Seignorage and Capital Taxation: Tax Competition Revisited

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Paper number 06/03

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This version: October 3, 2005

Abstract

We re-examine the standard view that capital taxes are too low when capital is mobile across tax jurisdictions. We do so by emphasising a previously neglected implication of non-cooperative capital tax setting in a world with national currencies. Namely, capital taxes also affect foreign seignorage. This horizontal externality may lead, ceteris paribus, to too high national capital taxes, and may more than offset the usual effects of tax competition. In this case, and contrary to conventional wisdom, national capital taxes will be too high. Conditions under which the latter is indeed the case are derived and discussed.

Keywords: Tax Competition, Seignorage.

JEL Classification Numbers: H25, E62, H77

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1 Introduction

Mobility of tax bases between tax jurisdictions gives rise to horizontal externalities that tend to leave regional/state/national taxes too low. This standard wisdom is expressed forcefully in the well-established models of Zodrow and Mieszkowski (1986) and Wilson (1986) (ZMW hereafter): competition for mobile capital leads to too low capital taxes.[1] The analysis in ZMW has since been enriched in various directions to provide instances in which capital taxes may be too high.[2] These instances include:[3] trade in capital- and labour-intensive goods (Wilson, 1987), large capital-importing countries (De Pater and Myers, 1994), large foreign ownership of immobile factors (Huizinga and Nielsen, 1997), competition for amenities (Noiset, 1995, and Wooders et. al., 2001), commonality of the capital tax base between states and federal governments (Keen and Kotsogiannis, 2002), government failure (Edwards and Keen, 1996), political economy considerations (Fuest and Huber, 2001, Kessler et al, 2002, Grazzini and van Ypersele, 2003, and Lockwood and Makris, 2005).

In addition, there is a growing body of empirical evidence that higher capital mobility has not clearly led to cuts in corporate tax rates, at least for OECD countries. In particular, recent work by Hallerberg and Basinger (1998, 2001), Devereux, Lockwood, and Redoano (2002), Garrett (1998), Quinn (1997) Rodrik (1997), Swank and Steinmo (2002)) find rather mixed effects[4] of relaxation of capital controls on corporate tax rates.

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[1] Low capital taxes may not be an exclusive characteristic of open economies, that compete for capital. As Chamley (1986) and Judd (1985) emphasise, even when a closed economy is considered, in the long-run the accumulated distortions on capital and labour, through the effect of capital taxes on interest rates and wages, dominate the distortions on labour, that arise from the effect of labour income taxes on labour supply. So, the optimal steady-state capital tax in a closed economy is zero.

[2] For an excellent recent survey see Wilson (1999).

[3] On a related topic, Kehoe (1989), by building on the capital levy problem discussed, for instance, in Fischer (1980), has shown that an attempt to coordinate to higher taxes may not prove beneficial even if tax competition leads to a 'race to the bottom', as long as governments cannot pre-commit to their tax policies. In such an environment, an anticipation of coordination to higher taxes after savings have taken place will lead to low savings and hence low aggregate capital stock in the first place. On another related topic, Bucovetsky and Wilson (1991) show that if tax authorities can deploy a savings, as well as a capital, tax then the resulting policy mix is efficient, and hence there is no scope for coordination.

[4] Specifically, Devereux, Lockwood, and Redoano (2002) is probably the most comprehensive, as it allows for four different measures of exchange controls, and studies not only statutory rates of corporate tax, but

Nevertheless, the message of the basic ZMW model and anecdotal evidence of capital taxes in OECD countries seem to drive many of the debates for tax coordination. For instance, OECD (1998) calls for countries to refrain from harmful tax competition.

This paper re-examines the standard view that capital taxes are too low when capital is mobile across tax jurisdictions. It does so, by emphasising a previously neglected implication of non-cooperative capital tax setting in a world with national currencies. Specifically, regional governments compete with one another for mobile capital, as in standard models, but they enjoy also revenues that arise from the inflation tax on residents' real money holdings. Money demand depends on income and the cost of holding money. These in turn depend on regional tax policies. Capital taxes, then, give rise to an horizontal externality by affecting foreign public revenues from issuing national currency. This tax externality may lead, ceteris paribus, to too high national capital taxes, and may more than offset the usual effects of tax competition. In this case, and contrary to conventional wisdom, national capital taxes will be too high. So, the main result of this paper is that tax coordination, by means of a small multilateral increase in the capital tax, may not lead to a welfare improvement relative to the non-cooperative outcome. Arguably, seignorage accounts for a very small amount of government revenue. Nevertheless, our result is based on the *marginal* effects of local capital taxes on seignorage. In fact, it is shown that the direction of a welfare improving multilateral change in capital taxes depends critically on the interest-elasticity of the demands for capital and real money balances, on the income-elasticity of money demand, and on whether policies are discretionary.

The organisation of the paper is the following. Next Section presents the basic model. Section 3 examines some benchmark environments, while Section 4 investigates whether non-cooperative capital taxes are too low or too high. Section 5 discusses some extensions to the basic model, and Section 6 concludes.

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also effective marginal and average rates, for almost all OECD countries, and allows for strategic interaction in corporate tax setting between countries. It finds that depending on the choice of measure of capital controls and corporate tax rates, a unilateral or multilateral liberalisation of controls may lower *or* raise corporate taxes. This is broadly consistent with the findings of Quinn (1997), Rodrik (1997), Garrett (1998) and Swank and Steinmo (2002) who simply find that capital controls have no significant effect.

2 The Model

To present the basic argument in the simplest possible manner, we deploy a stylised model which abstracts from many features of empirical reality. How our basic argument might be modified in a more general framework is discussed in Section 5.

Our framework is the standard capital taxation model of ZMW, appropriately modified to incorporate money holdings and an inflation tax set by national central banks. There are $n > 1$ symmetric countries. Taxes and public spending in each country are set by the fiscal branch of the national government. Each country has its own national currency, in the form of fiat money, which is managed by the national monetary authority, the country's central bank (CB hereafter). We will refer hereafter to the fiscal and monetary branches of a national government jointly as the (consolidated) government.

Each country $j = 1, ..., n$ is populated by a representative household. There is a single, composite and traded good, and no uncertainty. There is also a world market for bonds. It is assumed that there are no transaction costs or restrictions in trading in this market. That is, there is perfect capital mobility. Let ρ denote the real interest rate in this market.[5]

To capture the basic workings in place we also deploy a two-period model, where each country is endowed with e units of the single good.[6] Moreover, the basic model postulates that the single good is produced in each and every jurisdiction by means of combining capital and a fixed factor, like land. The case of capital being combined, for production purposes, with an endogenous but immobile across jurisdictions factor is discussed in Section 5.

We assume that governments do not possess an unrestricted lump-sum tax. So, in the basic model tax authorities do not tax the fixed factor. The case of governments taxing the income from the fixed factor at a rate $\theta > 0$, which is less than the unrestricted optimal one, is discussed in Section 5. One reason for governments facing restriction in their ability to use

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[5]The law of one price, the Fisher parity condition and the uncovered interest rate parity conditions, that ensure no arbitrage in the markets for the single good and for (real or nominal, domestic or foreign) assets, imply that the real interest rate is common for all countries.

