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Florence LACHET-TOUYA

CATT-UPPA
UFR Droit, Economie et Gestion
Avenue du Doyen Poplawski - BP 1633
64016 PAU Cedex
Tél. (33) 5 59 40 80 01
Internet : **http://catt.univ-pau.fr/live/**

UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

TAX INTERACTIONS WITH ASYMMETRIC INFORMATION AND NONLINEAR INSTRUMENTS

Florence LACHET-TOUYA*

18 juillet 2013

Abstract

When same authorities belonging to a same level of government derive their receipts from a mobile tax base, a competition mechanism takes place among them that triggers externalities. Likewise, when different layers of decision-makers exert their taxing power upon a common base, the choices made by one tier affect the receipts that the other governments can collect. Generally speaking, the decisions made by one government affect the tax revenue that can be collected by the decisionmakers belonging to the same tier of government or by stacked jurisdictions : externalities arise, the existence and the magnitude of which are closely related to the nature of the tax, to the mobility of the base and to the distribution of tax competence among decisionmakers. This paper proposes a model where both horizontal and vertical interactions take place. Uncertainty concerning the base, that is, the amount of capital likely to be invested, is introduced and a generalization of taxation schemes is provided in order to assess the robustness of traditional analyses results in a more general and realistic scheme. The analysis shows that horizontal and vertical externalities point towards opposite directions : while horizontal competition leads to inefficiently low rates, the common pool problem arising from the stacking of decisionmakers taxing a same base gives rise to a phenomenon of over-taxation. The paper aims at finding out whether the combination of both externalities yields higher or lower global tax rates than the one that would emerge in a unique government case. It turns that an excessively high level of taxation emerges. Nevertheless, the vertical tax externality is lessened with respect to the vertical competition case : the global tax rate sets at an intermediary level so that the outcome is brought closer to the social optimum issue.

Keywords : Vertical and horizontal tax externalities, Informational asymmetry, Tax competition, Common Agency, Nonlinear taxes.

*Université de Pau et des Pays de l'Adour, Faculté d'Economie et de Gestion, CATT, avenue du Doyen Poplawski, BP 1633, 64 016 Pau, FRANCE. I am hugely indebted and very grateful to David MARTIMORT and Jacques LE CACHEUX for their help and support, their research advice and numerous constructive discussions. I would also like to thank the anonymous referee for helpful comments and detailed suggestions. All errors are mine.

JEL Classification : D72, D82, H23, H30, H32, H71, H77.
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1 Introduction

> "There are fascinating times for the study of fiscal federalism. On the one hand, we are witnessing widespread efforts at devolution in both industrialized and developing nations as countries seek to improve the performance of the public sector by bringing decision-making closer to the people. On the other hand, we see in Europe the evolution of a new top layer of government that introduces more centralized policy-making. The multi-level character of government seem to be taking on an increasingly complex character." Oates, Fiscal federalism and European Union : Some reflections, 2002, Società italiana di economia pubblica, XIV conferenza.

Indeed, the issue of fiscal relationships between different levels of government comes up with a particular acuteness in the current context of shaping the future of the European Union with the topic of a potential own tax resource for the European budget. As far as the latter issue is concerned, the obviously increasing importance of European public goods (infrastructures, research . . .) and the needs for a more significant budget at the community level to finance these goods and common policies call for a genuine own resource, which means giving to Europe the power to tax. According to the principle of "No taxation without representation", the supra-national level would thus be made accountable for the policies undertaken thanks to this resource and the lack of congruence between on the one hand the structure of the European budget and, on the other hand, the aims of the Union would be reduced. One of the potential candidates could be a corporate income tax, which could allow lessen the distortions stemming from the differences between national systems if some tax harmonisation were before performed.

Taxation is especially at stake when authorities are vying for mobile tax bases. In traditional public finance literature, it has been shown that a unilateral rise in tax rate is an incentive for the mobile base to move towards another jurisdiction, which makes the locality that raised its tax suffer a reduction of available receipts. As a result, noncooperative same-level benevolent governments levy tax rates and provide a supply of public good that are inefficiently low[1]. Another crucial point is the vertical dimension of intergovernmental relationships. Indeed, the very essence of both federal and unitary countries is multileveled governments, which typically involves some commonality of tax base between higher- and lower- level decision-makers. The issue of vertical tax externalities started being addressed by the end of the eighties, with the papers of Flowers (1988) and Johnson (1988), and a real significant theoretical impulse was given with the works of Keen (1998), Keen and Kotsogiannis (2002, 2003, 2004), essentially. The developing literature devoted to this issue emphasizes the excessively high level of taxation resulting from the co-occupation of a same base. Actually, when a decision-maker increases her tax rate, authorities that belong to different layers of government are inflicted a negative externality conveyed by a tax base drop and the social marginal cost of raising tax revenue from the common base is under-valued.The global rate is too high and tax receipts are too weak with respect to the socially optimal outcome of a unique tax rate.

[1]In the survey of horizontal tax competition, we will precise how these results can be modified according different assumptions.

Because very often the map of territorial organizations is fragmented and overlapping, both horizontal and vertical fiscal external effects come into play and the interactions beween them are worth analysing.

Yet, studies achieved with regard to vertical tax externalities and their interactions with horizontal external effects suppose that the upper-tier faces no informational problem and, in particular, that the stock of capital (i.e. the mobile taxed factor) is known. Or, as some authors have recognized, informational asymmetries may be an important feature of tax competition. In particular, the level of mobile tax base may not be common knowledge[2]. Indeed, informational issues can represent a key element in the relationship between tax-payers and governments. Besides, taxation problems in multilayer government schemes can be seen as multiprincipal problems. In some cases, the agent (i.e. the taxpayer) may have a better knowledge than governments concerning one of her relevant parameters. Models analyzing the interactions between several principals can help improve the comprehension and knowledge of constitutional structures in which rival powers interact, especially as many principals (the governments) often contract with a unique and common agent (the taxpayer)[3]. What's more, unlike perfect information frameworks, in such models, governments compete in tax schedules, that is, functions that link the level of taxes on capital to the amount of capital invested in each jurisdiction. Nonlinear instruments allow a better adjustment to uncertainty than do fixed tax rates when decision-makers cannot commit to strategic variables and allow a formulation of the tax problem that more closely corresponds to the actual tax systems. To put it in a nutshell, assuming at the same time information asymmetries and nonlinear taxes allows enlightening real-life contexts.

Though the nonlinear tax scheme assumption within a framework involving asymmetries of information has been introduced in horizontal tax competition studies by Laussel and Lebreton, it has not been addressed by vertical tax competition literature.

This paper thus addresses the issue of strategic tax interactions not only between policymakers belonging to the same layer but also among different tiers of governments taxing a common base in the light of two related new assumptions : the introduction of uncertainty over the amount of capital likely to be invested and a generalization of taxation schemes via instruments that make taxes depend on the level of capital invested. Indeed, in some cases, the agent may have a better knowledge than governments concerning one relevant parameter. The article has the following structure : After a brief survey of existing literature on horizontal tax competition and on vertical externalities, the first section introduces the model we use to address tax competition. Section II displays the benchmark case, that is the setting of the unique government, while the following one is dedicated to the analysis of the vertical externality. The the last section investigates the interaction between horizontal and vertical external effects.

