Capital Tax Competition Re-visited

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Abstract

We re-visit the view that non-cooperative capital taxes and hence provision of local public goods may be inefficiently too low when capital is mobile across tax jurisdictions. We emphasise that taxes affect also capital stocks and tax revenues in other jurisdictions across time. These intertemporal externalities may lead, ceteris paribus, to too high regional capital taxes, and even dominate the contemporaneous effects of tax competition that have been the focus of the received literature. These neglected intertemporal externalities arise from the effects of taxes on the private income from interregionally immobile production factors, and thereby on the aggregate net supply of capital over time, for any given net interest rates.

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1 Introduction

Harmful capital tax competition is a recurrent theme of policy debates in developed countries.[0] This is vividly reflected in the debate over coordination of capital taxes both within the European Union and elsewhere. See for instance OECD (1998) for a call for countries to refrain from harmful tax competition, and the Ruding Report (1992), European Commission (1998) and the Primarolo Report (1999) for similar calls within the European Union.

The literature on capital tax competition has been instrumental in shaping this debate. The reference work in this strand of research is by Zodrow and Mieszkowski (1986) and Wilson (1986) (ZMW hereafter). They emphasise that competition between tax jurisdictions for mobile capital leads to a 'race to the bottom' with respect to source-based capital taxes and thereby to low provision of regional/local public goods (which can also include pure redistributive transfers to residents). Specifically, integration of capital markets opens up the possibility of capital flows between regions. As a result, to increase inward flows, governments undercut each other in terms of capital taxes. In fact, to put it another way, under capital mobility across regions, equilibrium capital taxes will tend to be inefficiently too low. The reason is straightforward. An increase in the domestic tax leads to a decrease in the domestic net interest rate and, thereby, a capital outflow. This capital outflow translates into an increase in the capital employed in the other regions. Thus, for any given non-domestic taxes, an increase in the domestic capital tax leads to an increase in capital tax-bases and, thereby, local public good provisions in the other tax jurisdictions. Therefore, capital taxes, under integrated capital markets, give rise to a positive externality.[1] In general, the extent of the 'race to the bottom' in the basic model is

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[1]The two alternative ways of describing the 'race to the bottom' result of ZMW are closely related. The reason is that the equilibrium of the closed-economy variant of the ZMW model coincides with the efficient outcome in ZMW when capital is mobile across regions.

positively related to the *elasticity of the demand for capital with respect to its user-cost*.

The analysis in ZMW has since been enriched in various directions to provide instances in which 'race to the bottom' of source-based capital taxes may not materialise. These instances include:[2] trade in capital- and labour-intensive goods (Wilson, 1987), large capital-importing countries (De Pater and Myers, 1994), government failure (Edwards and Keen, 1996), large foreign ownership of immobile factors (Huizinga and Nielsen, 1997), commonality of the capital tax base between state and federal governments (Keen and Kotsogiannis, 2002), mobility of labour (Kessler et. al., 2002), agglomeration (Baldwin and Krugman, 2004), sharing of a common currency (Makris, 2006), political economy considerations (Lockwood and Makris, 2006), competition for amenities (Noiset, 1995, Wooders et. al., 2007, Bénassy-Quéré et. al., 2007). In all these papers, the above basic positive externality under integrated capital markets is always present, but, crucially, there are additional considerations why eventually taxes may not be too low.[3]

This influential literature have helped to identify in a neat and concrete way some very important issues involved in the taxation of mobile capital. All these issues involve the *contemporaneous* external effects of capital taxes. This literature, however, neglects the *intertemporal* externalities associated with source-based capital taxes. Recognising the existence of these external effects is crucial because they might lead, as we emphasise here, to opposite predictions to the ones given by the received literature. The reason is that the intertemporal externalities may be of an opposite direction to the one of, and even outweigh, the contemporaneous externalities.

Briefly, the basic mechanism at work, we emphasise in this study, is the following: an increase in the domestic tax on the capital deployed by domestic firms leads eventually, through the induced decrease in the current use of capital by domestic firms, to lower productivity and remuneration of production factors that, relative to capital, are less mobile between regions. This, in turn, leads to lower current private income from such factors.[4] Under consumption

[2] On a related topic, Bucovetsky and Wilson (1991) show that if tax authorities could tax investors' income from abroad, as well as capital, then the resulting policy mix is efficient, and hence there is no scope for tax coordination. Thus, exchange between tax authorities of information which is necessary for the taxation of foreign-source income can be seen as an alternative to tax coordination.

[3] See, for instance, the excellent reviews by Wilson (1999) and Wilson and Wildasin (2004).

[4] An obvious example of such factors is land. In this case, it is the disposable income of land owners that

smoothing, future consumption bears some of this drop in income. Hence, savings decrease as a response to lower current income. This will, in turn, lead to lower net supply of capital in the future, for any given future income and, importantly, any given current and future net interest rates. Market equilibrium implies that this drop in the net supply of capital will lead to *higher* future net interest rates, and thereby a shrinkage of capital tax-bases and local public good provisions across jurisdictions *in the future.* So, capital taxes, under integrated capital markets, give *also* rise to a negative intertemporal externality. The extent of this externality is positively related to the *elasticity of savings with respect to current income.* Therefore, if this elasticity is sufficiently high relative to the user-cost-elasticity of capital, then the negative intertemporal externalities will dominate the positive contemporaneous externality, emphasised in ZMW. This, in turn, would imply inefficiently too high non-cooperative capital taxes. In fact, as we discuss in Section 3 this could be a plausible possibility.

We describe, in Section 2, and analyse, in Section 3, a very simple and stylised model of capital tax competition. This model abstracts from many features of empirical reality. Nevertheless, these simplifications serve two purposes. First, to formalise the main channels at work in a transparent and easy to understand way. Second, to facilitate a direct comparison with the canonical model of capital tax competition. In fact, our starting model *is* the two-period version of ZMW, used also, for instance, in influential papers like Huizinga and Nielsen (1997) and Keen and Kotsogiannis (2002). Here, however, in contrast to the literature cited above, we do investigate the intertemporal implications of the non-cooperative setting of the *first-period* capital taxes.

In Sections 4 and 5 we discuss the robustness of the mechanism we emphasise in this paper, by analysing some more general and complicated models of capital tax competition and local public good provision. There, we clarify, as intuition would suggest, that the above intertemporal mechanism is still present. In more general models, however, it interacts with other mechanisms. These additional mechanisms sometimes dampen and sometimes reinforce, depending on the environment, the intertemporal externality we identify in our basic model of Sections 2 and 3. In Section 6 we discuss some more related literature. We postpone this discussion after we investigate our model in order to facilitate a better understanding of the

decreases. Another, less obvious, example which, however, is highly relevant for EU, due to cultural and linguistic reasons, is labour. In this case, it is the disposable income of immobile, across regions, workers that suffers from higher capital outflows.

contribution of our work.[5] Finally, in Section 7 we point to directions of future research that will further improve our understanding of capital taxation under integrated capital markets, and conclude.

2 The Model

The basic framework is the two-period version of the standard capital tax competition model of ZMW. There are $m > 1$ identical countries/regions/jurisdictions, each populated by H identical households, where H is very large. Taxes and public spending in each jurisdiction are set by the regional government. Let subscripts $t = 0, 1$ and $j = 1, 2, ..., m$ denote period t and country j respectively.

There is a single, composite and traded good in each period. So, prices of the single good across regions are the same. Let the first-period good be the numeraire good. The single good of each period is produced in each and every jurisdiction by means of combining capital and a fixed in supply factor of production. Second-period capital is an intermediate good which is produced at the end of first period by means of using the numeraire good as an input. Assume without loss of generality that one unit of the numeraire good can be transformed into one unit of capital. While supply of second-period capital is endogenous, the supply of capital in the first-period is pre-determined (by the associated use of the single good in the past).

Each and every government possesses a per-unit tax on capital employed domestically. In addition, public spending takes the form of local public good provision. Assume that governments run a balanced budget. The use of public debt is discussed in Section 4. Expressed in real terms, denote with $g_{t,j} \geq 0$ the level of public good. Moreover, denote with $\tau_{t,j} \geq 0$ and $k_{t,j} \geq 0$ the tax on and the level of capital, respectively. It is also assumed that governments do not possess an unrestricted lump-sum tax. Specifically, here, tax authorities do not tax the fixed factor of production. The case of governments taxing - in a constrained way -

[5] Our work is also related to another strand of research, with a more quantitative orientation. In particular, Roeger et.al. (2002), Klein et.al. (2005) and Mendoza and Tesar (2005) calibrate two-economy dynamic models where mobile capital is taxed. Yet, in all these papers public spending is exogenously given and thereby the tax externality emphasised in ZMW, and re-visited here, is not present. In fact, in these papers, the externalities that emerge from the use of capital taxes work exclusively through the endogenous adjustment of the rest of the distortionary taxes, with the latter taking place in order to maintain fiscal solvency. Also, in these papers, externalities are not explicitly analysed.

the income from the fixed factor is discussed in Section 4. One reason for governments facing restrictions on their ability to use lump-sum taxes is that administratively feasible forms of such taxes might not be politically feasible. A typical example here is the poll tax in Great Britain imposed by Margaret Thatcher, which is largely viewed as one of the reasons for her having been driven out of office.[6] It is also assumed that a tax on savings is not available. This assumption is motivated from the fact that in practice it is difficult to tax capital income on a residence basis, due to administrative and tax compliance problems associated with taxing foreign-source income.[7] The government's budget constraint is

$$g_{t,j} = \tau_{t,j} k_{t,j}. \tag{1}$$

Governments are assumed to be benevolent: each government j chooses regional policies $\{g_{t,j}, \tau_{t,j}\}_{t \geq 0}$ that satisfy the fiscal constraint (1) to maximise the intertemporal welfare of its residents.

We turn to the description of the private sector. It is assumed that there is perfect capital mobility between regions. So, in effect, there is a common market for capital in each period. Perfect competition is the mode of trade in this market. Trade in this market takes place at the start of each period. Capital is demanded by firms from each and every country. Also, to simplify exposition, let us assume that capital is supplied directly by households. Let ρ_t denote the net real interest rate in this market. That is, one unit of capital in period t costs firms that produce in $j-$region $1 + \rho_t + \tau_{t,j}$ units of the period's single good. From that, $1 + \rho_t$ is paid to the suppliers of capital and $\tau_{t,j}$ is paid to the region-j government.[8]

[6] See for instance Wilson (1999).

[7] For a model where the degree of information sharing between tax authorities for tax purposes is endogenously determined to be zero, which in turn implies that residents do not, in effect, face a tax on their capital income upon repatriation and hence on their savings, see Makris (2003).