[6]Our aim in this paper is not to study the use of money, the associated inflation dynamics and the implications for the intertemporal consumption smoothing behaviour of agents. Our aim instead is to investigate how the predictions of the ZMW model, which came to be the workhorse in the capital tax competition literature, are modified once one takes into account the presence of seignorage. For this reason the investigation of a fully dynamic model is out of the scope of the present paper, and is left for future research.

lump-sum taxes is that administratively feasible forms of such taxes would 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.[7] We also assume 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.[8]

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, for simplicity, that governments do not inherit any debt or money liabilities; that is, the "initial" private holdings of money and public debt are zero. Governments, however, can issue public debt in the first period, i.e. they may enter the capital market. In the first period, the typical government can also issue domestic currency.

Expressed in real terms, denote with γ_j the level of first-period public good, which is financed through issues of public debt and money. Let d_j and $\bar{m}_j$ be the (real) levels of public debt and money supply in country j (in the first period). Notice that the government's (second-period) debt liabilities are $(1 + \rho)d_j$. Issues of money create also liabilities for the consolidated government in the second period. In more detail, assume without loss of generality, as countries are symmetric, that foreign private holdings of domestic currency are not feasible. Also, governments are assumed for simplicity to hold no foreign reserves. Then, the first-period real revenue the government acquires from money creation is $\bar{m}_j$, often referred to as the cash-flow measure of seignorage. At the end of the second period, the government, through the central bank, buys back the outstanding nominal money stock. Let π_j denote inflation. The government's (second-period) real liability due to money creation is then equal to $(1 - \pi_j)\bar{m}_j$. Note thus that the inflation rate is effectively a tax on real money balances $\bar{m}_j$. Let g_j be the (real) level of second-period public good. So, the second-period revenue requirements are $g_j + (1 - \pi_j)\bar{m}_j + (1 + \rho)d_j$. These requirements are financed through capital taxes. Denote with t_j and k_j the tax on and the level of capital in country j (in the second period).

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[7]See for instance Wilson (1999).

[8]For a model where the degree of information sharing between tax authorities 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, i.e. a tax on their savings, see Makris (2003).

The government's first- and second-period budget constraints are, respectively,

$$\gamma_j = d_j + \bar{m}_j \tag{1}$$

$$g_j = t_j k_j - \bar{m}_j(1 - \pi_j) - d_j(1 + \rho), \tag{2}$$

which give rise to the government's intertemporal budget constraint

$$g_j = t_j k_j + \bar{m}_j(\pi_j + \rho) - \gamma_j(1 + \rho). \tag{3}$$

To interpret this constraint note that total public good provision, in terms of second-period good, is $g_j + \gamma_j(1 + \rho)$. Recall that issues of money are used to buy units of the single good in the first period to finance public good production. Note, however, that issuing money amounts also to switching from interest-bearing, i.e. public debt, to non-interest-bearing means of financing public good production. This constitutes a gain for the consolidated government and is captured in the term $\rho\bar{m}_j$. Recall also that inflation is, in effect, a tax on the real money balances, giving rise to inflation tax revenues of $\pi_j\bar{m}_j$ units. So, manipulation of money supply gives rise to total real revenues of $(\rho + \pi_j)\bar{m}_j$ units, in second-period terms. We call this hereafter as (the opportunity or stock measure of) seignorage.[9]

Policy-setters are assumed to be benevolent: they choose policies to maximise the welfare of their representative household. National fiscal policies consist of $\{g_j, t_j, \gamma_j\}$ and they are chosen by the national fiscal authorities. Monetary policies are set by the national CB. What constitutes monetary policy in our model is discussed shortly after.

Note that in our basic model, due to the immobile factor being fixed and the unavailability of lump-sum taxes, we effectively abstain from labour income taxes. However, in all OECD countries a big part of government revenue derives from taxes on wage income. Thus, in Section 5 we also discuss how our basic result is affected by the availability of such taxes.

We turn to the description of the private sector in the typical country. Private production in country j takes place by means of a production function $f(k_j)$ with the standard properties $f(0) = 0, f' > 0, f'' < 0$. Capital k_j is bought in the capital market, and does not depreciate after its use. Rents, i.e. payments to the fixed factor, are thus given by $f(k_j) - (\rho + t_j)k_j$, and the demand for capital follows from the standard profit-maximisation condition

$$f'(k_j) = \rho + t_j. \tag{4}$$

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[9]See Walsh (2003) Chs 4.2 for various definitions of seignorage, and especially, for our purposes, pp. 139-140.

So, capital is a decreasing function of the gross rate of interest $\rho + t_j$, $k_j = k(\rho + t_j)$ with $k' = 1/f''(k_j)$. Also, equilibrium returns to the immobile factors w_j are a decreasing function of the gross interest rate: $w_j = w(\rho + t_j)$ with $w' = -k_j$ and $w(\rho + t_j) \equiv f(k(\rho + t_j)) - f'(k(\rho + t_j))k(\rho + t_j)$.

Restricting our attention to non-negative net real interest rates, i.e. $\rho \geq 0$, we have that the typical household allocates its endowment e to first-period consumption q_j and savings $s_j = e - q_j$. Savings consist of real money holdings m_j and bonds $b_j = s_j - m_j$. In the second period, the household liquidates money holdings, and receives its return from investment and the equilibrium returns to the immobile factors. These three sources of income comprise second-period consumption,

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\begin{aligned}
c_j &= (1 + \rho)b_j + m_j(1 - \pi_j) + w(\rho + t_j) \\
&= (1 + \rho)s_j + w(\rho + t_j) - (\pi_j + \rho)m_j.
\end{aligned}
\tag{5}
$$

As it is well-known, explaining demand for fiat money in an analytically tractable way is notoriously difficult. For this reason, existing models with money largely fall into two, admittedly simplistic, categories. There are those models where money is a necessary exchange medium; the cash-in-advance models. There are also the money-in-utility models which postulate that individuals derive utility from real money holdings, as the latter economise on transaction costs (e.g. shopping time) associated with purchases. These models yield similar predictions, which also comply with empirical evidence, about the demand for liquidity.[10]

Here we focus on the role of money as a medium of exchange that reduces transaction costs. In Section 5 we discuss how our results would be modified if we assumed, instead, the existence of a cash-in-advance constraint.