[2] *Martimort (1992), Laussel and Lebreton (1993, 1994).*

[3] Martimort and Stole (2003), Page and Monteiro (2003).

2 Brief survey of tax competition

2.1 Horizontal tax competition

Mobile tax bases are at the root of strategic tax competition, both within and between countries. Indeed, the existence of mobile tax bases that seek to optimally localize in order to get the higher after tax return possible triggers some competition among policymakers[4]. This mechanism induces horizontal tax externalities among same level governments.To a large extend, vying for mobile tax bases has been shown to put downward pressure on the degree of taxation in traditional literature based on the Pigouvian approach that sees the government as a benevolent social planner (as Wilson (1986), Zodrow and Mieszkowski (1986)). This main normative stream in public finance shows that when a decision-maker unilaterally and independently raises her tax rate, the mobile base can move into neighboring jurisdictions (since the net capital return becomes lower), thereby reducing the amount of tax receipts that can be collected in the locality that implemented a hike. If the first mover does not take this effect into account, her perceived marginal cost of public funds is higher than the real social cost, and the tax rates are set at a level lower than the level that would allow the provision of the optimal amount of local public good. However, when policymakers are Leviathan, horizontal tax competition may improve social welfare (Brennan and Buchanan (1977)).

Another strand of tax competition literature points mechanisms that lead to the opposite issue. For instance, political yardstick competition, that allows voters to use the performances of neighboring governments as a yardstick to assess the efficiency of their representative officials and decide accordingly whether to re-elect them or not, can lead to higher tax rates because some kind of collusion process can appear. A wider set of outcomes is also allowed through works taking into account the interest of public goods for firms and thus considering that, as they value public goods and services, governments can compete by increasing public good provision. In such a respect, starting from the standard Zodrow-Mieszkowski (1986) model, Dhillon, Wooders and Zissimos (2007) assume that the public good enters the production process of firms and that it is valued by the latter as it may enhance capital productivity. The result of this game can be efficiency or over-taxation and over-provision pf public good (i.e. race to the top), according factors as the degree of complementarity between capital and public good.

From the beginning of the neighties, models of common agency game have introduced informational asymmetries.

Leading papers are Laussel and Lebreton (1993, 1994). In the first one, they consider a single large investor who does not reside in the jurisdictions where he can invest, and the setting is a delegated common agency game : capital can be allocated in one or both jurisdictions or in none of them. The amount of total capital available is private information of the firm, whereas the policymakers of the two jurisdictions that compete for capital only have a prioris relative to this parameter. These principals are assumed to maximise their tax income. They choose simultaneously and non cooperatively the tax schedules they want to implement. The problem of the investor consists in deciding which levels of capital he is willing to invest in each

[4]For instance, if the base considered is capital, expanding it is valuable for local governments, as more capital generally means greater tax receipts, less unemployment, higher incomes and so forth.

jurisdiction, given the tax schedules proposed to her and provided that the amount of capital invested does not exceed the amount he owns. The equilibrium is the outcome where the firm optimally determines her investment choices, considering diversification as the best strategy, and two competing governments choose simultaneously the tax schedules that will maximize their tax revenues. This equilibrium is unique and all capital ends up being invested and equally divided among both jurisdictions[5]. In Laussel and Lebreton (1994), where there is a continuum of small investors, the existence of a unique equilibrium in tax schedules is demonstrated if the probability distribution has full support, and this equilibrium proves independent from the probability distribution. In the same strand of literature, additional results are provided. Olsen and Osmundsen (2001) analyse a model based upon a process of tax competition between two localities eager to capture the rents of a large investor partly owned by local shareholders. The firm has private information about the efficiency of her operations in both jurisdictions, whereas governments can only observe the levels of investment in each one. The investor can divide capital among two jurisdictions, and it is possible for her to redirect a part of the investment made in one locality towards the other one. The interaction between the two governments is modelled through the introduction of a joint cost. Policymakers are assumed to maximise expected domestic social welfare and thus integrate in their objective function the firm's profits, a part of which accrues to local shareholders. An equity externality arises that can make tax competition lead to results rather different from traditional common agency outcomes : lower investment levels and higher tax rates[6]. Olsen and Osmundsen (2002, 2003) also take into account spillovers correlated with the firm's productivity or an outside investment option ; in this context, tax competition may entail lower investment for inefficient types and higher investment for efficient ones in comparison with tax coordination.

2.2 Main findings about vertical tax externalities

Multilevel governments represent a common feature of fiscal arrangements, not only in such federations as Canada, where 70% of provincial goverments tax receipts come from overlapping bases, but also in such centralized states as France, where this mechanism accounts for the greatest part of local tax revenue. The "potential dependence of the tax base of each level of government on the tax policies pursued by the other" (Keen, 1998) triggers vertical externalities. They represent a growing concern as the number of multitiered-governments settings expands. The mechanism of vertical tax externality stemming from the co-occupancy of tax bases between several tiers of government was first analysed by Cassing and Hillman (1982) and highlighted by the pioneer work of Flowers (1988). Based on Brennan and Buchanan (1980), this model examines a situation in which two different layers of government eager to maximize their fiscal revenue tax a common mobile base. With respect to a unique government setting, the addition of a second authority endowed with tax powers induces an erosion of the common base. As

[5]No asymmetrical differentiable equilibrium can emerge in this model where the equilibrium net rates of return are strictly decreasing functions of the amounts of capital invested in the respective localities.

[6]The importance of taking into account the ownership structure has also been stressed by Calzolari (2000, 2002) who show that when the firm ownership is distributed among local and foreign entities, the firm can exert some kind of bargaining power or lobbying vis-à-vis governments.

each layer ignores the revenue losses incurred by the other policymaker when she raises her rate, the marginal cost of raising tax revenue from the common base is underestimated and the global tax rate is thereby excessively high. Besides, as demonstrated by Sobel (1997), the distortion is strengthened in a sequential framework, as the Stackelberg leader anticipates the revenue reduction and seeks to compensate for this effect through a hike in her tax level. The exhaustive study performed by Keen (1998) shows that when the lower level is Leviathan, federal and local taxes are strategic complements if the price-elasticity of the good demand is constant. If local decision-makers are benevolent, two additional effects appear : The decrease of demand for the good because of the consumer price rise (which lessens the loss of consumer welfare), and the reduced production of the local public good due to the shrinkage of the tax base (which makes the increase of local public good through higher tax rates more attractive). Empirical work yields results that vary according to the assumptions of the model studied.

Because both horizontal and vertical fiscal external effects come into play in territorial organizations, it appears relevant to take them into account simultaneously and to analyse the interactions between them.