[8] The single market for capital is a short-cut representation of national financial capital markets that foreigners have access to. Under that alternative representation, $r_{t,j}$ is the interest rate paid by region-j firms to investors who have channeled their savings to country j. Also, $r_{t,j} - \tau_{t,j}$ is the rate of return from investing in country j net of the tax imposed by region$-j$ government on each unit of income generated domestically. Perfect capital mobility implies no arbitrage and hence the net interest rates $r_{t,j} - \tau_{t,j}$, for any j, are equalised across regions. Thus, investors are indifferent over the allocation of their savings to domestic or non-domestic capital. Also, $k_{t,j}$ equals the total capital channelled to region j. Letting then ρ_t denote the common net interest rate across regions makes the two representations equivalent.

Private production in period t in region j takes place by means of a production function $f[k_{t,j}]$, with $f[0] = 0$, $f' > 0$, $f'' < 0$, where we have suppressed its dependence on the fixed in supply factor.[9] This fixed factor is assumed to be immobile between regions. A typical example here is land.[10] Assume without loss of generality that capital does not depreciate after its use, and that each region is endowed with 1 unit of the fixed factor. Payments to the fixed factor, i.e. rents, are given by $f[k_{t,j}] - (\rho_t + \tau_{t,j})k_{t,j}$. Assume also, to ensure interior solutions for simplicity of exposition, the Inada conditions $\lim_{k\to\infty} f'[k] = 0$ and $\lim_{k\to 0} f'[k] = \infty$. The demand for capital, for any given net interest rate and tax, follows from the standard profit-maximisation condition

$$f'[k_{t,j}] = \rho_t + \tau_{t,j}. \tag{2}$$

So, capital is a decreasing function of the gross rate of interest $\rho_t + \tau_{t,j} : k_{t,j} = k[\rho_t + \tau_{t,j}]$ with $k' = 1/f''[k]$. Denote the equilibrium rents by $w_{t,j}$. That is, $w_{t,j} = f[k[\rho_t + \tau_{t,j}]] - f'[k[\rho_t + \tau_{t,j}]]k[\rho_t + \tau_{t,j}] \equiv w[\rho_t + \tau_{t,j}] > 0$. Note that $w' = -k$: an increase in the gross interest rate, or capital's user-cost, leads to a decrease in the returns to the fixed factor.

Assume that each typical household owns $\frac{1}{H}$ of the domestic fixed factor. In the first period, the typical agent allocates her income from the fixed factor and the returns from past savings between current consumption $c_{0,j}$ and savings $s_{1,j}$. In the second period, the typical agent consumes all her disposable income, $c_{1,j}$. The first- and second-period budget constraints of the representative household in country j are, respectively,

$$c_{0,j} = \frac{w_{0,j}}{H} + (1 + \rho_0)s_0 - s_{1,j}, \tag{3}$$

$$c_{1,j} = \frac{w_{1,j}}{H} + (1 + \rho_1)s_{i,j}, \tag{4}$$

[9] To distinguish between collected terms in multiplications and arguments of functions, we use, hereafter, parentheses for the former and square brackets for the latter.

[10] The case of immobile between regions factors of production that are nevertheless non-fixed in supply would add additional complications without adding much in terms of insight. The analysis of such a case is in an Appendix which is available upon request. Arguably, in reality there are often production factors other than capital that are also mobile between regions. An example is labour. Nevertheless, it is also true that financial capital is in general more mobile than labour. For an important work along these lines see Kessler et. at. (2002). Note however that in that work the dynamics inherent in the accumulation of capital, which we emphasise here, are given short drift as there the supply of capital is exogenously given. A very interesting line of future work would be to combine the set-ups of our paper and Kessler et. al. (2002). That is, to investigate an environment where labour is imperfectly immobile *and* savings are endogenous.

where $s_0 > 0$ are the inherited savings brought forward from the past. We postulate the following preferences

$$V[c_{0,j}] + \beta V[c_{1,j}] + \Gamma[g_{0,j}, g_{1,j}], \tag{5}$$

where $\frac{\partial \Gamma}{\partial g_t} > 0$, $\frac{\partial^2 \Gamma}{\partial g_t^2} \leq 0$, $t = 0, 1$. We also assume that $V' > 0$ and $V'' < 0$. Moreover, assume that $\lim_{c \to 0} V'[c] = \infty$ to ensure positive equilibrium consumption. Assume also $\lim_{g_t \to 0} H \frac{\partial \Gamma[g_0, g_1]}{\partial gt} = \infty$ for any $g_{t'} \geq 0, t, t' = 0, 1, t \neq t'$. This assumption ensures that in any symmetric equilibrium (defined precisely shortly after) public good in each period is positive. Welfare maximisation, for given prices and policies, subject to (3) and (4) gives rise to the first-order condition:[11]

$$V'[c_{0,j}] = \beta(1 + \rho_1)V'[c_{1,j}]. \tag{6}$$

Equilibrium in the market for capital in period t is given by

$$\sum_j k[\rho_t + \tau_{t,j}] = H \sum_j s_{t,j}. \tag{7}$$

To understand this note first that the left hand side corresponds to total demand for capital by firms. Total supply of capital, on the other hand, consists of private savings. In effect, this condition is equivalent to the equilibrium condition that total demand for the single traded good in period t equals total supply.[12] In contrast to a closed economy, where savings equal the capital stock with the domestic interest rate adjusting appropriately, here a region j in period t could in principle be a net debtor $k_{t,j} > s_{t,j}$ or a net creditor $k_{t,j} < s_{t,j}$, with the net interest rate adjusting to equate *total* supply of capital with *total* demand for capital across regions. Note, however, that in a symmetric equilibrium we would have $\tau_{t,j} = \tau_t$ and $s_{t,j} = s_t$

[11] Our results would remain unaffected if preferences were given instead by $J[U[c_{0,j}, c_{1,j}], \Gamma[g_{0,j}, g_{1,j}]]$, as long as consumption in each and every period was a normal good. Relaxing our separability assumption between private and public consumptions, and hence allowing for savings to depend on public goods, would make the analysis and exposition much more complicated without altering the qualitative thrust of our results. Similar assumptions to the same effect have been deployed in the two-period models in the received literature, like Keen and Kotsogiannis (2002).

[12] To see this add period$-t$ private and public budget constraints for some country j to get $Hc_{t,j} + g_{t,j} = (1 + \rho_t)Hs_{t,j} - Hs_{t+1,j} + w_{t,j} + \tau_{t,j}k_{t,j}$, where $s_{2,j} \equiv 0$ and $s_{0,j} \equiv s_0$. After using the definition for $w_{t,j}$, and summing over j, one has $\sum_j (Hc_{t,j} + g_{t,j} + Hs_{t+1,j}) = \sum_j (k_{t,j} + f[k_{t,j}] + (1 + \rho_t)(Hs_{t,j} - k_{t,j}))$. Since capital is an intermediate good, supplied by individuals to firms, total demand for the single traded good in period t is $\sum_j (Hc_{t,j} + g_{t,j} + Hs_{t+1,j})$. Total supply is $\sum_j (k_{t,j} + f[k_{t,j}])$. So, demand equals supply if and only if $\sum_j (Hs_{t,j} - k_{t,j}) = 0$.

for any $j = 1, ..., m$, and hence

$$k[\rho_t + \tau_t] = Hs_t. \tag{8}$$

That is, though off a symmetric equilibrium some countries may be net debtors and some net creditors, in a symmetric equilibrium there is no net trade in capital. Given that tax jurisdictions are identical, symmetric equilibria will be of special importance here.

To capture non-cooperative tax-setting, we focus on situations where, given history, fiscal authorities hold Nash conjectures against each other when policy is chosen. We also assume policy pre-commitment. Specifically, we assume that tax authorities have a commitment mechanism that enables them to announce all taxes at the start of the first period, and abide by such an announcement when the time comes to administer the announced taxes. This assumption is made to identify the main mechanism in place, regarding the external effects of *first-period* capital taxes, in a neat way. However, arguably, lack of pre-commitment is a plausible alternative. The investigation, thus, of capital tax competition in the absence of pre-commitment is postponed for Section 5.

As a means of summary let us describe here the timing of events. First, it will help understanding to split each period in stages. In the first stage of each period t, supply of capital is pre-determined by the savings of the previous period, and firms choose their demands for capital. The capital market clears at some net interest rate ρ_t. In the second stage, production takes place, firms in each region j pay $\frac{w_{t,j}}{H}$ to each resident and $1 + \rho_t$ to each supplier of capital, and taxes are collected and private and public consumption takes place. At the end of this stage, private savings are also determined. At the third and last stage of each period, any supplied savings are transformed into next period's capital. Savings of the second and last period are of course zero. Finally, each and every regional government chooses (and announces) all of its taxes for given stocks of first-period capital, and prior to firms placing their orders for first-period capital.[13] In doing so, it takes into account the effects of the announced policies

[13] The assumption that capital-tax-setting takes place for given first-period capital stock is standard in problems of optimal capital taxation (see for instance Kessler et.al., 2002, Kehoe, 1989, ZMW, and Chamley, 1986). Our results would, however, be qualitatively the same if we assumed that regional governments choose (and announce) the whole path of their current and future taxes at some initial 'policy announcement' stage prior to the determination of the first-period capital supply. The analysis of such case is in an Appendix which is available upon request. The assumption that (period$-t$) taxes are set prior to the firms placing their orders for their (period$-t$) capital is necessary for the presence of competition for capital between governments.

on the behaviour of households and firms, and on the market-clearing net interest rates.[14]

The *non-cooperative equilibrium* of our economy is defined as the prices ρ_t^* and $\{w_{t,j}^*\}_{j=1}^m$, and the vectors of taxes $\vec{\tau}_t^* \equiv \{\tau_{t,j}^*\}_{j=1}^m$ and allocations $\vec{k}_t^* \equiv \{k_{t,j}^*\}_{j=1}^m$, $\vec{g}_t^* \equiv \{g_{t,j}^*\}_{j=1}^m$, $\vec{c}_t^* \equiv \{c_{t,j}^*\}_{j=1}^m$, for any $t = 0, 1$, and $\vec{s}_1^* \equiv \{s_{1,j}^*\}_{j=1}^m$ that satisfy: (a) $c_{0,j}^*$, $c_{1,j}^*$ and $s_{1,j}^*$ are consistent with utility maximisation subject to own budget constraints for given prices and policies, (b) price- and tax-taking profit-maximisation: $k_{t,j}^* = k[\rho_t^* + \tau_{t,j}^*]$, (c) remuneration of immobile factors: $w_{t,j}^* = w[\rho_t^* + \tau_{t,j}^*]$, (d) ρ_t^* is the market-clearing net interest rate in period t, (e) government-solvency: $g_{t,j}^* = \tau_{t,j}^* k_{t,j}^* \geq 0$, and (f) $\{\tau_{0,j}^*, \tau_{1,j}^*\}$ is a best response to $\{\tau_{0,j'}^*, \tau_{1,j'}^*\}$ for any $j, j' = 1, ..., m$, $j \neq j$, given a balanced fiscal budget and the anticipated competitive equilibrium (as this is described by optimal capital demands, consumption levels and savings for given any taxes and prices, and by rents and market-clearing net interest rates for any given taxes.)