When money enters the utility function, individuals are viewed as benefiting from the flow of services yielded by money holdings. These services can be thought of as a description of the advantages of intermediate exchange. These advantages arise from the fact that converting illiquid assets to purchasing power and arranging barter transactions are costly, in terms of time and resources, activities. So, what matters, in terms of welfare, is the command of money holdings over goods or some measure of the transaction services, in terms of the single good, that money holdings provide. Thus, the utility derived from the flow of services yielded by

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[10]See Blanchard and Fischer (1989) Ch 4, Obstfeld and Rogoff (1996) Chs 8.1-8.3 and Walsh (2003) Chs 2 and 3 for some excellent discussions of the issues involved.

money holdings is related to the value, in terms of the single good, of money holdings. In fact, models with money in utility can be viewed as shortcuts of models where money helps to reduce the time needed to purchase consumption goods.[11]

In the context of our model, the presumption is that households gain utility from the real money balances they have at the start of the (second) period,[12] by economising on the transaction costs that are involved in purchasing consumption goods at the end of the period. So, we postulate the following preferences

$$H(q_j)V(c_j, m_j(1 - \pi_j))\Gamma(\gamma_j, g_j), \tag{6}$$

where[13] $H(0) = 0, H' > 0, H'' < 0, \Gamma(0,0) = 0, \Gamma_\gamma > 0, \Gamma_g > 0, \Gamma_{\gamma\gamma} < 0, \Gamma_{gg} < 0$. The[14] dependence of welfare on $m(1 - \pi)$ requires an explanation. Following Carlstrom and Fuest (2001) we assume that money balances available *before* going to purchase goods facilitate transactions and thereby yield utility.[15] So, the second-period real money balances, i.e. how many units of the single good can be purchased in the second period with the nominal money holdings acquired in the first period, are $r \equiv m(1 - \pi)$. We[16] also assume that $V(0,0) = 0$, $V_c > 0, V_r > 0, V_{cc} < 0,$ *and* $V_r V_{cc} < V_{rc} V_c$. Conditioned on the satisfaction of the second-order sufficient condition, the latter assumption is necessary and sufficient for real money balances

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[11]For a cash-in-advance model where money is required also for transactions involving investment see Abel (1985).

[12]See also Lucas (1982) and Carlstrom and Fuest (2001).

[13]Utility is assumed to be separable in the first-period consumption for expositional simplicity only; relaxing this assumption will not affect the qualitative nature of our results.

[14]Lettered subscripts are used to denote respective partial derivatives.

[15]In fact, this assumption makes the timing of acquiring and using money more consistent with cash-in-advance models.

[16]Utility is assumed to be separable in the public good to prevent money demand from being affected by the level of public good provision. Relaxing this assumption would complicate the analysis without altering significantly the main message of the paper. In more detail, with non-separable utility the equilibrium level of second-period public good provision in region j becomes a *non-linear* function of revenues from capital taxation, the price of money $\pi_j + \rho$, interest rate ρ, private wealth $(1 + \rho)e + w_j$ and first-period public good. Our results would be qualitatively robust as long as the stability condition $1 > (\pi + \rho)\partial m/\partial g$ was imposed. This condition would ensure that higher capital tax revenues were still implying higher levels of local public good provision. Notice also that a similar separability assumption has also been deployed by Bucovetsky and Wilson (1991) to ensure that tax revenues from labour income do not in turn depend on the level of local public good provision.

to be a normal good.

Let the net-of-taxes wealth be denoted with h_j. That is, $h_j = (1 + \rho)e + w_j$. The household's intertemporal budget constraint is $q_j(1 + \rho) + c_j + m_j(\pi_j + \rho) = h_j$. Let $z_j \equiv \pi_j + \rho$ denote the j−country cost of holding money, and $\delta_j \equiv 1 - \pi$ be the rate of return to money. Standard consumer theory then tells us that savings in each and every country j are given by a function $\sigma(\rho, z_j, w_j, \delta_j, e)$ with $\sigma_e > 0$ and $\sigma_w < 0$ - by normality of consumption and real money balances, $\sigma_z < 0$ - if consumption and real money balances are normal goods and gross substitutes - and $\sigma_\rho(.) > 0$ representing the net effect due to an increase in the price of past consumption - if current and future consumptions are normal goods and gross substitutes. Furthermore, σ_δ is ambiguous. Also, by the normality of consumption and real money balances, we have that $(1 + \rho)\sigma_w + 1 > 0$. Given that equilibrium rents are a function of the net interest rate and the capital tax, we have that savings in country j are ultimately given by a function $s(\rho, t_j, \pi_j)$.[17] Let us denote with s_ρ the effect on savings of the typical country of a marginal increase in the after-tax real interest rate, i.e. $s_\rho \equiv \sigma_\rho + \sigma_z - \sigma_w k_j$. Assume hereafter that $s_\rho > 0$. Denote also with s_π and s_t the effect on savings of the typical country of a marginal increase in inflation and capital tax respectively. Note that $s_\pi = \sigma_z - \sigma_\delta$ is ambiguous, while $s_t = -\sigma_w k > 0$.

Welfare maximisation subject to the budget constraint (5) for given prices and policies, gives also a demand for liquidity which is increasing with disposable income $y_j \equiv (1 + \rho)s_j + w(\rho + t_j) \equiv y(\rho, t_j, s_j)$, as money here is a normal good, and decreasing with the relative price of holding money, $\rho + \pi_j$. Money demand also depends, in an ambiguous manner, on $1 - \pi_j$, i.e. the real interest rate on money holdings. In more detail, assuming that the second order sufficient condition is satisfied, optimal money holdings, when $\rho + \pi_j > 0$, satisfy the following first order condition of the household's problem:

$$V_r(c_j, m_j(1 - \pi_j)) = \frac{(\rho + \pi_j)}{1 - \pi_j} V_c(c_j, m_j(1 - \pi_j)). \tag{7}$$

This condition,[18] combined with the second-period budget constraint (5), gives a money demand $m_j = m(\rho + \pi_j, y_j, 1 - \pi_j)$, with $m_z < 0$ and $m_y > 0$, while m_δ is ambiguous.

[17]The dependence on the endowment e is suppressed for expositional clarity.

[18]Note that, given the second order conditions, this condition gives a demand for real money balances which is decreasing with the nominal interest rate i ($= \frac{\rho + \pi}{1 - \pi}$), increasing with the level of consumption c, and decreasing with the real interest rate of money $1 - \pi$.

Recall that disposable income is a function of the interest rate, the returns to the immobile factors and thereby the interest rate and the capital tax, and, finally, of savings. Thus $m_j = m(\rho + \pi_j, y(\rho, t_j, s(\rho, t_j, \pi_j)), 1 - \pi_j) \equiv l(\rho, t_j, \pi_j)$. Clearly, given savings, demand for money is decreasing with capital taxes, as higher taxes decrease disposable income. Furthermore, demand for real money balances is increasing with savings, as disposable income increases with savings. Recall that savings increase with the capital tax due to normality of consumption. To see the net effect of capital taxes on money demand, note that $l_t = -km_y[(1+\rho)\sigma_w + 1] < 0$, due to normality. So, the overall effect of capital taxes on the demand for money (through the disposable income) is negative as, due to normality, the direct effect of a tax-induced decrease in the returns to the immobile factors on disposable income dominates the indirect effect on disposable income through the associated decrease in savings. Also, $l_\pi = m_z - m_\delta + m_y(1+\rho)s_\pi$, which has an ambiguous sign. It will also prove useful for what follows to investigate the effect on liquidity of changes in the real interest rate. Increases in the latter result, ceteris paribus, in higher price of money and hence in lower real money balances. At the same time, however, an increase in the real interest rate has an ambiguous effect on the disposable income, for given savings, as it increases the returns from savings but it also decreases the returns to the immobile factors. Finally, an increase in the real interest rate increases savings, disposable income and thereby demand for money. So, the effect on liquidity of changes in the real interest rate is ambiguous. In more detail, $l_\rho = m_z + m_y[s - k + (1+\rho)s_\rho]$.