Keen (1995) shows that both externalities point in different directions when a tax base overlap is combined to horizontal tax competition and that the economy ends up on the downward sloping side of the Laffer curve. Keen and Kotsogiannis (2002), (2004) tackle this issue through a model of benevolent governments, based on Zodrow and Mieszkowski (1986) with the addition of a higher level of policymaker and an endogeneized supply of capital. They show that the final effect depends on the elasticity of savings supply, capital demand, the level of income taxation, households'preferences for local or national public goods, and the degree of mobility of the tax base... In a Leviathan policymakers framework, Keen and Kotsogiannis (2003) prove that receipts are strictly higher for both local and federal governments if the tax rate is reduced by at least one of them. Furthermore, when the public goods provided by the different tiers of governments are substitute, social welfare also increases. Through an industrial organization point of view, Flochel and Madiès (2002) also analyze the resulting effect of simultaneous horizontal and vertical competition in a federal government in which decision-makers seek to maximize their revenue. They conclude that the competition between same level policymakers reduces the cumulated tax rate but cannot totally offset the vertical externality. Similarly to horizontal tax competition analyses, some authors have shown that the conclusions could be greatly modified if productivity-enhancing public goods were introduced. For instance, Dhalby and Wilson (1998, 2003) show that an insufficient supply of public good can emerge if state and federal governments apply an ad valorem tax on wages and produce a public good that improves labor productivity. Thanks to a model based on Keen and Kotsogiannis (2002), Madiès (2004) demonstrates that if states provide such a public good whereas the central government provides a residential public good, a fiscal feed-back effect may arise and the resulting dominant effect is not clear-cut. To put it in a nutshell, the net impact of the interaction between horizontal and vertical externalities appears rather ambiguous and assumption-dependent.

3 A model of taxation with nonlinear instruments : Framework and main assumptions

Through a model taking information asymmetries into account, we study tax interactions among different layers of governments, one of them being composed of many jurisdictions competing for firms. The first kind of information asymmetry likely to emerge is adverse selection, which corresponds to the fact that the base, i.e. the firm, possesses an informational advantage upon the government with respect to an exogenous feature such as the amount of capital available for investment. The second type of informational problem that may arise and create a gap between the firm and the policymaker stems from a moral hazard process according to which some endogenous variables of the firm cannot be observed by the government : the firm may choose to allocate capital towards another use than local investment. This is a common agency game setting in which the agent, the firm, holds a private information about the amount of capital available, whereas the governments are the imperfectly informed principals[7].

This work departs from Keen and Kotsogiannis (2002, 2003, 2004) in the way that it assumes that governments do not perfectly know the total amount of capital the firm possesses and may locally invest. In Keen and Kotsogiannis (2002, 2003, 2004), the magnitude of both externalities and the prevalence of one of them depends on the taxation of the fix factor, on savings supply and capital demand elasticities. In the following model, we conclude on the domination of one kind of externalities when both tax effects interplay.

3.1 Choice of the instruments

We choose to endogeneize the instruments used, that is we consider nonlinear taxes which allow a better analysis of the firm's investment choices and governments' policies. This choice is justified not only from a theoretical point of view, as the firm holds private information, but also rests on practical grounds. Indeed, though corporate taxes are usually proportional, often tax advantages are offered that make them depart from mere proportional taxes (deductible capital allowances, tax exemptions...) and support the use of nonlinear instruments. As explained by Olsen and Osmundsen (2001), governments should be less informed than the firm concerning some features of hers because of the international nature of major enterprises, of interfirm transactions, of complex technologies that imply obstacles for the authorities to ascertain the firm's efficiency... As a result, the instruments are not lump-sum, they depend on the agents' choices and involve incentive effects.

We restrict to twice differentiable nonlinear deterministic transfers and use the First-Order Approach, developped by Martimort and Stole (2002), to compute the best response of the principals to pure-strategy nonlinear contracts offered by their rival in a differentiable equilibrium. Actually, in such a setting, different contracts proposed by a principal do not affect the same way the firm's incentives to invest in the jurisdiction of the other principal. An externality

[7] In such all-or-nothing games in which the agent cannot restrict to contract with only some of the principals, diversifying investment is a better strategy for the firm than instead investing locally all the capital she owns or directing it to the alternative economic area.

is created by the fact that a local government's decisions affect the design of the contracts the rival principal proposes to firms since they introduce a change in firms' incentives to behave with respect to the principal.

In common agency settings, two types of externalities may arise, preventing the use of the Revelation Principle : a direct effect via a common parameter, and a contractual externality as the actions taken by one principal necessarily affect the situation of the other ones (Martimort and Stole (2002)). Besides, this principle can be questioned when the contracts become more complex or exhaustive. Some other difficulties may emerge such as the fact that if in the usual principal-agent setting the latter generally trusts the principal's direct mechanism when she has to reveal her private information, in a framework involving many principals one of them may induce the agent to misrepresent to other principals, which can make thruthful equilibria disappear.

Many authors have shown how to go beyond such troubles and proposed amended versions of this principle.

A pioneer approach is Epstein and Peters (1999) who demonstrate that the Revelation Principle can be implemented in a multi-principal-multi-agent framework with an enlarged set of the agent's types. In a one-principal setting, a nonlinear schedule can replicate the same outcome as any deterministic direct communication process ; there is no loss of generality in confining to strategically decentralized menus of relevant contracting parameters. This is the Taxation Principle (Guesnerie, 1981, 1995, and Rochet, 1986), according to which, in the one principal context, "for any truth-telling, direct-revelation mechanism, there exists an associated schedule or menu of choices which can be offered to the agent and which implements the same equilibrium outcome through decentralization"(Martimort and Stole, 2002, p.1659-60)[8].

An extension of the previous principle to multiprincipals frameworks is the Delegation Principle (Page, 1999), which can be used to characterize the set of equilibria from all message games. This principle suggests that "the set of equilibrium outcomes obtainable in an indirect communication game with arbitrary message spaces can be replicated as equilibrium outcomes in a game in which the principal payoff relevant menus from which the agent chooses"(Martimort and Stole, 2002, p.1664). Thus, when it appears difficult to characterize the set of all equilibria, the Delegation Principle guarantees that there is no loss of generality in considering the class of unrestricted menu games, provided that the restrictions imposed by the size of the underlying communication spaces are taken into account.

In this paper, we use this extended Principle.

The game is an intrinsic common agency game, i.e. a all-or-nothing game where the agent does not have the option to contract exclusively with a single principal (Bernheim and Whinston (1986), Martimort and Stole (2004)).

3.2 The players

We consider an organization made of two same-level governments, the jurisdictions, supposed to be identical in all relevant aspects, and of an upper-tier authority. All decision-makers

[8]Page and Monteiro (2003) hint at the Competitive Taxation Principle in this framework and underline that nonlinear pricing schedules and catalogs are strategically equivalent.

are considered to be endowed with independent spending and taxing powers. Local governments can contract with the firm on the amount of capital she invests in the jurisdictions. The higher-level government can tax the whole amount of capital locally invested. Tax authorities are supposed to be Leviathan.