A symmetric equilibrium is then the non-cooperative equilibrium with $\tau_{t,j}^* = \tau_t^*$ for any t and any j. Hence, $s_{1,j}^* = s_1^*$, $c_{t,j}^* = c_t^*$, $k_{t,j}^* = k_t^*$, $Hs_t^* = k_t^*$, where $s_0^* \equiv s_0$, and $g_{t,j}^* = g_t^*$ for any t and any j. Due to ex ante identical regions we will focus on symmetric equilibria. Before we proceed in the investigation of the efficiency properties of the symmetric equilibrium regional capital taxes, it is crucial that we derive the equilibrium net interest rates in each period. We do so next. Notice that hereafter we drop the asterisk, that denotes equilibrium values, whenever there is no risk of confusion.

2.1 Private Equilibrium

We will refer hereafter to the net interest rates as simply the interest rates. Let $\rho[\vec{\tau}_t, \vec{s}_t]$ be the market-clearing interest rate in period t, as this is determined implicitly by (7). Similarly, after recalling (8), let $p[\tau_t, s_t]$ be the period$-t$ market-clearing interest rate as a function of the symmetric equilibrium capital tax τ_t and capital supply s_t.

Recall that the first-period capital stock is the pre-determined. Note thus that $\frac{\partial p_0}{\partial \tau_0} = -1$, and that $\frac{\partial \rho[\vec{\tau}_0, \vec{s}_0]}{\partial \tau_{0,j}} |_{\{\tau_{0,j} = \tau_0\}_{j=1}^m} = \frac{1}{m} \frac{\partial p_0}{\partial \tau_0}$ for any $j = 1, ..., m$. That is, the effect on the equilibrium interest rate of a marginal increase in any of the m regional taxes, evaluated at a symmetric equilibrium, is equal to $1/m^{th}$ of the effect on the equilibrium interest rate of a marginal increase

[14]Note that in many papers in the literature, like ZMW, regions are assumed to be very small so that governments perceive the endogenous net interest rate as out of their control. In our set-up, this would be equivalent to m being very large.

in **all** symmetric equilibrium regional taxes. As we will see later on, it is the divergence in size (due to $m > 1$) between $\frac{\partial p_0}{\partial \tau_0}$ and $\frac{\partial \rho[\vec{\tau}_0, \vec{s}_0]}{\partial \tau_{0,j}} |_{\{\tau_{0,j}=\tau_0\}_{j=1}^{m}}$ that gives rise to the contemporaneous tax externality at period $t = 0$. Also, due to $\frac{\partial p_0}{\partial \tau_0} < 0$, this externality will be positive, as we will see in the next Section.

Turning to period $t = 1$, the equilibrium interest rate will depend on the equilibrium first-period savings $s_{1,j}$ in any region j. After some tedious, but standard, calculations that use the consumer budget constraints and first order condition, we have that the equilibrium first-period savings in region j are described by a function $s[\rho_1, \frac{w_{1,j}}{H}, e_{0,j}]$, where $e_{0,j} \equiv \frac{w_{0,j}}{H} + (1 + \rho_0)s_0$ is the first period disposable income. Specifically, we have that $\frac{\partial s[\bullet]}{\partial \rho_1}$ is ambiguous, reflecting the standard conflict between the substitution and income effects on savings of the interest rate. Also, $\frac{\partial s[\bullet]}{\partial e_{0,j}} > 0$ and $\frac{\partial s[\bullet]}{\partial (w_{1,j}/H)} < 0$, capturing the optimality of consumption smoothing when consumption in each period is a normal good (which is the case in our model). That is, an increase in current (resp. future) income results in an increase (resp. a decrease) in savings as a means of shifting income/consumption across periods.[15]

Rents $w_{t,j} = w[\rho_t + \tau_{t,j}]$, for any $t = 0, 1$, equilibrium savings $s_{1,j} = s[\rho_1, \frac{w_{1,j}}{H}, e_{0,j}]$ for any country j, and market-clearing in period $t = 1$, $\rho_1 = \rho[\vec{\tau}_1, \vec{s}_1]$, determine implicitly the equilibrium interest rate in period $t = 1$ as a function $\rho_1[\bullet]$ of the first-period interest rate and of capital taxes across time and across regions. That is, $\rho_1 = \rho_1[\vec{\tau}_1, \vec{\tau}_0, \rho_0]$, where we have suppressed the dependence on s_0 for expositional clarity. Similarly, we have that the second-period market-clearing interest rate at a symmetric equilibrium p_1 is given by $p_1 = p_1[\tau_1, \tau_0, p_0]$, where the latter is the implicit solution with respect to p_1 of the equilibrium condition $Hs[p_1, \frac{w[p_1+\tau_1]}{H}, e[p_0 + \tau_0]] = k[p_1 + \tau_1]$, where $e[p_0 + \tau_0] \equiv \frac{w[p_0+\tau_0]}{H} + (1 + p_0)s_0$. The comparative statics on $p_1[\bullet]$ will be of particular interest. To this end, first let $s_p \equiv \frac{\partial s[p_1, \frac{w[p_1+\tau_1]}{H}, e[p_0+\tau_0]]}{\partial p_1} - \frac{\partial s[p_1, \frac{w[p_1+\tau_1]}{H}, e[p_0+\tau_0]]}{\partial (w_1/H)} \frac{k_1}{H}$. This is the overall effect on savings of a marginal change in the symmetric equilibrium interest rate of period $t = 1$. Recall that second-period market-clearing at symmetric equilibrium implies that $s_1 = \frac{k_1}{H}$. After some trivial calculations, the latter implies that in a symmetric equilibrium $s_p > 0$. So, in a symmetric equilibrium, savings are increasing with their returns. Furthermore, due to first-period market-clearing at symmetric equilibrium, i.e. $s_0 = \frac{k_0}{H}$, we have that $\frac{\partial e[p_0+\tau_0]}{\partial p_0} = 0$ and hence $\frac{\partial s[p_1, \frac{w[p_1+\tau_1]}{H}, e[p_0+\tau_0]]}{\partial p_0} = 0$.

[15] Formally, after eliminating $c_{0,j}$ and $c_{1,j}$ from the consumer's first order condition, by using the budget constraints, we have that $\frac{\partial s_1}{\partial e_{0,j}} = \frac{V''[c_{0,j}]}{V''[c_{0,j}]+\beta(1+\rho_1)^2 V''[c_{1,j}]}$, $\frac{\partial s_1}{\partial (w_{1,j}/H)} = -\frac{\partial s_1}{\partial e_{0,j}} \frac{\beta(1+\rho_1)V''[c_{1,j}]}{V''[c_0]}$ and $\frac{\partial s_1}{\partial \rho_1} = -\frac{\partial s_1}{\partial e_{0,j}} \frac{\beta(V'[c_{1,j}]+(1+\rho_1)V''[c_{1,j}]s_{1,j})}{V''[c_{0,j}]}$.

So, in a symmetric equilibrium, first-period income and thereby savings are independent of the first-period interest rate.

It follows then directly that

$$\begin{aligned}
\frac{\partial p_1}{\partial p_0} &= 0, \\
\frac{\partial p_1}{\partial \tau_0} &= \frac{k_0}{Hs_p - k_1'} \frac{\partial s[p_1, \frac{w[p_1+\tau_1]}{H}, e[p_0+\tau_0]]}{\partial e_0} > 0, \\
\frac{\partial p_1}{\partial \tau_1} &= \frac{k_1'}{Hs_p - k_1'} + \frac{k_1}{Hs_p - k_1'} \frac{\partial s[p_1, \frac{w[p_1+\tau_1]}{H}, e[p_0+\tau_0]]}{\partial (w_1/H)} < 0.
\end{aligned} \tag{9}$$

Therefore, at a symmetric equilibrium, the contemporaneous marginal effect of the second-period capital tax on the second-period interest rate is negative. The reason is that higher second-period capital taxes imply lower demand for capital and hence lower income from the fixed factor in the second period, which in turn implies, due to consumption smoothing, higher first-period savings. Both lower demand for and higher supply of second-period capital imply a lower capital-market-clearing interest rate in the second period. Moreover, the overall effect on the second-period interest rate of a marginal increase in the first-period capital tax is positive: $\frac{\partial p_1}{\partial p_0}\frac{\partial p_0}{\partial \tau_0} + \frac{\partial p_1}{\partial \tau_0} = \frac{\partial p_1}{\partial \tau_0} > 0$. Thus, an increase in the symmetric equilibrium first-period capital tax results in an increase in the symmetric equilibrium second-period interest rate. The reason is the following: recalling $w_t' = -k_t$, an increase in the first-period capital tax leads to lower capital demand and hence lower returns to the immobile factor and lower income and savings in the first period, for any given path of interest rates and any given future income. Therefore, in increase in the first-period capital tax lowers the supply of second-period capital, which in turn has a positive effect on second-period's equilibrium interest rate.

Before leaving this Section, it will also prove helpful to bring up the relation between $p_1[\tau_1, \tau_0, \rho_0]$ and $\rho_1[\vec{\tau}_1, \vec{\tau}_0, \rho_0]$. To start with, recall that, due to first-period capital-market-clearing at symmetric equilibrium, we have $\frac{\partial e_{0,j}}{\partial \rho_0} = 0$ and hence $\frac{\partial \rho_1[\vec{\tau}_1, \vec{\tau}_0, \rho_0]}{\partial \rho_0} |_{\{\tau_{t,j}=\tau_t\}_{j=1,t=1,2}^m}$ $= \frac{\partial p_1}{\partial \rho_0} = 0$. Also, note that $\frac{1}{m}\frac{\partial p_1}{\partial \tau_1} = \frac{\partial \rho_1[\vec{\tau}_1, \vec{\tau}_0, \rho_0]}{\partial \tau_{1,j}} |_{\{\tau_{t,j}=\tau_t\}_{j=1,t=1,2}^m}$. As we shall see, it is the divergence in size between $\frac{\partial p_1}{\partial \tau_1}$ and $\frac{\partial \rho_1[\vec{\tau}_1, \vec{\tau}_0, \rho_0]}{\partial \tau_{1,j}} |_{\{\tau_{t,j}=\tau_t\}_{j=1,t=1,2}^m}$ that gives rise to the contemporaneous tax externality in period $t = 1$. Due to $\frac{\partial p_1}{\partial \tau_1} < 0$, this externality will be positive. Note also that $\frac{1}{m}\frac{\partial p_1}{\partial \tau_0} = \frac{\partial \rho_1[\vec{\tau}_1, \vec{\tau}_0, \rho_0]}{\partial \tau_{0,j}} |_{\{\tau_{t,j}=\tau_t\}_{j=1,t=1,2}^m}$. Crucially, for our results, it is the divergence in size (due to $m > 1$) between $\frac{\partial p_1}{\partial \tau_o}$ and $\frac{\partial \rho_1[\vec{\tau}_1, \vec{\tau}_0, \rho_0]}{\partial \tau_{o,j}} |_{\{\tau_{t,j}=\tau_t\}_{j=1,t=1,2}^m}$ that, as we will shortly see, gives rise to the intertemporal externality of the first-period tax. Due to $\frac{\partial p_1}{\partial \tau_0} > 0$, this externality will be negative, counteracting thus the contemporaneous externality of the first-period tax.

