24)
US NEIGH INC*10^3			1.051 (2.61)*
US NEIGH INC^2 *10^8			-3.358 (2.71)*
C NEIGH DENS*10^3			-0.161 (0.46)
US NEIGH DENS*10^3			0.030 (0.49)
C NEIGH GRANT			389.721 (0.75)
CUS NEIGH GRANT			-1,938.169 (2.85)*
C NEIGH GDP			-16.937 (0.62)
US NEIGH GDP			142.326 (1.05)
Federal unemployment rate	0.003 (0.06)	0.014 (0.35)	0.032 (0.84)
Federal GDP*10^6	4.02 (1.00)	4.22 (1.33)	5.24 (1.70)
Constant	6.318 (0.94)	7.551 (1.10)	5.876 (0.93)
year effects	no	no	no
province effects	yes	yes	yes
Observations	110	110	110
R-squared	0.81	0.85	0.91
Ftest on own controls (p-value)	0.0000	0.0000	0.0035
Ftest on NEIGH controls (p-value)			0.0002
Ftest on province effects (p-value)	0.0011	0.0000	0.0000

Robust t-statistics in parentheses

* significant at 5%; ** significant at 1%

Notes: Column (1) presents OLS regression of a Canadian province tax rate on cigarettes on the federal tax rate on cigarette. Columns (2) presents an OLS regression of the Canadian province tax rate on cigarettes on the federal tax rate on cigarette and the average tax rate of the Canadian neighboring provinces. We do the same regression in (3), by adding neighboring controls. Numbers in parentheses are robust t-statistics (with the standard error adjusted for clustering by province). Variables are defined in table 1 and described in detail in the data appendix.

Table 3: The impact of federal tax on provincial tax

Dependent Variable	TAX: province cig. tax rate (sales tax + specific unit tax)	TAX: province cig. tax rate (sales tax + specific unit tax)	TAX: province cig. tax rate (sales tax + specific unit tax)
Interaction with C NEIGH TAX of a dummy=1 when TAX lower than C NEIGH TAX			-0.879 (0.88)
Federal tax-rate on cigarettes+federal sale tax	0.028 (0.15)	0.136 (0.76)	0.122 (0.34)
C NEIGH TAX	0.950 (4.50)**	1.076 (5.23)**	1.307 (2.53)*
US NEIGH TAX	2.969 (1.03)	2.759 (1.10)	3.741 (1.16)
EXPE	-3.217 (0.96)	-0.618 (0.17)	-7.854 (1.02)
dummy when equalization holds	0.289 (1.01)	0.134 (0.78)	0.349 (0.80)
dummy when TAX higher than C NEIGH TAX	0.123 (1.98)	0.157 (2.19)	-0.732 (0.77)
DENS	-0.184 (0.97)	-0.326 (2.20)	-0.124 (0.56)
CHILD	-24.353 (2.38)*	-15.318 (1.34)	-40.901 (1.47)
AGED	-35.633 (2.00)	-47.566 (3.56)**	-29.490 (1.21)
POP $*10^7$	-1.351 (0.24)	0.280 (0.06)	-0.524 (0.08)
UNEMP	0.073 (3.60)**	0.071 (2.41)*	0.155 (1.31)
INC$*10^3$	-0.783 (1.96)	-0.739 (1.56)	-1.341 (1.36)
INC^2 $*10^8$	3.346 (1.95)	3.219 (1.60)	5.290 (1.43)
GDP	-81.506 (1.22)	-36.185 (0.71)	-160.650 (1.27)
Dummy=1 if the premier of the Government belongs to the Liberals	-0.091 (1.02)	-0.054 (0.67)	-0.200 (1.30)
Dummy=1 if the premier of the Government belongs to the Progressive Conserv.	-0.191 (1.02)	-0.131 (0.67)	-0.230 (1.30)

C NEIGH UNEMP	-0.022 (0.35)	-0.022 (0.42)	-0.139 (0.83)
US NEIGH UNEMP	0.118 (2.12)	0.157 (2.65)*	0.190 (1.45)
C NEIGH INC*10^3	-1.618 (3.59)**	-1.357 (2.84)*	-2.035 (2.57)*
C NEIGH INC^2 *10^8	6.431 (3.45)**	5.384 (2.79)*	7.999 (2.62)*
US NEIGH INC*10^3	0.523 (1.13)	0.498 (1.18)	0.672 (1.03)
US NEIGH INC^2 *10^8	-1.819 (1.33)	-1.661 (1.18)	-2.322 (1.01)
C NEIGH DENS*10^3	-0.074 (0.21)	-0.425 (0.95)	0.327 (0.55)
US NEIGH DENS*10^3	-0.006 (0.10)	-0.033 (0.50)	-0.043 (0.42)
C NEIGH GRANT	1,030.884 (1.26)	803.276 (1.27)	1,421.467 (1.15)
CUS NEIGH GRANT	-1,981.173 (2.42)*	-2,155.575 (2.39)*	-1,425.931 (0.98)
C NEIGH GDP	-55.140 (2.60)*	-45.224 (1.84)	-35.135 (0.99)
US NEIGH GDP	186.768 (1.00)	226.650 (1.24)	212.553 (0.82)
Federal unemployment rate	0.064 (1.18)	0.064 (1.08)	0.058 (0.79)
Federal GDP*10^6	4.02 (1.00)	9.35 (3.01)*	12.2 (0.02)
Constant	17.180 (2.33)*	11.184 (1.28)	27.553 (1.66)
year effects	no	no	no
province effects	yes	yes	yes
Observations	110	110	110
R-squared	0.87	0.87	0.80
Overidentification test	0.04	0.19	0.45
Ftest on own controls (p-value)	0.0000	0.0000	0.0000
Ftest on NEIGH controls (p-value)	0.0000	0.0000	0.0000
Ftest on province effects (p-value)	0.0000	0.0000	0.0000

Robust t-statistics in parentheses
* significant at 5%; ** significant at 1%

Notes: Column (1) presents a 2 stages least squares estimate of a regression of the Canadian province tax rate on cigarettes on the federal tax rate on cigarette and the average tax rate of the Canadian neighboring provinces: we do not instrument the federal tax. We do the same regression in (2), but instrumenting the federal tax. In column (3) we add the interaction of C NEIGH TAX with a dummy equal to 1 when TAX is lower than C NEIGH TAX. Numbers in parentheses are robust t-statistics (with the standard error adjusted for clustering by province). Variables are defined in table 1 and described in detail in the data appendix.