Given the above, the value function of typical agent in country j is

$$U(\rho, t_j, \pi_j, \gamma_j, g_j) \equiv H(e - s(\rho, t_j, \pi_j))V(y(\rho, t_j, s(\rho, t_j, \pi_j)) - (\rho + \pi_j)l(\rho, t_j, \pi_j), l(\rho, t_j, \pi_j)(1 - \pi_j))\Gamma(\gamma_j, g_j),$$

(8)

with - due to the envelope theorem:

$$U_\rho = [s_j - k_j - m_j]V_cH\Gamma, \tag{9}$$

$$U_t = -k_jV_cH\Gamma, \tag{10}$$

$$U_\pi = -m_j[V_c + V_r]H\Gamma. \tag{11}$$

Equilibrium in the market for capital is given by

$$\sum_j k(\rho + t_j) = \sum_j (s_j - \gamma_j). \tag{12}$$

To understand this note that the left-hand side corresponds to total demand for capital by firms. Total supply on the other hand consists of private purchases of bonds net of private

purchases of public bonds, i.e. $\sum_j (b_j - d_j)$. Thus, after using the definition of savings, the government's first-period budget constraint and money-market equilibrium $m_j = \bar{m}_j$, total supply is equal to $\sum_j (s_j - m_j - d_j) = \sum_j (s_j - \gamma_j)$. With savings depending on the real interest rate, inflation and the capital tax, market-clearing implies an equilibrium real interest rate $\rho = \rho(\vec{t}, \vec{\pi}, \vec{\gamma})$, where $\vec{t} \equiv \{t_1, ..., t_n\}$, $\vec{\pi} \equiv \{\pi_1, ..., \pi_n\}$ and $\vec{\gamma} \equiv \{\gamma_1, ..., \gamma_n\}$. Note that in a symmetric equilibrium we have

$$ k(\rho + t) = s(\rho, \pi + \rho, w(\rho + t), 1 - \pi, e) - \gamma, \tag{13} $$

and thus $\rho = p(t, \pi, \gamma)$. Note that, evaluated at a symmetric equilibrium, $\frac{\partial \rho(\vec{t}, \vec{\pi}, \vec{\gamma})}{\partial t_j} = \frac{p_1}{n} < 0$ and $\frac{\partial \rho(\vec{t}, \vec{\pi}, \vec{\gamma})}{\partial \pi_j} = \frac{p_2}{n}$, with the sign of p_2 be ambiguous.

Equilibrium in the market for money is given by[19]

$$ \bar{m}_j = l(\rho(\vec{t}, \vec{\pi}, \vec{\gamma}), t_j, \pi_j). \tag{14} $$

Thus, given capital-market clearing, equilibrium inflation depends on capital taxes and first-period public goods, foreign inflations and the regional money supply. Recall, from the description of the consumer's value function, that inflation affects consumer's welfare. Also, given $\rho = \rho(\vec{t}, \vec{\pi}, \vec{\gamma})$, from what affects welfare, inflation is the only variable that the CB has control upon, through the manipulation of the money supply $\bar{m}_j$. Therefore, inflation is the ultimate variable of interest to the CB: the CB's *policy goal* is inflation. For this reason, we treat inflation as the direct instrument of monetary policy. This assumption does not mean that the CB directly sets prices in the economy. Instead, it should be interpreted as the CB, through its actual *policy tools*, being able to exercise close control over inflation. In terms of our model, this simply means that the CB adjusts, residually, the money stock $\bar{m}_j$ so that, for any given regional fiscal policies, foreign inflations and any chosen inflation target, the market for money clears given the associated total demand for money. Note, also, that in the context of our model, the money aggregate $\bar{m}_j$ is not a good policy goal. The reason is that if money supply is set at a certain level by the CB, then inflation will also be influenced by regional taxes and first-period public goods, through the interest rate. That is, if the CB deploys a money aggregate target/goal then it, effectively, looses the close control of inflation - the CB's

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[19]Given equilibrium in the markets for money and capital, the market for the single, composite and traded good in the second period clears residually, i.e. $\sum_j (c_j + g_j) = \sum_j (f(k_j) + k_j)$.

ultimate variable of interest.[20] For these reasons, we assume that in our model, as it is also the case in UK, for instance, the CB's target/goal is inflation, and not the money supply. That is, we assume hereafter that the CB *chooses* inflation to maximise welfare in its jurisdiction.[21]

Given the symmetry of our model we focus on symmetric equilibria. We also focus on situations where fiscal authorities hold Nash conjectures against each other, to capture non-cooperative tax-setting. Similarly, CBs hold Nash conjectures against each other, to capture non-cooperative monetary policies.

Equilibrium characterisation will also depend on whether policy is discretionary or not. Pre-commitment of policies amounts to policy-makers being able to abide by their policy announcements/rules, while policies are discretionary when they are set after consumers have made their decisions. Absent enforcement, it may be optimal, in many instances, to deviate from a policy rule once individuals have made commitments based on the expectation that the rule will be upheld. Thus, if policy-makers can exercise discretion, private decisions will have to take into account the incentives of the policy makers once private commitments take place.

In our context, whether policy is discretionary or not amounts to whether policy-makers can commit or not on their policies prior to individuals deciding on their savings and money holdings. In our model, the distinction between pre-commitment and discretion is important because inflation and tax policies distort savings and the demand for real money balances. In more detail, recall that savings and the demand for money depend, among others, on the price of money holdings. As the price of money, $\rho + \pi$, depends on inflation (directly) and capital taxes (indirectly via the real interest rate), policies distort individual decisions. So, optimally announced policies (when savings and money holdings are not yet determined) are in general different to ex post optimal policies (when savings and real money balances are in place). This

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[20]In reality, of course, even the money aggregate is out of the CB's close control due to monetary shocks. In fact, for this reason, money growth is usually an *intermediate target*, which only provides the central bank with information about economic developments that will affect the goal variables. Given this and other relevant information, the CB then manipulates its policy instruments/tools in an attempt to reach the adopted policy goals. For a discussion of monetary (intermediate) targets, goals, and policy instruments/tools see Walsh (2003) Ch. 9.

[21]If we ignored the distinction between goals and tools/instruments and assumed that the CB chooses the money aggregate, instead of inflation, then capital taxes would generate the usual horizontal externality emphasised by ZMW and an externality due to the presence of seignorage, which however is different than the one we emphasise here. Specifically, this externality would arise from tax-induced changes in foreign inflation.

is a mere consequence of the fact that from the point of view of policy-makers savings and money demand are infinitely inelastic ex post, and therefore policy-distortions upon savings and money holdings are lower ex post than ex ante.[22]

In what follows, we assume that the typical fiscal government and central bank possess the same ability to pre-commit. We do so in order to isolate the efficiency implications for decentralised tax policy of the mere existence of national monetary authorities in control of national inflation. Introducing an asymmetry vis-a-vis pre-commitment technologies would bring about additional considerations,[23] and would obscure the picture, without altering the main insights of our paper.