We, now, turn to the investigation of non-cooperative capital taxes.

3 Are Capital Taxes Too Low?

Tax authorities in region j maximise the welfare of their representative household subject to the private equilibrium and the region$-j$ fiscal constraint, taking as given the tax-policy of the other jurisdictions. The objective function of the region-j tax authorities is:

$$\begin{aligned}
& \sum_{i=0}^{1} \beta^i U^i + \Gamma[\tau_{0,j} k[\rho_0 + \tau_{0,j}], \tau_{1,j} k[\rho_1 + \tau_{1,j}]] \\
\text{with } U^t &\equiv U[\rho_t, \tau_{t,j}; s_{t,j}, s_{t+1,j}] \equiv \\
& V[(1+\rho_t)s_{t,j} + \frac{w[\rho_t + \tau_{t,j}]}{H} - s_{t+1,j}], \\
s_{1,j} &= s[\rho_1, \frac{w[\rho_1 + \tau_{1,j}]}{H}, (1+\rho_0)s_0 + \frac{w[\rho_0 + \tau_{0,j}]}{H}], \\
\rho_0 &= \rho[\vec{\tau}_0, \vec{s}_0], \;\; \rho_1 = \rho_1[\vec{\tau}_1, \vec{\tau}_0, \rho[\vec{\tau}_0, \vec{s}_0]] \\
\text{and } s_{0,j} &\equiv s_0, s_{2,j} \equiv 0.
\end{aligned}$$

Non-cooperative taxes equate the regional marginal benefit from an extra unit of public good to the regional marginal cost of public funds, for given taxes in the other regions. In more detail, using the envelope theorem vis-a-vis consumers' problem, and recalling our assumption that ensures positive public good provision, the typical capital tax τ_t, $t = 0, 1$, at a symmetric equilibtium is positive and such that:

$$V'[c_0]k_0 = H\frac{\partial \Gamma[g_0, g_1]}{\partial g_0}\{k_0 + \tau_0 k'_0(\frac{1}{m}\frac{\partial p_0}{\partial \tau_0} + 1)\} + H\frac{\partial \Gamma[g_0, g_1]}{\partial g_1}\tau_1 k'_1 \frac{1}{m}\frac{\partial p_1}{\partial \tau_0}, \tag{10}$$

$$\beta V'[c_1]k_1 = H\frac{\partial \Gamma[g_0, g_1]}{\partial g_1}\{k_1 + \tau_1 k'_1(\frac{1}{m}\frac{\partial p_1}{\partial \tau_1} + 1)\}. \tag{11}$$

As existence is not the main issue of this paper, assume hereafter that a symmetric equilibrium exists.[16] Conditional on existence, then, we turn to analyse the efficiency of the typical regional capital taxes. To start with, note that at a symmetric equilibrium the welfare of the typical household is $\sum_{t=0}^{1} \beta^t U[p_t, \tau_t; s_t, s_{t+1}] + \Gamma[\tau_0 k[p_0 + \tau_0], \tau_1 k[p_1 + \tau_1]]$, with $s_2 \equiv 0$, where $s_1 = s_1[p_1, \frac{w[p_1+\tau_1]}{H}, (1+p_0)s_0 + \frac{w[p_0+\tau_0]}{H}]$, $p_0 = p[\tau_0, s_0]$ and $p_1 = p_1[\tau_1, \tau_0, p_0]$. We ask:

[16] If there is no (symmetric) Nash equilibrium, then this on itself is a criticism of the ZMW model, and many other models in the literature, where an equilibrium is assumed to exist for the fixed capital stock, in static models, or for fixed τ_0 and hence e_0, p_0 and g_0, in two-period models.

starting from any symmetric equilibrium, would a simultaneous marginal increase in each and every regional period-t capital tax,[17] while maintaining regional taxes in other periods at their non-cooperative equilibrium levels, be welfare-improving? After using the envelope theorem, this comparative static is described by:

$$\begin{aligned}
\tfrac{\partial}{\partial \tau_t} \quad & \{U[p[\tau_0, s_0], \tau_0; s_0, s_1] + \beta U[p_1[\tau_1, \tau_0, p[\tau_0, s_0]], \tau_1; s_1, 0] \\
& + \Gamma[\tau_0 k[p[\tau_0, s_0] + \tau_0], \tau_1 k[p_1[\tau_1, \tau_0, p[\tau_0, s_0]] + \tau_1]]\} \\
= \quad & (1 - \frac{1}{m}) \sum_{v=0}^{1} \frac{\partial \Gamma[g_0, g_1]}{\partial g_v} \tau_v k_v' \frac{\partial p_v}{\partial \tau_t} \equiv (1 - \frac{1}{m}) \sum_{v=0}^{1} Z_v \frac{\partial p_v}{\partial \tau_t} \equiv (1 - \frac{1}{m}) W_{\tau_t}.
\end{aligned}$$

Therefore, given that $m > 1$, a coordinated marginal increase in all period$-t$ symmetric equilibrium capital taxes across regions is welfare improving if and only if $W_{\tau_t} > 0$.[18]

To understand the above, note that changes in the interest rates affect welfare across regions. In fact, Z_v in the above equation is the net effect, evaluated at the symmetric equilibrium, of a marginal increase in the common interest rate ρ_v on the welfare of the typical household in *any* region. Note that here $Z_v < 0$, which reflects the negative effect of the interest rate ρ_v on the period-v capital tax bases across jurisdictions. It follows that taxes affect - through interest rates - welfare across regions. Notice also that in our model tax externalities arise solely through the effects of taxes on the interest rates, as there are no direct spillover effects. However, at a symmetric equilibrium, non-cooperative taxes take into account only $1/m^{th}$ of their total welfare effect across regions. The non-internalised tax externality, at *any* symmetric equilibrium, is thus captured by $(1 - \frac{1}{m})W_{\tau_t}$. So, if $W_{\tau_t} > 0$ then the net externality is positive and period$-t$ taxes are inefficiently low. If instead $W_{\tau_t} < 0$ then the net externality is negative and period$-t$ taxes are inefficiently high.

Let us start with the efficiency properties of the second-period tax. After recalling our discussion of the equilibrium interest rates in the previous Section, we have

$$W_{\tau_1} = Z_1 \frac{\partial p_1}{\partial \tau_1} > 0. \tag{12}$$

[17] Because countries are identical there is no reason from an efficiency point of view to distort the international allocation of capital. So, Pareto efficient capital taxes are uniform across regions.

[18] We do not investigate the welfare effect of increasing marginally the symmetric equilibrium capital taxes in each and every period, i.e. $W_\tau \equiv (1 - \frac{1}{m}) \sum_{t=0}^{1} W_{\tau_t}$. The reason is that (a) if W_{τ_1} and W_{τ_2} have the same sign then that sign characterises also W_τ, and (b) if W_{τ_1} and W_{τ_2} have opposite signs then changing marginally all regional taxes in each period towards the same direction would be inferior to changing marginally all regional taxes according to the prescriptions of W_{τ_1} and W_{τ_2}.

So, second-period capital taxes are too low at a symmetric equilibrium. The tax externality in the second-period is positive: an increase in a region's tax leads to a decrease in the current common interest rate and thereby an increase in the capital-tax base and public good provision in the other tax jurisdictions. $W^1_{\tau_1}$ describes the externality that has been emphasised in the two-period version of the ZMW model.[19]

The canonical two-period model *does not* discuss, however, the efficiency properties of the initial tax τ_0. In fact, in the received models it is implicitly assumed that τ_0 is exogenously given.[20] Of course, if the initial-period tax was fixed at its second-best efficient level, then we would have by construction that $W_{\tau_0} = 0$. However, there is no reason to expect a priori that the symmetric equilibrium first-period tax will be efficient. The reason is that, despite the fact that when taxes are set the supply of capital is pre-determined, a *unilateral* change in a region's tax will induce a change in the allocation of capital between countries. That is, to put it another way, though a tax on inherited savings, s_0, is lump-sum, a tax on first-period mobile capital is distortionary due to the possibility of tax-induced capital flows between regions.[21]

By either focusing on static models or by investigating two-period models but without investigating the non-cooperative first-period capital tax, the cited in the Introduction literature neglects the *intertemporal* externality of capital taxes. To investigate the latter here, notice that

$$W_{\tau_0} = -Z_0 + Z_1 \frac{\partial p_1}{\partial \tau_0}. \tag{13}$$

The first term captures the contemporary externality of the initial capital tax (recall that $\frac{\partial p_0}{\partial \tau_0} = -1$). It echoes the corresponding external effect in the ZMW model. As $-Z_0 > 0$, this externality is positive. So, taxes tend to be too low, all other things equal. Note that the extend of this externality is positively related to the responsiveness of capital to its user-cost,

[19] In a static model, where the supply of capital is pre-determined, the externality would be described up to a scalar $(1 - \frac{1}{m})$ by a formula similar to (12), with the only difference that $\frac{\partial p_1}{\partial \tau_1}$ is replaced by -1.

[20] See for instance Keen and Kotsogiannis (2002) and Huizinga and Nielsen (1997).

[21] This is in contrast to what happens in the well-known model of Chamley (1987). That model is a closed-economy one, and hence in equilibrium savings of a country are always equal to its capital stock. Thus, in equilibrium the interest rate is given by $p_t = f'[s_t] - \tau_t$, which implies that a tax on capital is, in effect, a tax on savings. Also, as inherited capital is pre-determined, the first-period tax is lump-sum. For this reason, in a second-best environment, the first-period tax is assumed to be exogenously given at a level lower than its unrestricted optimum, and normalised to zero.

k_0'. We call this the tax-competition effect.