We assume there is a unique firm that can invest its capital either in one locality or in both of them, or else dedicate it to another use. The amount of capital available for investment, θ, is a private information of the agent. θ is a continuous parameter that belongs to the set $\Theta = \left[\underline{\theta}; \overline{\theta}\right]$. The prior of the governments relative to θ are described by a common knowledge law represented by the continuous distribution function $G(\theta)$ and the strictly positive density function $g(\theta)$, with the the MLRP being satisfied $\frac{d}{d\theta}\left(\frac{1-G(\theta)}{g(\theta)}\right) < 0$. Besides, $\frac{d}{d\theta}(g(\theta))$ is nonnegative.

Timing of the game :

1. Nature determines θ and the agent learns her private parameter.
2. Contracts are offered by the principal(s) : $\{T(k_i(\theta)); k_i(\theta)\}, \{\tau(k(\theta)); k(\theta)\}$.
3. The firm simultaneously accepts or rejects the contracts.
4. The agent reports her type to each of the principal ; we assume that this report is unobservable to the other principal and that no communication among them occurs.
5. Capital is invested and taxes are levied according to the contract.

The firm θ receives the output (prices are normalized to one) net of taxes, the profit writes

$$U(\theta) = \{f(k_1) - T(k_1) + f(k_2) - T(k_2) - \tau(k_1 + k_2) + M(\theta - k_1 - k_2)\}.$$

In this common agency framework, we use indirect mechanisms instead and apply the Taxation Principle (θ is unobservable to the principals and they cannot discriminate among the different possibles types of firms in such a private information setting).

Whatever her type $\theta \in \Theta$, an agent that accepts the contract makes an announcement θ^a and is thus required to pay a tax $t(\theta^a)$, while she is induced to invest a fraction $k(\theta^a)$ of the capital at her disposal. The best choice for the firm being to tell the truth,

$$U(\theta) = \max_{\theta^a} \{f(k(\theta^a)) - t(\theta^a) + M(\theta - k(\theta^a))\}.$$

$T(k_i)$ designs the tax levied by the local government of jurisdiction i (i=1,2) on the amount of capital invested there : $k_i(\theta)$. The upper-tier applies a tax $\tau(\cdot)$ upon the whole local investment $\sum_{i=1}^{2} k_i(\theta)$. We consider that capital cannot be subsidized, that is marginal taxes are necessarily positive.

We denote $f(k_i(\theta))$ the output in jurisdiction i as a function of the capital locally invested. $f(\cdot)$ is three times continuously differentiable, $f'(\cdot) > 0$, $f(0) = 0$, $f''(\cdot) < 0$: the production function is assumed to be monotonously increasing in capital with decreasingly profitable successive units of capital as the capital stock expands.

$M(\theta - k_1(\theta) - k_2(\theta))$ represents the opportunity benefit of not investing locally all the capital available. $M(\cdot)$ is exogenous, increasing and strictly concave : $M'(\cdot) > 0$, $M"(\cdot) < 0$. Besides, we assume that $M'''(\cdot) > 0$.[9]

We consider there is a unique homogenous good produced by the jurisdiction and taken as *numeraire*. The only production factor is capital (for a simplicity stake, we do not make the assumption of a fixed factor). The good can be either consumed or used as an input in the production of the local public good.

4 Benchmark situation : A Unique Decision-maker

We assume there is a unique revenue-maximizing government.

An investor has to choose the level of capital to be invested locally (under the constraint not to invest more capital than what he owns).

As previously indicated,

$$U(\theta) = \max_{\theta^a} \{f(k(\theta^a)) - t(\theta^a) + M(\theta - k(\theta^a))\}.$$

The necessary and sufficient conditions for the contract to be incentive are

$$\begin{aligned} \dot{U}(\theta) &= M'(\theta - k(\theta)), \\ \dot{k}(\theta) &> 0. \end{aligned}$$

[9]For the first order approach to be valid, quasi-concavity of the agent's utility wrt θ^a is sufficient. Quasi-concavity is satisfied for all incentive compatible contracts. Let $u(\theta^a, \theta)$ be the agent's utility when her type is θ and she reports θ^a.

$u(\theta^a, \theta) = f(k(\theta^a)) - t(\theta^a) + M(\theta - k(\theta^a))$.

Thus, :

$$\frac{\partial u(\theta^a, \theta)}{\partial \theta^a} = f'(k(\theta^a)) k'(\theta^a) - t'(\theta^a) - M'(\theta - k(\theta^a)) k'(\theta^a).$$

By incentive compatibility,

$$f'(k(\theta)) k'(\theta) - t'(\theta) - M'(\theta - k(\theta)) k'(\theta) = 0, \forall \theta$$

i.e.

$$t'(\theta^a) = f'(k(\theta^a)) k'(\theta^a) - M'(\theta - k(\theta^a)) k'(\theta^a)$$

As a result,

$$\frac{\partial u(\theta^a, \theta)}{\partial \theta^a} = [M'(\theta^a - k(\theta^a)) - M'(\theta - k(\theta^a))] k'(\theta^a) = \int_{\underline{\theta}}^{\overline{\theta}} M"(s - k(\theta^a)) ds k'(\theta^a).$$

This equation is positive when $\theta^a < \theta$ and negative when $\theta^a > \theta$. Therefore, $u(\theta^a, \theta)$ is quasi-concave in θ^a and is maximized at $\theta^a = \theta$, and the first order approach is justified.

Besides, the firm cannot invest more capital than she owns. We assume that this financial constraint, $\theta \geq k(\theta)$, is not binding at the optimum. Indeed, two participation constraints are added to ensure that diversifying her investment is a better strategy for the firm than investing locally all the capital she owns or directing it towards the alternative area[10].

The Taxation Principle allows the implementation of incentive nonlinear schemes, making the optimal tax depend on the amount of capital invested $\{T(k(\theta))\}$.

$k(\cdot)$ is a monotonically increasing function, so it can be inverted to yield θ as a function of k.

Tax schedules are assumed to be deterministic and twice continuously differentiable. We consider indirect mechanisms.

The programme of the government becomes

$$\max_{\{U(.),k(.)\}} \int_{\underline{\theta}}^{\overline{\theta}} T(k(\theta)) g(\theta) d\theta \tag{1}$$

subject to

$$U(\underline{\theta}) = 0 \tag{2}$$

$$\dot{U}(\theta) = M'(\theta - k(\theta)) \tag{3}$$

$$\dot{k}(\theta) > 0. \tag{4}$$

The informational gap stemming from the firm's better knowledge of a relevant characteristic induces the government to give her a rent in order to prevent a misrepresentation of her true type.[11]

$$\int_{\underline{\theta}}^{\overline{\theta}} U(\theta) g(\theta) d\theta = \int_{\underline{\theta}}^{\overline{\theta}} \frac{1 - G(\theta)}{g(\theta)} M'(\theta - k(\theta)) g(\theta) d\theta.$$

See Annex for detailed calculations.