In terms of our model, if pre-commitment of policies is feasible then (all) policy-setters take into account, when deciding upon policy, that $m_j = l(\rho, t_j, \pi_j)$ and $s_j = s(\rho, t_j, \pi_j)$, and hence $\rho = \rho(\vec{t}, \vec{\pi}, \vec{\gamma})$. If, on the other hand, policies are discretionary then m_j and s_j are treated by policy-makers as exogenously given. So, under discretion, policies are chosen *as if* $l_\rho = l_t = l_\pi \equiv 0$ and $s_\rho = s_t = s_\pi \equiv 0$, and hence $\partial\rho/\partial\pi_j = 0$ and $\partial\rho/\partial t_j = -\frac{k'_j}{\sum_i k'_i}$. However, in a rational expectations equilibrium, individuals can foresee the actual policies. Therefore, in equilibrium, the demand for money $l(\rho(\vec{t}, \vec{\pi}, \vec{\gamma}), t_j, \pi_j)$ and savings $s(\rho(\vec{t}, \vec{\pi}, \vec{\gamma}), t_j, \pi_j)$ must still be satisfied. To capture in a concise way the different incentives on the part of policy-makers, we follow hereafter the notational convention that $m_j = \hat{l}(\rho, t_j, \pi_j)$ and $s_j = \hat{s}(\rho, t_j, \pi_j)$ with $\hat{l}_\mu = \hat{s}_\mu = 0$ if policy-makers can exercise discretion, and $\hat{l}_\mu = l_\mu$ and $\hat{s}_\mu = s_\mu$ otherwise, where $\mu = \rho, t, \pi$. Also, $\rho = \hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma})$ with $\hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma}) = \rho(\vec{t}, \vec{\pi}, \vec{\gamma})$ if policy-makers can pre-commit, while $\partial\hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma})/\partial\pi_j = 0$ and $\partial\hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma})/\partial t_j = -\frac{k'_j}{\sum_i k'_i}$ if policies must be credible. Furthermore, we denote the symmetric equilibrium interest rate by $\hat{p}(t, \pi, \gamma)$, with $\hat{p}_t(t, \pi, \gamma) = \frac{\hat{s}_t - k'}{k' - \hat{s}_\rho}$ and $\hat{p}_\pi(t, \pi, \gamma) = \frac{\hat{s}_\pi}{k' - \hat{s}_\rho}$.

Finally note that as the typical monetary and tax authorities face the same objective function a direct application of the envelope theorem implies that the sequence of the moves between the typical CB and the typical fiscal authority is not crucial for policy determination. In fact, non-cooperative tax and monetary policy is given by maximising the typical resident's

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[22]For some excellent discussions of the dynamic, or time, inconsistency problem of policies, see Blanchard and Fischer (1989) Ch 11.4, Persson and Tabellini (2000) Ch 12.2 and 15, and Walsh (2003) Ch. 8.. Note also that the implicit assumption here, as in all models of capital tax competition, including Kehoe (1989), is that tax authorities can commit on their capital taxes prior to capital stock being decided upon by firms.

[23]See for instance Huber (1998), Dixit and Lambertini (2003).

welfare with respect to t_j, γ_j and π_j, taking into account that $m_j = \hat{l}(\rho, t_j, \pi_j)$, $s_j = \hat{s}(\rho, t_j, \pi_j)$ and $\rho = \hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma})$.

The objective function of the typical CB and tax authorities, or equivalently of the typical consolidated government, can then be written as:

$$W(\vec{t}, \vec{\pi}, \vec{\gamma}) \equiv U(\hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma}), t_j, \pi_j, \gamma_j, t_j k(\hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma}) + t_j) + (\hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma}) + \pi_j)\hat{l}(\hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma}), t_j, \pi_j) - (1 + \hat{\rho}(\vec{t}, \vec{\pi}, \vec{\gamma}))\gamma_j).$$
$$(15)$$

Before we proceed to the investigation of the equilibrium tax policies, it will be helpful for our understanding to examine the first-best allocations, and the optimal inflation policy when regional governments can fully-utilise a lump-sum tax. We do so next.

3 Benchmark Cases

In this Section we investigate some benchmark cases that will help our understanding of the forthcoming results. We start with the examination of the first-best allocations.

Since regions are symmetric there is no reason for differentiating between them. Thus, in first-best $q_j = q$, $c_j = c$, $\gamma_j = \gamma$, $g_j = g$, $r_j = r$ and $k_j = k$ for any $j = 1, ..., n$. Also, since capital is productive, we have that $k = e - q - \gamma$. Thus, the first-best second-period private and public consumptions and the first-best real money holdings in the typical region are given by

$$\max_{q,c,\gamma,g,r} H(q)V(c,r)\Gamma(\gamma, g) \text{ subject to } c + g \leq e - q - \gamma + f(e - q - \gamma) \qquad (16)$$

where the latter inequality is the second-period resource constraint of the typical region.

Clearly then, as the marginal cost of issuing money is zero, the *optimal quantity of money* is the one that satiates consumers, i.e. $V_r = 0$.[24] Also, as consumption is valued and the marginal rate of transformation between the second-period private and public good is one, in the first-best there are no wasted resources and the marginal utilities of second-period private and public consumption are equalised, i.e. $c + g = e - q - \gamma + f(e - q - \gamma)$ and $\Gamma_g V = V_c \Gamma$. Similarly, we have that the first-best levels of first-period private and public consumption are given by $H'V = HV_c(1 + f')$ and $H\Gamma_\gamma = H'\Gamma$. Denote first-best values with the superscript o.

In the absence of a central planner, taxes have to be used to transfer private resources into public good production. In addition, manipulation of monetary policy may be necessary

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[24]See also Blanchard and Fischer (1989) pp. 191 and Walsh (2003) pp. 60.

to raise revenues further for the purposes of financing local public goods. Suppose, for the purposes of the rest of this Section, that local fiscal authorities can fully utilise an unrestricted lump-sum tax τ. That is, let private consumptions in region j be such that $c_j = (1+\rho)(e-q_j) + w_j - \tau_j - (\pi+\rho)m_j$. Public consumptions in turn are such that $g_j + (1+\rho)\gamma_j = \tau_j + (\rho+\pi)m_j$: given the availability of unrestricted lump-sum taxes, it is not optimal for local governments to use any distortionary taxes, including capital taxes. Note now that optimisation by firms and consumers implies $\rho = f'(k_j)$ and $H'V = HV_c(1 + f')$. The latter, as in the first-best, states that the marginal rates of substitution and transformation between first- and second-period consumptions are equalised. As condition (7) still determines the trade-off between consumption and real money holdings, we have directly that optimal money holdings decrease with income, and hence the CB's revenues are negatively related to the lump-sum income taxes. Moreover, money holdings decrease with the cost of holding money $\rho + \pi$. In addition, equilibrium in the capital market, and the symmetry of countries, imply that $k_j = k$, $q_j = q$, $c_j = c$, $\gamma_j = \gamma$, $g_j = g$, $\tau_j = \tau$ and $k = e - q - \gamma$.