However, τ_0 affects also the second-period interest rate, p_1. The term $Z_1 \frac{\partial p_1}{\partial \tau_0}$ captures the intertemporal externality of the initial tax. After recalling that, due to consumption smoothing, $\frac{\partial p_1}{\partial \tau_0} > 0$, we have that $Z_1 \frac{\partial p_1}{\partial \tau_0} < 0$. This sign captures the fact that the intertemporal externality of the first-period tax is negative. To see this, recall from the previous Section that a higher first-period capital tax reduces the supply of second-period capital and hence pushes the future interest rate *upwards*. Thus, an increase in the tax τ_0 *reduces future* capital stock, tax revenues and, thereby, welfare abroad. So, the intertemporal externality of the initial tax *counteracts* the tax-competition effect. Importantly, notice that, for any given responsiveness of capital demand to its user-cost, the intertemporal externality is more acute the more responsive first-period savings are to first-period income. This is reflected in that, recall from (9), $\frac{\partial p_1}{\partial \tau_0}$ is increasing in $\frac{\partial s_1}{\partial e_0}$. Notice also from (9) that $\frac{\partial p_1}{\partial \tau_0}$ is decreasing in the responsiveness of savings to next-period's interest rate s_p. So, if the first-period-income-responsiveness of savings is sufficiently high and/or the interest-elasticity of savings sufficiently low, relative to the responsiveness of capital demand to its user-cost, then the intertemporal externality dominates the tax-competition effect. Thus, first-period taxes are too high! In fact, after defining the elasticities of savings with respect to current income and interest and of capital demand with respect to its user-cost with $\varepsilon_e \equiv \frac{\partial s_1}{\partial e_0} \frac{e_0}{s_1}$, $\varepsilon_p \equiv \frac{\rho_1 s_p}{s_1}$ and $\eta_t \equiv -\frac{k_t'}{k_t}$, respectively, we have that:

Proposition: *If the income-elasticity of savings relative to the user-cost-elasticity of current capital demand, $\frac{\varepsilon_e}{\eta_0}$, is sufficiently high and/or the interest-elasticity of savings relative to user-cost-elasticity of future capital demand, $\frac{\varepsilon_p}{\eta_1}$, is sufficiently low, then capital taxes in the first-period are inefficiently too high.*

Proof: We have from above that $W_{\tau_0} < 0$ if and only if $Z_1 \frac{\partial p_1}{\partial \tau_0} < Z_0$. The latter after some straightforward manipulations, that make also use of market-clearing $Hs_t = k_t$, can be rewritten as $\frac{\varepsilon_e}{\eta_0} > \frac{\frac{\varepsilon_p}{\eta_1} + \frac{p_1}{p_1+\tau_1}}{\gamma_0} \frac{\tau_0}{p_0} \frac{\frac{\partial \Gamma[g_0,g_1]}{\partial g_0} g_0 \frac{p_0}{p_0+\tau_0}}{\frac{\partial \Gamma[g_0,g_1]}{\partial g_1} g_1 \frac{p_1}{p_1+\tau_1}}$, where γ_0 denotes the first-period level of public spending relative to total current income , i.e. $\gamma_0 \equiv \frac{g_0}{He_0}$. Clearly then the higher $\frac{\varepsilon_e}{\eta_0}$ and/or the lower $\frac{\varepsilon_p}{\eta_1}$ is the more likely it is that the first-period capital taxes will be too high. ■

This Proposition provides us with some testable predictions for the efficiency properties of capital taxes. We leave an empirical investigation of these predictions for future research, as such an investigation is out of the scope of the current work. It is worth noticing however that the above result might be more than just a theoretical curiosum. To see this, suppose a stationary fiscal environment in that the inclusive capital tax rate is constant, i.e. $\tau_0/\rho_0 = \tau_1/\rho_1$. Suppose also that public good preferences are such that $(\frac{\partial\Gamma[g_0,g_1]}{\partial g_0}/\frac{\partial\Gamma[g_0,g_1]}{\partial g_1})(g_0/g_1) = 1$; that is, one percentage increase in second-period public good is required to leave households indifferent after a one percentage decrease in first-period public good.[22] Furthermore, assume that production function is such that the inverse elasticity of marginal product, i.e. $-\frac{f'(k)}{f''(k)k}$, is constant. This implies that the elasticity of capital with respect to its user-cost is constant, i.e. $\eta_1 = \eta_0 \equiv \eta$. In such an environment, the condition in the proof above becomes $\varepsilon_e > \frac{\varepsilon_\rho + \frac{p_1}{p_1+\tau_1}\eta}{\gamma_0}\frac{\tau_0}{p_0}$. Importantly, this condition might hold in reality. Take, for instance, the example of United States used in Keen and Kotsogiannis (2002). Using an estimate of 0.25 for the first-period elasticity of capital with respect to its user-cost (by Chirinko et al. (1999)), and supposing a tax-inclusive tax rate $\tau/p = 0.2$ - which is in line with the calculation of the effective marginal tax by Chennells and Griffith (1997) - we can estimate the values of $\frac{\tau_0}{p_0} = 0.2$ and $\frac{p_1}{p_1+\tau_1}\eta = 0.208$. In addition, using an estimation of total tax receipts as a proportion of GDP equal to 29,6% (from OECD statistics for the year 2003) we can estimate $\gamma_0 = 0.296$. Furthermore, using the much-cited estimate for the interest-elasticity of savings in Boskin (1978) of 0.411, we have that capital taxes will be too high if the income-elasticity of savings is greater than 0.42. This value is much lower than the estimate in excess of 1 in Boskin (1978).[23] Thus, even if we allowed for $\frac{\frac{\partial\Gamma[g_0,g_1]}{\partial g_0}g_0}{\frac{\partial\Gamma[g_0,g_1]}{\partial g_1}g_1} \in (1,\ 2.4)$, these calculations would still point towards over-taxation. Of course, these simple calculations are only indicative, but they do demonstrate the possibility that taxes may be too high because of their intertemporal external effects.

4 Some Extensions

In this Section we discuss some of our earlier assumptions. In particular, we examine how sensitive the overall capital tax externality is to the particular assumptions we have deployed, like available taxes and public debt.

It will help the understanding of the implications of these extensions to recall from above that the direction of the net externalities of period$-t$ capital taxes depends, crucially, on (a) the effects of the period$-t$ capital taxes on the interest rates, and (b) on the marginal welfare effect, at the symmetric equilibrium, of an increase in the interest rate of any period $v = 0, 1$,

[22] This would, for instance, be the case if $\Gamma(g_0, g_1) = g_0^{\phi_0} g_1^{\phi_1}$, with $1 > \phi_t > 0$, $t = 0, 1$, and $\phi_0 = \phi_1$.

[23] See also Boskin (1988) for a reported estimate of 0.7 which is still much higher than 0.42.

i.e. Z_v.

Bearing this in mind, one should then expect three types of changes in W_{τ_t}, in (12) and (13), by moving into a more general environment. First, the marginal welfare effect, at the symmetric equilibrium, of an increase in the interest rate of period v, Z_v, may be modified. Second, the effects of the period$-t$ capital taxes on the interest rates may be different. Third, equilibrium taxes values may also differ from those in the basic model above. The latter on its own would only affect the *size* of the *net* capita-tax externalities, all other things equal. Nevertheless, the essence of our message has to do with the *direction* of the net capital-tax externalities. For this reason, we focus for the rest of this Section on the first two types of changes in $W_{\tau_t}, t = 0, 1$.

4.1 Public Debt

We start with the case of public debt. When governments have an inherited level of public debt d_0 and can borrow d_1 in the first-period then the $j-$government's budget constraints become $g_{0,j} = \tau_{0,j}k_{0,j} - (1 + \rho_0)d_0 + d_1$ and $g_{1,j} = \tau_{1,j}k_{1,j} - (1 + \rho_1)d_1$. Also, symmetric equilibrium implies that period-t capital market clears when $Hs_t = k_t + d_t$. So, public debt policy also affects the interest rates. A discussion however of the efficiency properties of non-cooperative public debt is out of the scope of the current work.[24] Retaining, thus, our focus on capital taxes, we have that, for any given path of public debt $\{d_t\}_{t=0}^{1}$, the effects of capital taxes on the interest rates remain qualitatively the same after the introduction of public debt. Following similar steps to the ones in the previous Section, one can also see that Z_t increases by $-\frac{\partial\Gamma[g_0,g_1]}{\partial g_t}d_t$, for any $t = 0, 1$. This additional term represents the welfare effect across each and every region, at a symmetric equilibrium, that arises from the marginal effect on period$-t$ public debt liabilities of an increase in the period$-t$ interest rate. So, if governments are net debtors, $d_t > 0$, $t = 0, 1$, an increase in the period$-t$ interest has a negative effect on public consumption, and hence welfare, across regions. Therefore, regarding the second-period tax, we have, due to $\frac{\partial p_1}{\partial \tau_1} < 1$, that the additional externality is again positive, leading to too low second-period taxes. This echoes the discussion in Jensen and Toma (1991). In Jensen and Toma (1991), a two-period model with local public good provision in both periods, and the immobile factor being fixed, is also discussed. In addition, capital can be taxed in both periods

[24] See Jensen and Toma (1991) for a related discussion.

and governments can issue public debt. Nevertheless, the analysis there takes place under a specific utility function which, crucially, implies (see their Lemma 1) that, in equilibrium, capital taxes do not affect future interest rates and hence servicing of debt. In terms of our notation, this is equivalent to $\frac{\partial p_1}{\partial \tau_0} = 0$. However, as we highlight here, the tax externality associated with the servicing of public debt will in general have both a contemporaneous and an intertemporal aspect. Specifically, turning our attention to the first-period tax, we have that the contemporaneous and intertemporal externalities due to the existence of public debt are of opposite direction. In fact, an increase in the first-period tax reduces the debt liability of the first period, with welfare effect $\frac{\partial \Gamma[g_0,g_1]}{\partial g_0} d_0 > 0$, while it increases the debt liability in the second period, with welfare effect $-\frac{\partial p_1}{\partial \tau_0}\frac{\partial \Gamma[g_0,g_1]}{\partial g_1} d_1 < 0$. So, the net tax externality will again depend on the relative size of the savings income- and interest-elasticities and capital demand elasticities. However, now, it will also depend on the path of public debt. So, for instance, if public debt is highly increasing over time, then, all other things equal, the intertemporal externality due to the servicing of public debt is likely to dominate. In this case, first-period taxes will be too high.