With respect to a perfect information setting, the principal has to offer a rent to the agent because of the informational gap that exists with the latter. Indeed, due to her superior knowledge of a relevant characteristic, the firm has an incentive to misrepresent her true type, i.e. the amount of capital she can invest, and to use the implicit threat of redirecting part of the capital available to another economic use. The agent tries to draw an interest from her informational advantage over the government, who is no longer able to reap all the profit through taxation.

[10]

$$\begin{aligned} f(k(\theta)) - t(\theta) + M(\theta - k(\theta)) &\geq f(\theta) - t(\theta) \\ f(k(\theta)) - t(\theta) + M(\theta - k(\theta)) &\geq M(\theta). \end{aligned}$$

[11] In the perfect information case, as the government would know the amount of capital available for investment, it would be equivalent to make taxes depend on k or on θ, and we could restrict to direct contract.

In order to bring the outcome closer to an efficient solution, the contract must elicit the firm's hidden type, and only giving up a rent to her can allow succeeding. As the informational gap prevents her from having a perfect knowledge of the relevant parameter of the agent, the government is not able to set the appropriate tax rate upon the firm but a lower one, and the tax receipts she can collect are less important :

$$\int_{\underline{\theta}}^{\overline{\theta}} \left\{ f\left(k\left(\theta\right)\right) + M\left(\theta - k\left(\theta\right)\right) - \frac{1 - G\left(\theta\right)}{g\left(\theta\right)} M'\left(\theta - k\left(\theta\right)\right) \right\} g\left(\theta\right) d\theta.$$

Deriving the first order condition gives[12] :

$$f'\left(k\left(\theta\right)\right) = M'\left(\theta - k\left(\theta\right)\right) - \frac{1 - G\left(\theta\right)}{g\left(\theta\right)} M"\left(\theta - k\left(\theta\right)\right)$$

Besides, from the envelope theorem, the unitary marginal tax rate $T'^{U}\left(\cdot\right)$ expresses as

$$T'^{U}\left(k^{U}\left(\theta\right)\right) = f'\left(k\left(\theta\right)\right) - M'\left(\theta - k\left(\theta\right)\right)$$

Direct computations yield the following unitary equilibrium tax

$$T'^{U}\left(k^{U}\left(\theta\right)\right) = -\frac{1 - G\left(\theta\right)}{g\left(\theta\right)} M''\left(\theta - k^{U}\left(\theta\right)\right) \tag{5}$$

Remark : it is important to check whether marginal tax rates are an increasing or a decreasing function of the amount of capital invested.[13]

$$T"^{U}\left(k\left(\theta\right)\right) = -\frac{d}{d\theta}\left(\frac{1 - G\left(\theta\right)}{g\left(\theta\right)}\right) \frac{M''\left(\theta - k\left(\theta\right)\right)}{\dot{k}\left(\theta\right)} + \frac{1 - G\left(\theta\right)}{g\left(\theta\right)} M'''\left(\theta - k\left(\theta\right)\right) \left[1 - \frac{1}{\dot{k}\left(\theta\right)}\right] \leq 0 \ .$$

The more the firm invests in the jurisdiction, the less the marginal tax rate can be raised. Not only the mobility of the agent but also and above all her private information strongly affect the government's ability to implement her preferred tax policy.

Remark : See Annex 2 for a change in the nature of the government.

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[12] The concavity of the problem is verified as :

$$f''\left(k\left(\theta\right)\right) \times \dot{k}\left(\theta\right) = \left[M''\left(\theta - k\left(\theta\right)\right) - \frac{1 - G\left(\theta\right)}{g\left(\theta\right)} M'''\left(\theta - k\left(\theta\right)\right)\right] \left[1 - \dot{k}\left(\theta\right)\right] - \frac{d}{d\theta}\left(\frac{1 - G\left(\theta\right)}{g\left(\theta\right)}\right) M''\left(\theta - k\left(\theta\right)\right) < 0$$

[13]
$$\dot{k}\left(\theta\right) = \frac{M"\left(\theta - k\left(\theta\right)\right)\left[1 - \frac{d}{d\theta}\left(\frac{1 - G\left(\theta\right)}{g\left(\theta\right)}\right)\right] - \frac{1 - G\left(\theta\right)}{g\left(\theta\right)} M'''\left(\theta - k\left(\theta\right)\right)}{f"\left(k\left(\theta\right)\right) + M"\left(\theta - k\left(\theta\right)\right) - \frac{1 - G\left(\theta\right)}{g\left(\theta\right)} M'''\left(\theta - k\left(\theta\right)\right)} \in \left]0; 1\right[$$

5 Concurrent taxation of a common base

We consider that two different levels of government, with only one decision-maker a layer, simultaneously and non cooperatively levy taxes on firms. Both bottom-up and top-down tax externalities can arise.

Let's consider that thue upper-layer of government, say the central government, sets a tax $\tau(.)$ upon the amount of capital locally invested. As far as he's concerned, the lower-tier of government, for instance a local decisionmaker, levies a tax $T(.)$ on the same base.

The profit of a firm θ writes

$$U(\theta) = f(k(\theta)) - T(k(\theta)) - \tau(k(\theta)) + M(\theta - k(\theta)).$$

The program of the local government is

$$\max_{k(\theta)} \int_{\underline{\theta}}^{\overline{\theta}} T(k(\theta)) g(\theta) d\theta = \int_{\underline{\theta}}^{\overline{\theta}} [f(k(\theta)) + M(\theta - k(\theta)) - \tau(k(\theta)) - U(\theta)] g(\theta) d\theta$$

subject to

$$\begin{aligned} U(\underline{\theta}) &= 0 \\ \dot{U}(\theta) &= M'(\theta - k(\theta)) \\ \dot{k}(\theta) &> 0. \end{aligned} \tag{6}$$

Which, using the same methodology as in the previous part, yields :

$$f'(k(\theta)) = M'(\theta - k(\theta)) + \tau'(k(\theta)) - \frac{1 - G(\theta)}{g(\theta)} M"(\theta - k(\theta))$$

Likewise, the objective function of the federal government is

$$\max_{k(\theta)} \int_{\underline{\theta}}^{\overline{\theta}} \tau(k(\theta)) g(\theta) d\theta = \int_{\underline{\theta}}^{\overline{\theta}} [f(k(\theta)) + M(\theta - k(\theta)) - T(k(\theta)) - U(\theta)] g(\theta) d\theta$$

subject to the same set of constraints.