Consider now the benchmark case of the national lump-sum tax and inflation being chosen by a central *consolidated* government. Note that with the opportunity cost of money $\pi + \rho$ being equal to zero consumers acquire money up to the point of satiation. Recall that equalisation of the marginal rates of substitution and transformation between first- and second-period consumptions, money-satiation and equalisation of the marginal utilities of private and public consumption is the first-best outcome. One can very easily confirm that the first-best allocations are feasible. In fact, given money-satiation, all the government needs to do is to set public spending γ^o, g^o and lump-sum tax $\tau^o \equiv \gamma^o(1 + f'(e - q^o - \gamma^o)) + g^o$. Clearly, then, the *optimal rate of inflation* would be a rate of deflation equal to the real rate of interest, i.e. $\pi = -\rho$.

Setting inflation rate such that the private opportunity cost of money is zero, i.e. equal to the social marginal cost of printing money, is the famous Friedman rule for optimal inflation derived in Friedman (1969). However, zero nominal interest rates may no longer be optimal if the consolidated government does not possess a lump-sum tax instrument. The reason is that in this case variations in inflation tax revenues to achieve the Friedman rule will require adjustments in other distortionary taxes. In fact, when money is treated as a commodity, as it is done here, the optimal mix between inflation tax and other distortionary taxes follows the

well-known Ramsey rule.[25]

In the next Sections, we assume away the availability of unrestricted lump-sum taxes, and focus on the efficiency properties of regional capital taxes. As we shall see, some of the inefficiencies that arise in this case rely on the nominal interest rate be positive. Deriving the exact conditions for the latter to be true is out of the scope of the present study. Nevertheless, in an environment where regional distortionary taxes are set non-cooperatively, many of the lessons of the literature on optimal taxation in monetary models are still valid. In more detail, one can show that, as intuition would suggest, the optimal, from the CB's point of view, revenue from issuing money is positive as long as public consumption is sufficiently valued. But positive revenues from issuing money require positive nominal interest rates and positive demand for money. Therefore, in what follows we focus on environments where the public good and real money balances are sufficiently valued so that the symmetric non-cooperative equilibrium features positive cost of holding money and positive money holdings.

4   Capital Taxation in the Presence of Seignorage

We are now ready to investigate the equilibrium capital tax policies.[26]   At an interior solution, the typical capital tax t is given by $\frac{\partial W(\vec{t},\vec{\pi},\vec{\gamma})}{\partial t_j} = 0$, which evaluated at the symmetric equilibrium gives:

$$-H(q)\{\Gamma(\gamma,g)V_c(c,r)[(m-\gamma)\frac{\hat{p}_t}{n}+k]+V(c,r)\Gamma_g(\gamma,g)\{[tk'+m-\gamma+(\pi+\rho)\hat{l}_\rho]\frac{\hat{p}_t}{n}+k+tk'+(\pi+\rho)\hat{l}_t\}\} = 0.$$
(17)

We are now ready to analyse the efficiency of the typical regional capital tax policy and hence whether a coordinated change in regional taxes, for the given equilibrium level of inflation and first-period public good, is welfare improving or not. In doing so, the presumption is that the equilibrium tax t, cost of holding money $\rho + \pi$, real money balances and first-period public

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good, γ, are strictly positive.[27] We also assume hereafter that public debt, $d = \gamma - m$, is non-negative.[28]

To start with, note that at a symmetric equilibrium welfare (15) becomes:

$$W(t, \pi, \gamma) \equiv U(\hat{p}(t, \pi, \gamma), t, \pi, \gamma, tk(\hat{p}(t, \pi, \gamma) + t) + (\pi + \hat{p}(t, \pi, \gamma))\hat{l}(\hat{p}(t, \pi, \gamma), t, \pi) - (1 + \hat{p}(t, \pi, \gamma))\gamma). \tag{18}$$

A marginal increase in the uniform capital tax t results in:

$$
\begin{aligned}
W_t(t, \pi, \gamma) &= -H(q)\Gamma(\gamma, g)V_c(c, r)[(m - \gamma)p_t + k] \\
&\quad + H(q)V(c, r)\Gamma_g(\gamma, g)\{[tk' + m - \gamma + (\pi + \rho)\hat{l}_\rho]\hat{p}_t + k + tk' + (\pi + \rho)\hat{l}_t\} \\
&= (1 - 1/n) \times \tag{19} \\
&\quad \{\hat{p}_t H(q)\{[(m - \gamma)(V(c, r)\Gamma_g(\gamma, g) - \Gamma(\gamma, g)V_c(c, r)) + V(c, r)\Gamma_g(\gamma, g)(tk' + (\pi + \rho)\hat{l}_\rho)]\}\} \\
&\equiv W_t,
\end{aligned}
$$

where the last equality follows from using (17). A coordinated increase in symmetric capital taxes t is welfare improving if and only if $W_t > 0$. If $W_t > 0$ then the net tax externality is positive, and the non-cooperative equilibrium is characterised by under-taxation of capital, for the given equilibrium level of inflation and first-period public good. If, on the other hand, $W_t < 0$ then the net tax externality is negative, and the non-cooperative equilibrium capital taxes are too high. As, by assumption $n > 1$, we clearly have that the direction of inefficiency in the equilibrium capital tax depends on the balance between the terms in the curly brackets.

The term $\hat{p}_t H(q)V(c, r)\Gamma_g(\gamma, g)tk' > 0$ represents the positive externality that arises from the effect on capital tax revenues abroad of tax-induced changes in the real interest rate. To see this, note that the marginal effect on capital tax revenues of a change in price of capital is negative, $tk' < 0$. As interest rates decrease with capital taxes, i.e. $\hat{p}_t < 0$, we have that an increase in the capital tax leads to a decrease in tax revenues. As tax revenues are valued, i.e. $\Gamma_g(\gamma, g) > 0$, this constitutes a positive externality, which leaves, ceteris paribus, taxes too low. Note that the extend of this externality is positively related to the responsiveness of capital to the before-tax real interest rate $\rho + t$. This is the standard horizontal externality

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[27]Recall from the previous Section that sufficiently strong preferences for public good and sufficiently high marginal utility of money at zero holdings would ensure all these presumptions.

[28]Sufficiently high valuation for first-period public good would ensure that. Note also that the results would remain the same, qualitatively, if governments were running sufficiently small surpluses.

that arises due to the mobility of capital, and has been emphasised in the ZMW model. We call this the tax-competition effect.