4.2 Taxable Rents

We turn to the case of taxable returns to the immobile factor at a rate $\theta_t > 0$. In this case the $j-$government's budget constraint becomes $g_{t,j} = \tau_{t,j} k_{t,j} + \theta_t w_{t,j}$, and period-$t$ disposable income decreases by $\frac{\theta_t w_{t,j}}{H}$. We focus on an environment where the lump-sum tax θ_t is, due to information or political reasons, lower than its optimal unrestricted level. So, capital taxes are still in use, i.e. $\tau_t > 0$ for any $t = 0, 1$. Following similar steps to the ones in Section 3 one can then easily see that the effects of capital taxes on the interest rates remain qualitatively the same after the introduction of (restricted) taxes on rents/income.[25] In addition, Z_t increases by $\theta_t k_t (\frac{V'[c_t]}{H} - \frac{\partial \Gamma[g_0,g_1]}{\partial g_t})$, for any $t = 0, 1$. This additional term represents the welfare effect across each and every region, at a symmetric equilibrium, that arises from the effect of a marginal increase in the period$-t$ interest rate on taxed private income and rent-tax revenues. To understand this term, note that the marginal effect of an increase in the period$-t$ interest rate on the taxed returns to immobile factors is $-\theta_t k_t$. So, an increase in the period$-t$ interest rate

[25]Notice that the rents tax θ_t affects also the interest rate, through the dependence of savings on θ_t. A discussion however of the efficiency properties of the tax θ_t under capital mobility is out of the scope of the current work.

has a positive effect on private consumption and a negative effect on public consumption across regions, all other things equal. Clearly, the direction of the net welfare effect of an interest-rate-induced decrease in the taxed returns to the immobile factor depends on the relative marginal valuation of private and public consumptions. So, regarding the second-period tax, we have, due to $\frac{\partial p_1}{\partial \tau_1} < 1$, that the net externality in question is positive, leading to too low taxes, if $V'[c_1]/H < \frac{\partial \Gamma[g_0,g_1]}{\partial g_1}$, and vice versa. This echoes the discussion in the two-period model of Keen and Kotsogiannis (2002), where the immobile factor is fixed and first-period taxes are exogenously fixed. There the focus is on the contemporaneous externalities that arise when capital is taxed by both state and federal governments. However, our analysis here highlights that this additional externality, due to taxation of rents, also has both a contemporaneous and an intertemporal aspect. Specifically, to fix ideas, suppose that the valuation of public good is sufficiently high so that $V'[c_t]/H < \frac{\partial \Gamma[g_0,g_1]}{\partial g_t}$ for any t. Then, regarding the first-period tax, we have that the contemporaneous and intertemporal externalities are of opposite direction: the former is positive, while the latter is negative. The net externality will again depend on the relative size of the savings income- and interest-elasticities and capital demand elasticities.

5 Credible Capital Taxation

In this Section we discuss the implications for the nature of the intertemporal capital-tax externality of relaxing the assumption that governments possess pre-commitment with respect to the second-period taxes. To isolate the implications of the lack of pre-commitment for the main intertemporal externality we emphasise in this paper, let us focus on the case of no public debt and no taxes on rents, as in Section 3.

As it is standard in models of credible tax-setting, regions are assumed to be occupied by many small households that perceive policies to be unaffected by their decisions. That is, Hm is, in effect, assumed to be very large so that each household takes policies as given in maximising its welfare. As in Kehoe (1989), governments choose their taxes, in each period, after savings are determined but before firms decide on their capital demands.[26] Note that

[26]Note that in Kehoe (1989) as well the non-cooperative setting of first-period capital taxes is not investigated - that is, the intertemporal effects of capital taxes are neglected in that work as well. Furthermore, public spending is exogenously fixed. So strictly speaking that work is not about the consequences of tax competition for the provision of public services. In that paper, instead, 'race to the bottom' emerges to prevent capital flight

in such an environment the supply of capital is pre-determined. Nevertheless, capital taxes do affect the allocation of capital between regions. Therefore, capital tax competition is still allowed. That is, here, we investigate an environment where governments compete for a given stock of capital on a period-per-period basis because they cannot pre-commit on future taxes. This timing of events is a natural extension of ZMW, where regions compete for a given supply of capital, to a two-period environment with no pre-commitment in tax-setting.

It turns out that the main intertemporal mechanism we have identified in Section 3 is robust to lack of pre-commitment. We also demonstrate that an *additional* intertemporal externality may emerge. The reason is that non-cooperative setting of current capital taxes ignores the associated effects on future capital-tax bases and local public good provisions across regions that arise due to the dependence of future capital taxes across regions on current taxes. The direction of this additional externality depends on whether higher current taxes imply higher or lower future taxes. Depending on the environment, it could dampen or reinforce the intertemporal externality we have identified in Section 3.[27]

To simplify exposition let us introduce here an 'artificial' period $t = -1$, which is characterised by a public good level in each region of g_{-1}. This is exogenously given in period $t = 0$ (*the* first-period of our model). It is during this 'artificial' period that initial savings s_0 are also determined.

It is well known that in dynamic non-cooperative games multiplicity of equilibria arises. We focus on sub-game perfect equilibria in symmetric and differentiable (pure) Markov tax-strategies. For a discussion of the advantages of Markov strategies in dynamic games see Fudenberg and Tirole (1992) Ch. 13. As in the case of pre-commitment, our focus on symmetric equilibria is driven by the fact that regions are ex ante identical. Differentiability is required for analytical simplicity.

Markov strategies imply that actions in a given period depend only on the 'state'. The

and the induced excessive reliance on distortionary labour income taxes that would be necessary to raise the required pre-determined level of tax revenues. The focus in Kehoe (1989) has been to show that an attempt to cooperate in (second-period) tax-setting may not prove beneficial when governments cannot pre-commit to their tax policies.

[27] This insight also extends to the alternative case when taxes of each period are set prior to savings but after past production has been determined, i.e. when governments can pre-commit only for one period. A more detailed discussion of this case is in an Appendix which is available upon request

'state' is a (possibly multi-dimensional) variable which summarises the influence of past interactions on the current strategic environment. In other words, the state is the *minimal* information in the history of a game which is relevant for the strategic interaction between players. In our context, the state in any period t is the public good provision levels in the previous period, $\{g_{t-1,j}\}_{j=1}^{m}$, with $g_{-1,j} \equiv g_{-1}$, and the average supply of capital in each region j in period t, $\{S_{t,j}\}_{j=1}^{m}$. We thus focus attention to strategies on the part of each and every regional-j government of the form $\boldsymbol{\tau}_j(\mathbf{A}) \equiv \{\tau_{0,j} = T_{0,j}[A_0], \tau_{1,j} = T_{1,j}[A_1]\}$ for any j, where $A_t \equiv \{\{S_{t,j}\}_{j=1}^{m}, \{g_{t-1,j}\}_{j=1}^{m}\}$, with $T_{t,j}[\bullet]$ being differentiable for any $t = 0, 1$.

In a Markov Perfect Equilibrium (MPE), second-period taxes are a Nash equilibrium for any given public good provision levels and savings across regions in the first period, i.e. A_1. In turn, first-period taxes are a Nash equilibrium given the pre-determined levels of initial capital supply and past public goods, i.e. A_0, and the rationally anticipated response to changes in state A_1 of all regional governments with respect to their second-period taxes. In any period, governments take into account the effects of their policies in the yet to be determined private actions, prices and states.

To define formally the (Markov Perfect) equilibria for our model,[28] let us first denote with $\bar{S}_t$ the average capital supply in period t. Note that $\bar{S}_0 \equiv s_0$ and $\bar{S}_1 \equiv \frac{1}{m}\sum_{j=1}^{m} S_{1,j}$.

An *MPE* consists of the prices ρ_t^* and $\{w_{t,j}^*\}_{j=1}^{m}$, allocations $\vec{k}_t^* \equiv \{k_{t,j}^*\}_{j=1}^{m}$, $\vec{g}_t^* \equiv \{g_{t,j}^*\}_{j=1}^{m}$, $\vec{c}_t^* \equiv \{c_{t,j}^*\}_{j=1}^{m}$ and $\vec{s}_1^* \equiv \{s_{1,j}^*\}_{j=1}^{m}$, a profile of taxes $\{\boldsymbol{\tau}_j^*\}_{j=1}^{m} = \{\boldsymbol{\tau}_j^*(\mathbf{A})\}_{j=1}^{m}$, and a state-evolution equation $A_t = A_t^*[A_{t-1}, \vec{\tau}_{t-1}]$, $t = 0, 1$, that satisfy: (a) $c_{0,j}^*$, $c_{1,j}^*$ and $s_{1,j}^*$ are consistent with utility maximisation subject to own budget constraints for given state, prices and policies, (b) price- and tax-taking profit-maximisation: $k_{t,j}^* = k[\rho_t^* + \tau_{t,j}^*]$, (c) remuneration of immobile factors: $w_{t,j}^* = w[\rho_t^* + \tau_{t,j}^*]$, (d) capital-market clearing: $\rho_t^* = \rho[\vec{\tau}_t^*, \bar{S}_t^*]$, where $\rho[\vec{\tau}_t, \bar{S}_t]$, after a slight abuse of notation, is given implicitly by $Hm\bar{S}_t = \sum_j k[\rho_t + \tau_{t,j}]$, (e) government-solvency: $g_{t,j}^* = \tau_{t,j}^* k[\rho_t^* + \tau_{t,j}^*]$, (f) (i)$\{T_{1,j}^*[A_1]\}_{j=1}^{m}$ is a Nash equilibrium of the sub-game between regions defined by the state A_1, tax-actions $\tau_{1,j}$ and payoffs $W_{1,j}[A_1, \vec{\tau}_1]$, where $W_{1,j}[A_1, \vec{\tau}_1] \equiv \beta U[\rho[\vec{\tau}_1, \bar{S}_1], \tau_{1,j}, S_{1,j}, 0] + \Gamma[g_{0,j}, \tau_{1,j} k[\rho[\vec{\tau}_1, \bar{S}_1] + \tau_{1,j}]]$, and (ii) $\{T_{0,j}^*[A_0]\}_{j=1}^{m}$ is a Nash equilibrium of the game between regions defined by the state A_0, tax-actions $\tau_{0,j}$ and payoffs $W_{0,j}[A_0, \vec{\tau}_0; \vec{T}_1^*, A_1^*]$, where $W_{0,j}[A_0, \vec{\tau}_0; \vec{T}_1^*, A_1^*] \equiv$

[28] Allowing for tax-strategies to depend on past states and taxes would introduce the possibility for implicit-contract types of equilibria. We leave the investigation of such equilibria for future research.

$U[\rho[\vec{\tau}_0, s_0], \tau_{0,j}; s_0, \sigma_j[A_0, \vec{\tau}_0; \vec{T}_1^*, A_1^*]] + W_{1,j}[A_1^*[A_0, \vec{\tau}_0], \vec{T}_1^*[A_1^*[A_0, \vec{\tau}_0]]]$, and (g) $A_t^*[\bullet]$, $t = 0, 1$, describing in a compact way the evolution of the components of the state variable according to $S_{0,j} = s_0$, $S_{1,j} = \sigma_j[A_0, \vec{\tau}_0; \vec{T}_1^*, A_1^*]$, $g_{-1,j} = g_{-1}$ and $g_{0,j} = \tau_{0,j} k[\rho[\vec{\tau}_0, s_0] + \tau_{0,j}]$, for any $j = 1, ..., m$. In (f) and (g), $\sigma_j[A_0, \vec{\tau}_0; \vec{T}_1^*, A_1^*]$ are the equilibrium first-period savings, given the first-period state and capital taxes. Formally, $\sigma_j[A_0, \vec{\tau}_0; \vec{T}_1, A_1^*]$, $j = 1, ..., m$, is the solution with respect to $\{\sigma_j\}_{j=1}^m$ of the system: for any $j = 1, ..., m$, $\sigma_j \equiv \arg\max_s \{V[(1+\rho_0)s_0 + \frac{w_{0,j}}{H} - s] + \beta V[(1+\rho_1)s + \frac{w_{1,j}}{H}]$ subject to $w_{0,j} = w[\rho_0 + \tau_{0,j}]$, $\rho_0 = \rho[\vec{\tau}_0, s_0]$, $w_{1,j} = w[\rho_1 + T_{1,j}[A_1]]$, $\rho_1 = \rho[\vec{T}_1[A_1], \bar{S}_1]$, $A_1 = A_1^*[A_0, \vec{\tau}_0]$, and $\bar{S}_1 = \frac{\sum_{v=1}^m \sigma_v}{m}, j = 1, ..., m\}$.