Which yields

$$f'(k(\theta)) = M'(\theta - k(\theta)) + T'(k(\theta)) - \frac{1 - G(\theta)}{g(\theta)} M"(\theta - k(\theta))$$

We can deduce that

$$T'\left(k\left(\theta\right)\right)=\tau'\left(k\left(\theta\right)\right)$$

Besides, from the first-order condition,

$$f'\left(k\left(\theta\right)\right)-T'\left(k\left(\theta\right)\right)-\tau'\left(k\left(\theta\right)\right)-M'\left(\theta-k\left(\theta\right)\right)=0$$

As a result, marginal taxes in the vertical competition case, $T'^{V}\left(k^{V}\left(\theta\right)\right)$ and $\tau'^{V}\left(k^{V}\left(\theta\right)\right)$ express as

$$T'^{V}\left(k^{V}\left(\theta\right)\right)=\tau'^{V}\left(k^{V}\left(\theta\right)\right)=-\frac{1-G\left(\theta\right)}{g\left(\theta\right)}M''\left(\theta-k^{V}\left(\theta\right)\right) \tag{7}$$

$$T'^{V}\left(k^{V}\left(\theta\right)\right)+\tau'^{V}\left(k^{V}\left(\theta\right)\right)=2\times\frac{1-G\left(\theta\right)}{g\left(\theta\right)}M''\left(\theta-k^{V}\left(\theta\right)\right)$$

In order to determine whether the global tax rate is higher or lower than the unitary tax rate, let's consider the following concave function $\varphi\left(k\right)=f\left(k\left(\theta\right)\right)+M\left(\theta-k\left(\theta\right)\right)-\frac{1-G\left(\theta\right)}{g\left(\theta\right)}M'\left(\theta-k\left(\theta\right)\right)$. It reaches a maximun for $k=k^{U}$ (that is $\varphi'\left(k^{U}\right)=0$). Then,

$$\varphi'\left(k^{V}\right)=T'^{V}\left(k^{V}\left(\theta\right)\right)=\tau'^{V}\left(k^{V}\left(\theta\right)\right)>\varphi'\left(k^{U}\right)=0\implies k^{V}<k^{U}$$

Because she is taxed twice, a firm is deterred from locally investing a substantial amount of capital.

As a by-product

$$T'^{V}\left(k^{V}\left(\theta\right)\right)=\tau'^{V}\left(k^{V}\left(\theta\right)\right)=-\frac{1-G\left(\theta\right)}{g\left(\theta\right)}M''\left(\theta-k^{V}\left(\theta\right)\right)<T'^{U}\left(k^{U}\left(\theta\right)\right)=-\frac{1-G\left(\theta\right)}{g\left(\theta\right)}M"\left(\theta-k^{U}\right)$$

Besides, as

$$T'\left(k\right)+\tau'\left(k\right)=\varphi'\left(k\right)-\frac{1-G\left(\theta\right)}{g\left(\theta\right)}M"\left(\theta-k\right),\ T'^{V}\left(k^{V}\left(\theta\right)\right)+\tau'^{V}\left(k^{V}\left(\theta\right)\right)>T'^{U}\left(k^{U}\left(\theta\right)\right)$$

In a concurrent taxation of a common base setting, the cumulated tax rate results higher than in the cooperative case of a unique government. The marginal tax rate that any policymaker can implement is reduced as less capital is invested. Yet, the global tax rate remains higher than the degree of taxation charged in the reference case : the vertical external effect dominates.The cumulated tax is higher than in the cooperative case

$$\tau'^{V}\left(k^{V}\left(\theta\right)\right)=T'^{V}\left(k^{V}\left(\theta\right)\right)<T'^{U}\left(k^{U}\left(\theta\right)\right)<T'^{V}\left(k^{V}\left(\theta\right)\right)+\tau'^{V}\left(k^{V}\left(\theta\right)\right) \tag{8}$$

The marginal tax rate that any policymaker can implement is reduced as less capital is invested. Yet, the global tax rate remains higher than the degree of taxation charged in the reference case : the vertical external effect dominates.

Proposition 1 : *In a framework involving asymmetries of information, each layer of government reduces her tax rate with respect to a setting where he would be the only authority able to exert her fiscal power upon the base. When two tiers of decisionmakers simultaneously tax a common base, each one tries to get most of it, neglecting the negative externality conveyed upon the other government since the amount of revenue available is eroded. As a result, the cumulated tax rate ends up too high with respect to the optimal issue.*

When tax bases are, at least partially, the joint property of different layers of government, if one of them does not take into account the impact of her choices upon the other tier, an excessively high degree of taxation arises with respect to the level that would be set by a unique decisionaker. Indeed, any authority that raises her tax rate without internalizing the global effect this decision triggers upon the total amount of capital located in the area neglects the induced shrinkage in the common base that the other layer will suffer, and thus values the marginal cost of public funds at a lower level than the true marginal cost, which leads to excessively high taxes[14]. This is the *vertical tax externality.*

The same conclusion as in perfect information cases of an excessive cumulated tax emerges, but downward effects appear. Actually, as both governments ignore the amount of capital available and take their decisions simultaneously and non-cooperatively, each of them has to grant the agent an informational rent in order to provide her with incentives to reveal her true type and make the "appropriate" investment choices. The final informational rent accruing to the firm is higher when policymakers compete than when they cooperate. As a result, there is also a stacking of rents, which further reduces the global tax rate that can be levied : this is the *asymmetry of information effect.* Related to this argument, it appears that the upward taxation trend stemming from the superposition of various levels of governments is restrained by the alternative investment opportunity. Actually, the firm can decide to allocate part of the amount of capital she possesses (or the whole) to another economic use. This is particularly true if the firm is risk-averse, or if her expected return from local investment is hampered by taxation. As governments are aware of the existence of alternative investment opportunities for the firm, they must be cautious when they make their tax policy decisions not to set prohibitive tax rates that would deter the firm from locally investing. Instead, they have to provide her with incentives to direct her capital towards jurisdictions rather than allocate it in the other investment possibility. To some extend, this *portfolio diversification effect* imposes an upper limit on the taxation level that can be implemented by the decisionmakers, and softens the vertical externality.

6 Combining Horizontal and Vertical Interactions

The internal organization of countries often gives rise to both vertical and horizontal external effects. That's why it is important to analyse the interaction between them in a context involving

[14]This conclusion is consistent with the results of the industrial organization analyses led in a bilateral monopoly framework (Spengler, 1954, Tirole, 1988) which show that if both parties charge a markup, the final retail price will be higher than it would be in a vertically-integrated situation, and profits will be set at a lower level.

asymmetry of information.

In order to examine how vertical and horizontal tax externalities interact, we consider an institutional structure made of two levels of policymakers and we assume that the hierarchically lower layer is composed of two governments : i = 1 and 2.[15] All the incumbents are supposed to be revenue-maximizers. They play simultaneously.

Each local authority i taxes the capital that the firm has invested in her jurisdiction $k_i(\theta)$, whereas the upper-tier applies a tax upon the whole amount of local investment $\sum_{i=1}^{2} k_i(\theta)$. The profit of a firm θ depends on both contractual requirements and writes

$$U(\theta) = \max_{k_i} \left\{ \sum_{i=1}^{2} \{ f(k_i(\theta)) - T_i(k_i(\theta)) \} - \tau \left(\sum_{i=1}^{2} k_i(\theta) \right) + M \left(\theta - \sum_{i=1}^{2} k_i(\theta) \right) \right\} \quad (9)$$

We successively examine the strategy of each layer of government.