The term $-\hat{p}_t H(q)\gamma(V(c,r)\Gamma_g(\gamma,g) - \Gamma(\gamma,g)V_c(c,r))$ represents the net externality that arises from the effect on disposable income, for given savings, and servicing of the first-period public good abroad of tax-induced changes in the real interest rate. To start with, the term $\gamma\hat{p}_t H(q)\Gamma(\gamma,g)V_c(c,r) \leq 0$ reflects the negative externality that arises from the effect on foreign private consumption, for given savings, money holdings and price of money. In more detail, note that a change in the interest rate affects the return to savings and the return to immobile factors. In fact, the net effect of a marginal decrease in the interest rate on disposable income, for given savings, is $s-k$. Equilibrium in the capital market implies that the difference between private savings and investment equals the government's first-period total, interest- and non-interest-bearing, real debt, i.e. $s - k = d + m = \gamma$. So, an increase in the capital tax leads to a decrease in disposable income of $-\hat{p}_t\gamma$ units. As consumption is valued, i.e. $V_c > 0$, this constitutes a negative externality, that leads, ceteris paribus, to too high taxes. The term $-\gamma\hat{p}_t H(q)V(c,r)\Gamma_g(\gamma,g) \geq 0$ represents the positive externality that arises from the effect on the servicing of the government's total real liabilities. To see this, note that the marginal effect on the second-period net tax revenues of a change in price of capital is $-\gamma \leq 0$. As interest rates decrease with capital taxes, we have that an increase in the capital tax leads to an increase in second-period tax revenues by improving the fiscal position of the government. As tax revenues are valued, this constitutes a positive externality, which leaves, ceteris paribus, taxes too low. Note that both these externalities emerge due to the provision of a public good in the first-period. The net direction of this externality is positive if second-period public good is valued more than private consumption, and vice versa.[29] So, if, for instance, $V(c,r)\Gamma_g(\gamma,g) > \Gamma(\gamma,g)V_c(c,r)$ then this externality leads, ceteris paribus, to too low taxes. We call this the debt effect.

The remaining terms capture the externalities that arise due to the presence of money. To start with, the term $-m\hat{p}_t H(q)\Gamma(\gamma,g)V_c(c,r) > 0$ reflects the positive externality that arises from the effect on foreign private consumption, for given disposable income and money holdings, of tax-induced changes in the price of real money balances. Specifically, note that a marginal increase in the real interest rate, while maintaining income and real money balances,

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[29]See also Jensen and Toma (1991).

decreases consumption by the amount of real money holdings m. As interest rates decrease with capital taxes, we thus have that an increase in the capital tax leads to an increase in private consumption. As consumption is valued, this constitutes a positive externality, which leads to too low taxes, and thereby reinforces the tax-competition effect.

To understand the remaining term $H(q)V(c,r)\Gamma_g(\gamma, g) \, \hat{p}_t[m + (\pi + \rho)\hat{l}_\rho]$, note first that $(\pi + \rho)l(\rho, t, \pi)$ is the seignorage, in a symmetric equilibrium, of each and every national government. The existence of such revenue is the source of an horizontal externality, as national governments do not take into account the full effect of their tax choices on foreign CBs' revenues by affecting the world interest rate. In more detail, a decrease in the real interest rate decreases the gain on the part of the government, in terms of servicing liabilities, by switching from interest- to non-interest-bearing means of financing the first-period public good. Thus, an increase in the capital tax reduces seignorage, which is valued as a source of revenues for the provision of the second-period public good. This negative externality, which is captured by $H(q)V(c,r)\Gamma_g(\gamma, g)\hat{p}_t m < 0$, pushes towards too high taxes, *counteracting* the tax-competition effect. A decrease in the real interest rate affects also the demand for liquidity. Recall, however, from Section 2, that the effect of the real interest rate on demand for money is ambiguous. Thus, the net externality that arises from the existence of seignorage is of ambiguous direction. These two effects comprise what we refer to, hereafter, as the seignorage effect.

Our main concern is to identify conditions under which there is scope for a coordinated *decrease in capital taxes*. Whether taxes are too high depends on the balance of the seignorage, the debt and tax competition effects. Recall that $\hat{l}_\rho = \hat{m}_z + \hat{m}_y[\gamma + (1 + \rho)\hat{s}_\rho]$. Obviously, then, which effect dominates will depend on the elasticity of capital, the price- and income-elasticities of real money balances and the relative valuation of the second-period public good. Denote with $\hat{\varepsilon}_y$ the income-elasticity of the demand for liquidity, $\frac{y}{m}\hat{m}_y$, when policies are set, and with η the tax-elasticity of the demand for capital, $\eta \equiv -\frac{tk'}{k}$. Note also that at an interior solution with positive price of real money holdings, inflation is given by $\frac{\partial W(\vec{t}, \vec{\pi}, \vec{\gamma})}{\partial \pi_j} = 0$, which evaluated at the symmetric equilibrium is:

$$-H(q)V_c(c,r)\Gamma(\gamma, g)[(m - \gamma)\frac{\hat{p}_\pi}{n} + m] - H(q)V_r(c,r)\Gamma(\gamma, g)m +$$

$$H(q)V(c,r)\Gamma_g(\gamma, g)\{[tk' + m - \gamma + (\pi + \rho)\hat{l}_\rho]\frac{\hat{p}_\pi}{n} + m + (\pi + \rho)\hat{l}_\pi\} = 0.$$

So, the relative valuation of second-period public good depends, among others, on the interest-elasticity of money demand, the elasticity of capital and the inflation-elasticity of savings. Let

also $\hat{\varepsilon}_w^s = -\frac{w\hat{s}_w}{s}$ be the future-income-elasticity of savings. We, then, have:

Proposition: *A necessary and sufficient condition for capital taxes to be too high, given inflation and past public good provision, is that policies can be pre-committed upon and $\frac{\Gamma_g V - V_c \Gamma}{\Gamma_g V}$ $> \eta + \varepsilon_y \frac{(\pi+\rho)m}{y}[1 - \varepsilon_w^s \frac{s(1+\rho)}{w}].$*

Proof: Consider first discretionary policies. (19) then implies that W_t has the opposite sign of $tk' + (m-\gamma)(\Gamma_g V - V_c\Gamma)$. But from the first-order condition with respect to inflation we have that $\Gamma_g V - V_c\Gamma = V_c\Gamma > 0$. So, given also our assumption that governments do not run a surplus, i.e. $d = \gamma - m \geq 0$, we have that $W_t > 0$. Turn now to the case of pre-commitment. Eliminating m from (19) by using (17) results in $W_t = (n-1)\{k(V_c\Gamma - V\Gamma_g) - V\Gamma_g tk' - V\Gamma_g(\pi+\rho)l_t\}$. Using the fact that $l_t = -m_y[k - s_t(1+\rho)]$ and $s_t = -ks_w$, we have that W_t is proportional to $\eta - \frac{\Gamma_g V - V_c\Gamma}{\Gamma_g V} + \varepsilon_y \frac{(\pi+\rho)m}{y}[1 - \varepsilon_w^s \frac{s(1+\rho)}{w}]$. ∎

This Proposition emphasises that the net direction of capital tax externalities depends, among others, on whether governments can pre-commit, on the price elasticities of capital and money demand (the latter affects the relative valuation of public good), and on the income elasticity of money demand. Specifically, if policies are discretionary, the tax competition (net of debt) effect dominates the seignorage effect and taxes are too low. If, on the other hand, policies can be pre-committed upon, we have that, for given relative valuation of the public good, the less elastic capital is, the more likely is that capital taxes are too high.[30] Also, given $1 - \varepsilon_w^s \frac{s(1+\rho)}{w} = 1 + s_w(1+\rho) > 0$, we have, after noting that in equilibrium $y = k + f(k) - g + (\pi+\rho)m$ with $k + f(k) - g = c > 0$, that: the less sensitive to income money demand is, the more income-elastic savings are, the *lower* seignorage is, the lower public spending is, the higher the GDP is and the higher the ratio of savings income to non-capital income, the more likely is that capital taxes are too high.