Table 4: The effect of the the federal tax on tax competition

Dependent Variable	TAX: province cig. tax rate (sales tax + specific unit tax)	TAX: province cig. tax rate (sales tax + specific unit tax)	TAX: province cig. tax rate (sales tax + specific unit tax)
interaction with C NEIGH TAX of a dummy =1 when TAX higher than C NEIGH TAX		3.061 (2.83)*	3.014 (2.24)
Interaction of the federal tax rate with the interaction with C NEIGH TAX of a dummy =1 when TAX higher than C NEIGH TAX		-1.610 (3.36)**	-0.119 (0.04)
interaction with C NEIGH TAX of a dummy =1 when TAX lower than C NEIGH TAX	-2.994 (1.83)		
Interaction of the federal tax rate with the interaction with C NEIGH TAX of a dummy =1 when TAX lower than C NEIGH TAX	1.547 (2.99)*		1.442 (0.56)
C NEIGH TAX	1.529 (2.18)	-0.162 (0.16)	-1.381 (0.50)
US NEIGH TAX	-0.204 (0.03)	1.424 (0.30)	-0.085 (0.01)
EXPE	0.730 (0.04)	-4.434 (0.38)	0.329 (0.02)
dummy when equalization holds	-1.299 (0.86)	-1.306 (1.12)	-1.305 (0.92)
dummy when TAX higher than C NEIGH TAX	-0.078 (0.07)	0.293 (0.53)	-0.049 (0.05)
DENS	0.139 (0.26)	0.194 (0.47)	0.145 (0.34)
CHILD	-22.874 (0.34)	-35.846 (0.84)	-23.927 (0.41)
AGED	-29.777 (0.40)	-12.644 (0.24)	-28.472 (0.50)
POP $*10^7$	-11.854 (1.08)	-8.727 (1.08)	-11.661 (0.97)
UNEMP	0.064 (0.49)	0.072 (0.58)	0.064 (0.49)
INC$*10^3$	-1.320 (1.36)	-1.355 (1.46)	-1.322 (1.40)
$INC^2 *10^8$	5.558 (1.76)	5.516 (1.74)	5.554 (1.71)
GDP	13.670 (0.03)	-89.590 (0.40)	5.699 (0.02)

Dummy=1 if the premier of the Government belongs to the Liberals	-0.143 (0.65)	-0.140 (0.71)	-0.143 (0.66)
Dummy=1 if the premier of the Government belongs to the Progressive Conserv.	-0.144 (0.62)	-0.150 (0.76)	-0.145 (0.67)
C NEIGH UNEMP	-0.003 (0.01)	-0.047 (0.14)	-0.006 (0.02)
US NEIGH UNEMP	0.046 (3.08)*	0.094 (3.03)*	0.048 (3.05)*
C NEIGH $INC^2 *10^8$	7.406 (2.63)*	7.116 (2.55)*	7.382 (2.44)*
US NEIGH $INC*10^3$	1.646 (0.97)	0.644 (0.65)	1.569 (0.90)
US NEIGH $INC^2 *10^8$	-5.159 (1.13)	-2.304 (0.71)	-4.941 (1.02)
C NEIGH $DENS*10^3$	-0.214 (0.10)	0.306 (0.24)	-0.172 (0.10)
US NEIGH $DENS*10^3$	0.089 (0.37)	0.009 (0.05)	0.083 (0.36)
C NEIGH GRANT	1,453.538 (1.39)	1,470.081 (1.71)	1,456.913 (1.43)
CUS NEIGH GRANT	-1,595.849 (0.89)	-1,821.874 (1.01)	-1,610.297 (0.90)
C NEIGH GDP	24.451 (1.15)	35.404 (1.02)	25.435 (1.17)
US NEIGH GDP	65.296 (0.31)	153.530 (0.74)	71.055 (0.31)
Constant	14.928 (0.45)	25.119 (1.17)	15.742 (0.58)
year effects	yes	yes	yes
province effects	yes	yes	yes
Overidentification test	0.80	0.86	0.89
Observations	110	110	110
R-squared	0.80	0.80	0.80
Ftest on own controls (p-value)	0.0033	0.0004	0.0000
Ftest on NEIGH controls (p-value)	0.0000	0.0134	0.0000
Ftest on year effects	0.1262	0.3365	0.0241
Ftest on province effects	0.0000	0.0000	0.0001

Robust t-statistics in parentheses

* significant at 5%; ** significant at 1%

Notes: Columns (1) and (2) are two stage least squares regressions of the provincial tax rate on cigarettes on the federal tax rate interacted with the average tax rate of the neighboring provinces, respectively when TAX is lower than C NEIGH TAX and TAX is higher than C NEIGH TAX. Column (3) presents the same regression, including the interaction of the federal tax rate with both tax regimes. Numbers in parentheses are robust t-statistics (with the standard error adjusted for clustering by province). Variables are defined in table 1 and described in detail in the data appendix.