6.1 Problem of the upper-tier authority

We can write the program in function of the investment choice in one jurisdiction. Hence, if k represents the total amount the firm invests locally, and the level invested in jurisdiction i is k_i, then the profit of the firm writes

$$U(\theta) = \max_{k,k_i} \{ f(k_i) - T^*(k_i) + f(k - k_i) - T^*(k - k_i) - \tau(k) + M(\theta - k) \}. \quad (10)$$

As the governments play Nash, the upper-tier authority takes as given the tax rates set by the lower layer.

Deriving with respect to k gives

$$f'(k - k_i) - T'(k - k_i) - \tau'(k) - M'(\theta - k) = 0$$

The problem of the higher-level government consists in $\max_{\{k;U(\theta)\}} \int_{\underline{\theta}}^{\overline{\theta}} \tau(k) g(\theta) d\theta$

$$= \max_{\{k;U(\theta)\}} \int_{\underline{\theta}}^{\overline{\theta}} \{ f(k_i) - T(k_i) + f(k - k_i) - T(k - k_i) + M(\theta - k) - U(\theta) \} g(\theta) d\theta.$$

Maximization in k yieds

[15] For a simplicity sake, we assume that two symmetric localities, identical in all relevant aspects, compete for capital (investments in either jurisdictions are substitute). At equilibrium, tax rates converge and a same level of capital is allocated in both jurisdictions (this result critically depends on the assumption of decreasing marginal productivity of capital). It could be relevant to consider the case of asymmetric jurisdictions, which would be made possible thanks to differentiated technologies of production.

$$0 = f'(k - k_i) - T'(k - k_i) - M'(\theta - k) - \frac{1 - G(\theta)}{g(\theta)} M"(\theta - k)$$

So the central government marginal tax rate is

$$\tau'(k) = -\frac{1 - G(\theta)}{g(\theta)} M"(\theta - k) \tag{11}$$

6.2 Problem of a local government

If we come back to the initial expression of the profit of the firm, with jurisdictions 1 and 2

$$U(\theta) = \max_{k_1, k_2} \{f(k_1) - T(k_1) + f(k_2) - T(k_2) - \tau^*(k_1 + k_2) + M(\theta - k_1 - k_2)\}.$$

Optimizing with respect to k_2 implicitly defines k_2 as a function of k_1 and $\theta : k_2^*(k_1, \theta)$. As a by-product, the other same-level government (1) optimizes over the definition set a function the maximand of which is

$$f(k_1(\theta)) + f(k_2^*(k_1, \theta)) - T(k_2^*(k_1, \theta)) - \tau(k_1(\theta) + k_2^*(k_1, \theta)) + M(\theta - k_1(\theta) - k_2^*(k_1, \theta)) - U(\theta). \tag{12}$$

Slightly abusing notations and combining the results from the optimization processes, the tax rate set by any lower-level decision-maker writes

$$\begin{aligned} 0 = {} & f'(k_i) - \tau'\left(k_i + k_j^*\right) - M'\left(\theta - k_i - k_j^*\right) + \frac{1 - G(\theta)}{g(\theta)} M"\left(\theta - k_i - k_j^*\right) \\ & + \frac{\partial k_j^*}{\partial k_i} \left\{ f'\left(k_j^*\right) - T'\left(k_j^*\right) - \tau'\left(k_i + k_j^*\right) - M'\left(\theta - k_i - k_j^*\right) + \frac{1 - G(\theta)}{g(\theta)} M"\left(\theta - k_i - k_j^*\right) \right\}. \end{aligned}$$

Substituting the value of $\tau'(.)$ by its expression and combining the results from the optimization processes, the tax rate set by any lower-level decision-maker writes

$$T'\left(k_j^*\right) = -\frac{1 - G(\theta)}{g(\theta)} M"\left(\theta - k_i - k_j^*\right) \times \left[1 + \frac{\partial k_j^*}{\partial k_i}\right] \tag{13}$$

As the tax rate cannot be negative, $1 + \dfrac{\partial k_j^*}{\partial k_i}$ must be positive. Thus,

$$-1 < \frac{\partial k_j^*}{\partial k_i} < 0$$

6.3 Global level of taxation

In order to ease comparisons, let k^{HV} define the total amount of capital locally invested when both horizontal and vertical tax externalities are at work simultaneously.

Tax rates are

$$T'\left(k_i{}^{HV}\right) = -\frac{1-G(\theta)}{g(\theta)} M"\left(\theta - k^{HV}\right)\left[1 + \frac{\partial k_i^*}{\partial k_j}\right], \forall i = 1,2, \forall j = 2,1 \tag{14}$$

$$\tau'\left(k^{HV}\right) = -\frac{1-G(\theta)}{g(\theta)} M"\left(\theta - k^{HV}\right)$$

Which yields the cumulated tax rate

$$T'(k_j) + \tau'\left(k^{HV}\right) = -\frac{1-G(\theta)}{g(\theta)} M"\left(\theta - k^{HV}\right)\left[\underbrace{2}_{VE} + \underbrace{\partial k_i^*/\partial k_j}_{HE}\right], \forall i = 1,2, \forall j = 2,1 \tag{15}$$

Both vertical and horizontal tax externalities play. When horizontal competition is introduced, the monopoly power of the upper tier is strengthened as a race to the bottom may arise at the lower level of government inducing local authorities to reduce their degree of taxation and set lower tax rates than the upper-tier.

$$0 < \frac{T'\left(k_i{}^{HV}\right)}{\tau'\left(k^{HV}\right)} < 1$$

Applying the same methodology as previously, it appears that

$$k^{HV} < k^U \text{ and } T'\left(k_j(\theta)\right) + \tau'\left(k^{HV}(\theta)\right) > T'^U\left(k^U(\theta)\right), \forall j = 2,1 \tag{16}$$

Proposition 3 : *In a multi-level government setting involving some competition between same-layer authorities, the degree of capital taxation appears higher than in the unique policy-maker case : $T'\left(k^{HV}/2\right) + \tau'\left(k^{HV}\right) > T'\left(k^U\right)$. Informational asymmetries and the downward pressure exerted by same-layer decision-makers competition cannot offset the "race to the top" triggered by the simultaneous taxation of a common base by several levels of government.*

Likewise, whether the global degree of taxation is more or less important in such a setting than in the vertical case is also immediate

$$k^{HV} < k^V \ , \ -(2 + \partial k_i^*/\partial k_j) \times \frac{1-G(\theta)}{g(\theta)} M"\left(\theta - k^{HV}\right) < -2 \times \frac{1-G(\theta)}{g(\theta)} M"\left(\theta - k^V\right).$$

Proposition 4 : *The cumulated tax rate is set at an intermediary level between the taxes that are charged in the cooperative case and in the concurrent taxation setting*

$$T'\left(k^H\right) < T'\left(k_i^{HV}\right) + \tau'\left(k^{HV}\right) < T'\left(k^V\right)$$

The final global tax rate resulting from the interplay of both kinds of external effects is set at an intermediary level between the level resulting from horizontal competition in the absence of an upper-tier authority and the degree induced by the double taxation of a common base by two decisionmakers belonging to different layers of government. With respect to the existence of a unique decisionmaker, the presence of another layer of government increases the global taxation imposed upon the mobile base (firms) whereas a potential competition between same level authorities tends to exert a downward pressure upon the tax rates implemented and brings the issue closer to the optimal outcome. Nonetheless, the first effect results as the dominant one, local governments do not lower their degree of taxation enough to completely offset the double taxation effect.