A symmetric and differentiable MPE is an MPE in symmetric and differentiable strategies, i.e. when $T_{t,j}^*[A_t] = T_t^*[A_t]$ with $T_t^*[\bullet]$ being a differentiable function, for any $j = 1, ..., m$.

5.0.1 Equilibrium

It follows directly from the definition of MPE that firms' and households' behaviour is as in Section 2. Also, for given first-period state and capital taxes, the equilibrium first- and second-period interest rates are given by $\rho_0^* = \rho[\vec{\tau}_0, s_0]$ and $\rho_1^* = \hat{\rho}_1[A_0, \vec{\tau}_0; T_1^*, A_1^*]$, where $\hat{\rho}_1[A_0, \vec{\tau}_0; \vec{T}_1^*, A_1^*] \equiv \rho[\vec{T}_1^*[A_1^*[A_0, \vec{\tau}_0]], \frac{1}{m}\sum_{v=1}^m \sigma_v[A_0, \vec{\tau}_0; \vec{T}_1^*, A_1^*]] = \rho_1[\vec{T}_1^*[A_1^*[A_0, \vec{\tau}_0]], \vec{\tau}_0, \rho[\vec{\tau}_0, s_0]]$, respectively. In addition, strategic interaction between governments in the second period is identical to that in the static canonical model, where capital supply and past public good level in each region are pre-determined (here at levels $S_{1,j}$ and $g_{0,j}$). In particular, in contrast to the pre-commitment case, we have that when second-period taxes are set governments take into account that $\frac{\partial \rho_1}{\partial \tau_{1,j}} = -\frac{k'_{1,j}}{\sum_{v=1}^m k'_{1,v}}$. Following then similar steps to those in the canonical model, one can see that second-period capital taxes will be too low,[29] for any *given* state A_1

[29]In fact, following similar steps to the ones in Section 3, we have that the welfare effect of increasing marginally all second-period taxes, for *given* state A_1, evaluated at a symmetric equilibrium is $W_{\tau_1} = -\frac{\partial \Gamma[g_0, T_1^*[A_1] H S_1]}{\partial g_1} \frac{T_1^*[A_1]}{f''[HS_1]}(1 - \frac{1}{m}) > 0$. Thus, an *unanticipated* coordinated increase of the same size in second-period capital taxes across regions is welfare improving. Note, however, that in (a symmetric) equilibrium, for given first-period state A_0 and capital taxes τ_0 and for given *anticipated* second-period capital taxes τ_1, first-period savings are given by $s_1 = s[f'[Hs_1] - \tau_1, \frac{w[f'[Hs_1]]}{H}, e_0]$, where we have made use of the fact that in a symmetric equilibrium $k_1 = Hs_1$ and $\rho_1 + \tau_1 = f'[k_1]$. Note that $\frac{\partial s_1}{\partial \tau_1} = -\frac{\frac{\partial s}{\partial \rho}}{1 - s_\rho H f''}$. So, if $\frac{\partial s}{\partial \rho} > 0$ then, similarly to Kehoe (1989), if households *anticipated* a coordinated increase of the same size in all regional second-period capital taxes they would save less than S_1 in the first period in order to avoid the higher taxes. This would lead to lower equilibrium supply of second-period capital than HS_1. Thus, an anticipated attempt to increase uniformly all second-period taxes may not be welfare improving.

with positive capital supply, $S_1 > 0$.

We turn to our focus: the MPE first-period capital taxes. After using the envelope theorem vis-a-vis savings, the definition for MPE second-period capital taxes, the fact that in a symmetric equilibrium $k_t = HS_t$, $\rho_t + \tau_t = f'[HS_t]$, $g_t^* = T_t^*[A_t]HS_t, t = 0, 1$, and $S_0 = s_0$, and recalling our assumption that ensures positive public good provision, we have that $T_0^*[A_0]$ is positive and such that:

$$\begin{aligned}
& s_0 V'[c_0^*] \\
= \; & \frac{\partial \Gamma[g_0^*, g_1^*]}{\partial g_0}\{Hs_0 - \eta[A_0]\frac{g_0^*}{f'[Hs_0]}(1 - \frac{1}{m})\} \\
& - \frac{\partial \Gamma[g_0^*, g_1^*]}{\partial g_1}\eta[A_1]\frac{g_1^*}{f'[HS_1]}\frac{1}{m}\frac{\partial p_1}{\partial \tau_0} \\
& - \frac{\partial \Gamma[g_0^*, g_1^*]}{\partial g_1}\eta[A_1]\frac{g_1^*}{f'[HS_1]}\frac{1}{m}(\frac{\partial p_1}{\partial \tau_1} + 1)\frac{\partial T_{1,j}^*[A_1]}{\partial \tau_{0,j}} \\
& - \frac{\partial \Gamma[g_0^*, g_1^*]}{\partial g_1}\eta[A_1]\frac{g_1^*}{f'[HS_1]}\frac{1}{m}\frac{\partial p_1}{\partial \tau_1}\sum_{\substack{v=1 \\ v \neq j}}^{m}(\frac{\partial T_{1,v}^*[A_1]}{\partial \tau_{0,j}}),
\end{aligned} \tag{14}$$

where $\eta[A_t] \equiv -\frac{f'[HS_t]}{f''[HS_t]HS_t}, t = 0, 1$, with $\frac{\partial T_{1,v}^*[A_1]}{\partial \tau_{0,j}}, v = 1, ..., m$, being evaluated at the symmetric equilibrium. As in the corresponding problem under pre-commitment, the typical government takes into account that its tax choice will affect own welfare directly and by affecting the second-period interest rate, for any given second-period taxes. This is captured by the term at the left-hand side and the first two terms at the right-hand side of the above equilibrium condition.

Nevertheless, under non-commitment, second-period taxes in the *other* jurisdictions do depend on domestic first-period tax-choices. So, now, the typical government takes *also* into account that its tax-choices will affect future interest rates by means of influencing future taxes in other regions. This is captured by the fourth term at the right-hand side of the above equilibrium condition.

Under no pre-commitment, governments *also* take into account that their current tax-choices will also affect own tax-choices in the future. The corresponding welfare effect is reflected in the third term at the right-hand side of the above equilibrium condition. Crucially, this effect is not of second-order. The reason is that the ex ante perceived elasticity of the second-period interest rate with respect to second-period capital taxes is different from the ex post one. This follows from the fact that when second-period taxes are set savings are predetermined, while they are responsive to (anticipated) tax-changes when first-period taxes are set. In particular, the ex ante marginal effect of a region's second-period tax on the second-period interest rate, evaluated at a symmetric equilibrium, is $\frac{1}{m}\frac{\partial p_1}{\partial \tau_1}$. Instead, the ex post effect is $-\frac{1}{m}$.

Conditional on existence, let us turn to the efficiency properties of the equilibrium MPE first-period capital taxes. In particular, as in Section 3, we investigate whether a coordinated marginal increase in *all* symmetric regional taxes in the first period is welfare improving or not. Here, however, due to lack of pre-commitment, we must take into account that, following such a coordinated increase in first-period taxes, regions will re-adjust their second-period taxes optimally, as it is prescribed by $\vec{T}_1^*[A_1]$. To start with, recall that at a symmetric equilibrium the welfare of the typical household is $\sum_{t=0}^{1}\beta^t U[p_t,\tau_t;s_t,s_{t+1}]+\Gamma[\tau_0 k[p_0+\tau_0],\tau_1 k[p_1+\tau_1]]$, with $s_2\equiv 0$, where $s_1=s_1[p_1,\frac{w[p_1+\tau_1]}{H},(1+p_0)s_0+\frac{w[p_0+\tau_0]}{H}]$, $p_0=p[\tau_0,s_0]$ and $p_1=p_1[\tau_1,\tau_0,p_0]$. So, starting from any symmetric and differentiable MPE, a simultaneous marginal increase in each and every regional first-period capital tax results, after using the envelope theorem vis-a-vis savings *and* the definition for the MPE second-period capital tax, in the following welfare effect on the part of *any* household in *any* region j:

$$
\begin{aligned}
W_{\tau_0}^{NC} &\equiv -(1-\frac{1}{m})\sum_{v=0}^{1}\frac{\partial\Gamma[g_0^*,g_1^*]}{\partial g_v}\eta[A_v]\frac{g_v^*}{f'[Hs_v]}\frac{\partial p_v}{\partial\tau_0}\\
&-\frac{\partial\Gamma[g_0^*,g_1^*]}{\partial g_1}\eta[A_1]\frac{g_1^*}{f'[HS_1]}\sum_{\substack{j'=1\\ j'\neq j}}^{m}\frac{1}{m}\frac{\partial p_1}{\partial\tau_1}\sum_{v=1}^{m}(\frac{\partial T_{1,v}^*[A_1]}{\partial\tau_{0,j'}})\\
&-\frac{\partial\Gamma[g_0^*,g_1^*]}{\partial g_1}\eta[A_1]\frac{g_1^*}{f'[HS_1]}\sum_{\substack{j'=1\\ j'\neq j}}^{m}\frac{1}{m}\frac{\partial T_{1,j}^*[A_1]}{\partial\tau_{0,j'}},
\end{aligned}
$$

where, note, $\frac{\partial T_{1,v}^*[A_1]}{\partial\tau_{0,j'}}$, $v,j'=1,...,m$, are evaluated at a symmetric MPE equilibrium. $W_{\tau_0}^{NC}$ is the counterpart, under no pre-commitment, of W_{τ_0} in Section 3. So, taxes are too high if $W_{\tau_0}^{NC}<0$, and vice versa.

As in the canonical model, changes in domestic first-period taxes will affect current tax revenues across regions. Here, however, we emphasise that changes in domestic first-period taxes will also affect future tax revenues across regions. These intertemporal external effects will be of three kinds under no pre-commitment. The first will be of the type we have already identified in Section 3. Namely, through the effect of current taxes on the future interest rate for any given future capital taxes. These two externalities, for any given future taxes, are captured by the first term in the above formula. These terms echo W_{τ_0} in Section 3. Hence, our discussion there applies here as well.