7 Conclusion

Two kinds of tax externalities are at work in a multi-level territorial organization. The first one is a horizontal externality that arises between same-level governments. Each of them neglects the beneficial effect that raising its tax rate conveys on other jurisdictions (through the expansion of their tax bases), thereby leading to the equilibrium local tax and public good provision being inefficiently low. On the other hand, the reverse mechanism emerges in the vertical tax externality case. When two layers of government tax a common base, they do not take into account the damaging consequences of an increase in their tax rate for the other tier (*via* an erosion of the base), which yields overtaxation.

Most public organizations are characterized by both a stacking of governments and the existence of many policymakers at a same level. Vertical tax externalities represent a growing concern as the number of multitiered-governments settings expands and the complexity of territorial organizations increase. As a result, it is essential to deepen and improve our understanding not only of vertical effects but also of their interaction with horizontal tax competition.

The purpose of this paper has been to address the issue of strategic tax interactions not only between policymakers belonging to the same layer but also, and above all, among different tiers of governments taxing a common base, in the light of two related new assumptions : the introduction of uncertainty over the amount of capital likely to be invested and a generalization of taxation schemes via instruments that make taxes depend on the level of capital invested (i.e. the observable and verifiable variables) and that more closely correspond actual tax systems. As a consequence, the external effects likely to arise in such settings can be analyzed in a more general and realistic framework.

We have shown that the combination of both externalities lessened the magnitude of each one and brought the outcome closer to the social optimum. The vertical externality can be decomposed into a first effect reflecting the fact that when many layers of government occupy a same tax base the final level of taxation results inefficiently high and an informational effect stemming from the double ignorance of a relevant private parameter of the firm by both governments, that constrains them to give up a rent to the agent. This mechanism indirectly means that they must accept to lower their degree of taxation with respect to a perfect and complete information case. Furthermore, it is essential to underline that another element exerts

some kind of competitive pressure that strenghtens the informational asymmetries impact : Actually, the firm may revise her capital distributional choice between local investment and the alternative opportunity. As a consequence, governments must be careful not to set a deterrant level of taxation upon firms. As far as mobile tax bases are concerned, the simultaneity of horizontal tax competition and governments stacking results can, to some extend, be considered as socially desirable : when same level decisionmakers wish to attract a mobile base, the addition of another level of governments allows restauring social efficiency as with only competing jurisdictions endowed with tax competence the resulting degree of taxation would be sub-optimally low. Nevertheless, to go deeper into the analysis, it would be interesting to investigate whether the social optimum corresponds to the situation of a cooperative tax rate in a complete and perfect information context and try to determine if the interaction of both externalities results in a global tax rate lying above or below this cooperative tax rate.

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9 Annex

9.1 Annex 1 : The informational rent

When information asymmetries are introduced, the principal has to give up a rent to the agent in order to induce her to reveal her type.

From the incentive constraint

$$\int_{\underline{\theta}}^{\overline{\theta}} U(\theta)\, g(\theta)\, d\theta = \int_{\underline{\theta}}^{\overline{\theta}} \left(\int_{\underline{\theta}}^{\theta} M'(u - k(u))\, g(u)\, du \right) g(\theta)\, d\theta$$

Schemes are increasing, the constraint is thus binding for the weaker θ.

$$\int_{\underline{\theta}}^{\overline{\theta}} \left(\int_{\underline{\theta}}^{\theta} M'\left(u - k\left(u\right)\right) g\left(u\right) du \right) g\left(\theta\right) d\theta \overset{Fubini\ theorem}{=} \int_{\underline{\theta}}^{\overline{\theta}} \left(\int_{\theta}^{\overline{\theta}} g\left(u\right) du \right) M'\left(\theta - k\left(\theta\right)\right) d\theta$$

$\left[1 - G\left(\theta\right)\right] M'\left(\theta - k\left(\theta\right)\right) d\theta$ designs the informational rent.

By the way, the programme of the government

$$\max_{\{U(.),k(.)\}} \int_{\underline{\theta}}^{\overline{\theta}} T\left(k\left(\theta\right)\right) g\left(\theta\right) d\theta \tag{1}$$

subject to

$$U\left(\theta\right) = f\left(k\left(\theta\right)\right) - T\left(k\left(\theta\right)\right) + M\left(\theta - k\left(\theta\right)\right) \geq 0 \tag{2}$$

$$\dot{U}\left(\theta\right) = M'\left(\theta - k\left(\theta\right)\right) \tag{3}$$

$$\dot{k}\left(\theta\right) > 0. \tag{4}$$

becomes

$$\max_{\{U(.),k(.)\}} \int_{\underline{\theta}}^{\overline{\theta}} T\left(k\left(\theta\right)\right) g\left(\theta\right) d\theta \tag{1}$$

subject to

$$U\left(\underline{\theta}\right) = 0 \tag{2}$$

$$\dot{U}\left(\theta\right) = M'\left(\theta - k\left(\theta\right)\right) \tag{3}$$

$$\dot{k}\left(\theta\right) > 0. \tag{4}$$

Actually, as $\dot{U}\left(\theta\right) = M'\left(\theta - k\left(\theta\right)\right)$ by the envelop theorem and $M'\left(.\right) > 0$ by assumption, $U\left(\theta\right)$ is increasing in θ. Therefore, the least capital type $\underline{\theta}$ is indifferent between participating or not. The condition is binding as soon as the incentive rationality constraint is satisfied for the weakest type since rents are increasing in θ.

9.2 Annex 2 : If the government is benevolent

We can consider a policymaker interested in social welfare, i.e. who sets tax rates so as to maximize both the satisfaction of residents, through the provision of a public good, and the benefit of firms.

The programme of the government thus writes

$$\max S\left(I\right) + \int_{\underline{\theta}}^{\overline{\theta}} U\left(\theta\right) g\left(\theta\right) d\theta$$

subject to

$$\begin{aligned} U(\underline{\theta}) &= 0 \\ \dot{U}(\theta) &= M'(\theta - k(\theta)) \\ I &\leq \int_{\underline{\theta}}^{\overline{\theta}} T(k(\theta)) g(\theta) d\theta. \end{aligned}$$

After resolutions, the marginal tax rate set by the benevolent decisionmaker writes :

$$T'^{U}(k(\theta)) = -\frac{\lambda}{1+\lambda} \frac{1-G(\theta)}{g(\theta)} M''(\theta - k(\theta))$$

The conclusions stressed in the Leviathan case with regard to the comparison between the situations with perfect information and involving informational problems respectively remain valid. However, a benevolent government sets lower marginal tax rates than a Leviathan policymaker and firms are induced to invest a higher amount of capital.