The second kind of intertemporal externality - which is ignored by competing regions - arises through the dependence of the future interest rate on future taxes across regions, which, in turn, are affected by changes in all the non-domestic first-period capital taxes. This externality is captured by the second term in the above formula. The third kind of intertemporal externality - which is also ignored by competing regions - arises through the effects of the non-domestic first-period taxes on future domestic tax revenues for any given future interest rate. This effect arises due to the dependence of (domestic) future taxes on (foreign) current taxes. This effect is not of second order due to the fact that first-period savings are endogenous when first-period taxes are set. This externality is captured by the third term in the above formula. Thus, lack of pre-commitment gives rise to *additional* intertemporal externalities, that arise from the dependence of future taxes on current taxes.

Recalling our discussion of Section 3, we have that the first term of $W_{\tau_0}^{NC}$ is negative if the current-income elasticity of savings is sufficiently high. The other two terms, on the other hand, have opposite signs that depend on the effects of current on future capital taxes. The latter will depend on the specifics of preferences and technology, and hence a matter of empirical investigation. Such a task however is out of the scope of the current paper. In general, after recalling that $\frac{\partial p_1}{\partial \tau_1} < 0$, we have that if future taxes are increasing with current taxes then the second term is positive, while the third term is negative. So, all other things equal, the second type of intertemporal externality pushes to too low taxes, while the third type of intertemporal externality pushes to too high taxes. Conversely, if future taxes are decreasing with current taxes.

To understand further these additional externalities, let us use in $W_{\tau_0}^{NC}$ above that, at a symmetric equilibrium, $\frac{\partial T_{1,v}^*[A_1]}{\partial \tau_{0,v'}} = \frac{\partial T_{1,v}^*[A_1]}{\partial \tau_{0,v''}} \equiv q[A_1]$ and $\frac{\partial T_{1,v'}^*[A_1]}{\partial \tau_{0,v'}} = \frac{\partial T_{1,v}^*[A_1]}{\partial \tau_{0,v}} \equiv \tilde{q}[A_1]$ for any $v, v', v'' = 1, ..., m$, $v \neq v', v \neq v''$, due to the fact that regions are ex ante identical. Then the last two terms in $W_{\tau_0}^{NC}$ become:

$$-(1 - \frac{1}{m})\frac{\partial \Gamma[g_0^*, g_1^*]}{\partial g_1}\eta[A_1]\frac{g_1^*}{f'[HS_1]}\{\frac{\partial p_1}{\partial \tau_1}(\tilde{q}[A_1] + (m-1)q[A_1]) + q[A_1]\}.$$

Therefore, the direction of the net intertemporal externality due to no pre-commitment is towards too high taxes if $\frac{\partial p_1}{\partial \tau_1}(\tilde{q}[A_1] + (m-1)q[A_1]) + q[A_1] > 0$, and vice versa. To fix ideas suppose that $q[A_1] > 0$ and $\tilde{q}[A_1] > 0$. Then, if the interest rate is very responsive to current taxes, i.e. $\frac{\partial p_1}{\partial \tau_1} < -\frac{q[A_1]}{\tilde{q}[A_1]+(m-1)q[A_1]}$, this additional net intertemporal externality is positive and counteracts the intertemporal externality we have identified in Section 3. If, however, $\frac{\partial p_1}{\partial \tau_1} > -\frac{q[A_1]}{\tilde{q}[A_1]+(m-1)q[A_1]}$ this additional net intertemporal externality is negative and reinforces the intertemporal externality we have identified in Section 3. Conversely, if $q[A_1] < 0$ and $\tilde{q}[A_1] < 0$.

6 Related Literature

We can now discuss a number of papers that are, in addition to those cited so far, related to our work. In all these papers, governments use capital taxes in order to provide local public goods and/or lump-sum transfers to residents in a balanced-budget way. Moreover, interregionally immobile factors are in fixed supply.

Wrede (1999), discusses also an intertemporal externality. However, the externality in question is 'vertical'. Specifically, it arises from a common-pool problem between federal and state governments: governments tax a common resource reducing thereby the availability of the resource in the future. Crucially, also, in the investigated (interior) equilibrium there is no contemporaneous externality. The focus there is on (a) whether the total tax set by tax-revenue maximising governments in a federation is higher than the tax imposed by a single tax-revenue maximising government in a unitary state, and (b) how political stability and competition between state governments affects equilibrium taxes in a federation. Here instead the focus is on the investigation of 'horizontal', i.e. across regions, contemporaneous and intertemporal externalities when regional governments are benevolent and there is no federal government.

Coates (1993) investigates also a multi-period model of capital tax competition between regional governments. However, the intertemporal externalities we investigate here do not arise there. The reason is twofold. First, it is assumed there that the supply of capital in each period is exogenously fixed, maintaining thus the assumption of ZMW. Second, despite capital supply being fixed, capital taxes are assumed there to affect positively the equilibrium future capital stocks and thereby public good provision in other regions. So, in contrast to our work, both contemporaneous and intertemporal capital-tax externalities are by assumption positive. Importantly, also, the focus in that paper is on the comparison of the non-cooperative and cooperative equilibria when governments possess *unrestricted lump-sum* taxes.

Wildasin (2003) discusses capital taxation in a small open economy, by recognising the dynamics inherent in capital accumulation when capital inputs can only be adjusted by incurring adjustment costs. Here, instead, we assume zero capital adjustment costs, but we emphasise the interaction between non-cooperative capital taxes and the dynamics in capital accumulation that arise from the dependence of capital supply on past stocks of capital. Hence, our papers could be viewed as complementary in our understanding of international capital taxation in a multi-period/dynamic environment. Note also that the externalities emphasised in ZMW, and re-visited here, are not discussed in that paper. Instead, the focus in Wildasin (2003) is on whether governments, that perceive the world interest rate as time-invariant and exogenously given, will tax capital or not. The optimal decision is driven by the fact that taxing capital is harmful in the long run (as lump-sum taxes on the fixed factor can also be used in Wildasin's set-up) but is beneficial in the short run when non-residents own some of the domestically generated rents. The main result is that the capital tax is decreasing with the mobility of capital and increasing with the scope for redistribution to residents.[30]

Perhaps the most closely related work to ours is Koethenbuerger and Lockwood (2007). These authors have recently investigated an infinite horizon model of capital tax competition between regional governments, under pre-commitment and no capital adjustment costs, where savings are endogenous and no lump-sum taxes can be used. However, the intertemporal externalities we investigate here do not arise there. The reason is that in that paper the returns to the immobile factors are, as a result of assumptions on the available technology, *exogenously given.* In more detail, there, households receive each period a fixed endowment of the private good. In their set-up, there is, however, production uncertainty and households diversify risks by investing in *all* regions. So, the intertemporal externalities in that paper arise because taxes affect the returns to the optimal portfolio, and thereby savings and the supply of capital, for any given path of endowments. Here, on the other hand, there is no uncertainty, and the intertemporal externality we have emphasised above arises due to the effect of capital taxes

[30]Becker and Rauscher (2007) is also similar to Wildasin (2003) in that governments aim at redistributing income to the owners of a fixed in supply and interregionally immobile factor of production, and there are capital adjustment costs. There also the focus is on whether capital is taxed or not, and tax externalities are not investigated. The main differences between these two papers are that in the former the world net interest rate is endogenous, and capital tax revenues (net of lump-sum subsidies) are used to finance public infrastructure, which is the source of endogenous growth.

on the *endogenous* returns to immobile factors, and thereby savings and the supply of capital, *for any given* return to savings. Importantly, note also that in the absence of uncertainty the model in Koethenbuerger and Lockwood (2007) generates the standard 'race to the bottom' result. Hence, our papers can be viewed as complementary in our understanding of capital taxation in a multi-period/dynamic environment under no capital adjustment costs.

7 Discussion and Conclusions

In this paper we have re-visited the view that capital taxes may be too low when capital is perfectly mobile across tax jurisdictions and governments do not possess lump-sum taxes. We have done so by emphasising a previously neglected implication of non-cooperative capital tax setting. Namely, capital taxes affect also future capital stocks, and thereby tax revenues and local public good provisions, across jurisdictions. The main mechanism is that capital taxes have a negative effect on current income and hence on the net supply of future capital, for given net interest rates. Moreover, we have seen that under non-commitment, current capital taxes affect future taxes, and thereby welfare, across regions. These net externalities may lead, ceteris paribus, to too high regional capital taxes, and may more than offset the usual contemporaneous external effects of capital taxes. In this case, regional capital taxes will be inefficiently too high.

These insights are neglected in the received literature on capital tax competition between regional governments in a second-best environment under perfect capital mobility. The literature discussed in the Introduction and Section 4 has nevertheless provided us with many interesting channels through which a capital-tax-induced decrease in the *current* interest rate affects welfare in other regions negatively, counteracting thus the standard tax competition effect. In fact, this literature focuses mainly on the investigation of the welfare effects, in various environments, of an increase in the last-period interest rate, i.e. Z_1 in our set-up. Naturally, then, one avenue for research would be to re-visit all these channels, like publicly provided amenities, under the light of our findings. That is, by recognising the inherent dynamics in capital accumulation due to consumption smoothing, and the associated intertemporal tax externalities.

The specific details of the intertemporal externalities of capital taxes may depend on the environment under study. The modeling possibilities are however numerous, and most of them possibly equally important. As the aim of this paper has been to bring attention to the fact that taxation of mobile capital may as well entail intertemporal externalities, we have chosen to deploy the simplest model for the task in hand. Namely, we have used a two-period representative agent model. The choice of the representative agent paradigm has been driven from the fact this is also the chosen framework in ZMW and most of the literature that ensued it, and it is instructive to be able to directly compare our results with the canonical model. The choice of a two-period model has been driven from the fact that such a model is sufficient to deliver our message, without dwelling on the analytical complications of models with longer horizons. The importance of such a simple exercise is emphasised even more by the fact that, as we have also mentioned in the Introduction, such a model has also been used in the literature, neglecting, however, the intertemporal externalities we focus on here. Of course, fully understanding the net externalities involved in taxing mobile capital would require the study of other environments as well. The reason is twofold. On the one hand, as our analysis makes clear, it is the behaviour of the equilibrium interest rates that drives the directions of the contemporaneous and intertemporal tax externalities. On the other hand, the interest-rate dynamics do depend on the specifics of capital accumulation - that is, on the determinant of the supply of capital. Offering a complete analysis, however, is not feasible space-wise. We leave, therefore, the important task of the investigation of overlapping-generations models,[31] and infinite-horizon models for future research.[32]

8 References

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[31] In a companion paper of ours we make a first step towards this direction.

[32] An alternative framework could also be a finite-horizon model with more than two periods. Nevertheless, we expect that such a model might not give us any more significantly new insights. For instance, our main message carries through, qualitatively, to the three-period version of our basic model of Sections 2 and 3. The analysis of this model is in an Appendix, which is available upon request.

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