To gain some insight on the implications of this Proposition, assume that regional governments can pre-commit. Let us also focus on a very simple case. Namely, suppose that savings do not depend on inflation, i.e. $s_\pi = 0$, and that money demand is relatively inelastic with respect to the money's real interest rate δ, for any given price of liquidity z. One can then very easily see, from the first-order condition with respect to the inflation tax, that

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[30]The above Proposition investigates only local welfare improvements, and abstains from a global comparison between equilibrium and Pareto efficient policies. The reason is that the presence of three policy instruments, capital tax, first-period public good and inflation, considerably complicates a global analysis.

$\frac{\Gamma_g V - V_c \Gamma}{\Gamma_g V} = \varepsilon_z + \frac{V_r \Gamma}{\Gamma_g V} > \varepsilon_z$, where ε_z is the price elasticity of the demand for liquidity, $-\frac{\pi+\rho}{m} m_z$. Using the condition that determines the demand for money, (7), and re-arranging we have that the inflation-policy rule becomes $\frac{V_c \Gamma}{\Gamma_g V} \frac{1+\rho}{1-\pi} = 1 - \varepsilon_z$. Hence, in equilibrium we have $\frac{V \Gamma_g - \Gamma V_c}{V \Gamma_g} = 1 - \frac{\Gamma V_c}{V \Gamma_g} = 1 - (1 - \varepsilon_z)\frac{1-\pi}{1+\rho}$. So, in the simple case we focus here, taxes are too low under monetary autonomy if $\eta + \varepsilon_y \frac{(\pi+\rho)m}{y}[1 - \varepsilon_w^s \frac{s(1+\rho)}{w}] > \frac{\pi+\rho}{1+\rho} + \varepsilon_z \frac{1-\pi}{1+\rho}$.

Importantly, this condition might hold in reality, despite the fact that seignorage in many developed countries is a very small proportion of GDP. Take, for instance, the example of United States used in Keen and Kotsogiannis (2002). Using an estimate of 0.25 for the elasticity of capital with respect to the user-cost of capital (by Chirinko et al. (1999)), and supposing a tax-inclusive tax rate $t/\rho = 0.2$ - which is in line with the calculation of the effective marginal tax by Chennells and Griffith (1997) - we can estimate the value of 0.04 for the tax-elasticity η. In addition, using an estimation of (cash-flow definition of) seignorage m as a proportion to GDP equal to 1%, total tax receipts as a proportion of GDP equal to 29,6% (from OECD statistics for the year 2003), and price of liquidity of 2% we can calculate $(\pi+\rho)m/y = 0.00028$. Furthermore, using an estimate of 1/2 for the share of capital income to non-capital income we have that $\frac{(1+\rho)s}{w} = 0.5$. Using also nominal interest rates of 3%, we have that $\frac{\pi+\rho}{1-\pi} = 0,03$ and capital taxes will be too high if $\{[0.04 + \varepsilon_y 0.00028[1 - \varepsilon_w^s(0.5)]]\}(1.03) - 0.03 < \varepsilon_z$. Notice that the left hand side is decreasing in the future-income elasticity of savings and increasing in the income-elasticity of money demand. Given that empirical studies have found interest elasticities between zero and 0.5 and income elasticities between 0.5 and 1, of money demand,[31] these calculations suggest that too high taxes in the presence of seignorage may not be a mere theoretical curiosum.[32]

5 Extensions

In this Section we discuss some of our assumptions. In particular, we investigate how W_t in (19) is affected by relaxing some of our earlier assumptions. By doing so, we thus examine how sensitive the direction and the size of the overall capital tax externality is to the particular

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[31]See, for instance, the survey by Goldfeld and Sichel (1990), and Walsh (2003) pp. 58 for reports of some more recent estimates.

[32]Note that $(1 + i)(1 - \pi) = 1 + \rho$ where i is the nominal interest rate. So $\rho + \pi = (1 - \pi)\, i = (1 + \rho)i\, /\, (1 + i)$ and $\varepsilon_z = [-(i\partial m)/(m\partial i)]\,(1 + i)$. Also, for small inflation and nominal interest rates we have $\rho + \pi \simeq i$.

assumptions we have deployed, like available taxes and endogeneity of factors of production.

We start with the case of taxable returns to the immobile factors at a rate $\theta > 0$. In this case the government's budget constraint becomes $g_j = t_j k_j + \theta w_j + (\pi + \rho)m_j - (1 + \rho)\gamma_j$, and disposable income decreases by θw_j. As the case of unrestricted lump-sum tax has been analysed in Section 3, we focus here on an environment where the lump-sum tax θ faces an upper-bound which is lower than its optimal unrestricted level. So, capital and money-holdings taxes are still used. Following similar steps to the ones in the previous Section one can then easily see that W_t, in (19), increases by $(1 - 1/n)\hat{p}_t \theta k H(V_c \Gamma - V \Gamma_g)$. This term represents the net externality that arises, due to taxation of the returns to the immobile factors, from the effect on disposable income (and hence private consumption) and rent tax revenues abroad of tax-induced changes in the real interest rate. To understand this term, note that the marginal effect on disposable income of an increase in price of capital, in a symmetric equilibrium, is $s - (1 - \theta)k = \gamma + \theta k > \gamma$. As interest rates decrease with the capital tax, we thus have that an increase in the capital tax decreases disposable income by more than $-\hat{p}_t \gamma$ as long as the returns to the immobile factors are taxed. As consumption is valued, we have that this constitutes a negative externality which leaves, all other things equal, taxes too high. Similarly, the marginal effect on public revenues from taxation of the returns to the immobile factors of a change in price of capital, in a symmetric equilibrium, is $-\theta k < 0$. As interest rates decrease with the capital tax, we have that an increase in the capital tax increases revenues from taxing the returns to the immobile factor. As revenues are valued, we have that this constitutes a positive externality, which leads, ceteris paribus, to under-taxation of capital. These two horizontal externalities that arise due to the taxation of returns to immobile factor have also been identified by Keen and Kotsogiannis (2002) in a model with no money. Clearly, the direction of the net horizontal externality that arises due to constrained taxation of immobile factors depends on the relative marginal valuation of private and public consumptions.

However, *the taxation of the returns to the immobile factors reinforces also the seignor-age effect*. This is a direct consequence of the fact that now a tax-induced decrease in the equilibrium real interest rate decreases further disposable income. So, taxation of returns to immobile factor makes money demand even less negatively responsive to the interest rate. In particular, now we have that in a symmetric equilibrium $\hat{l}_\rho = \hat{m}_z + \hat{m}_y[\gamma + \hat{s}_\rho(1 + \rho)] + \hat{m}_y \theta e > \hat{m}_z + \hat{m}_y[\gamma + \hat{s}_\rho(1 + \rho)]$.

Next, we consider the implications of the immobile factor being endogenous. In partic-

ular, assume that the production function is homogenous of degree one. Let, with a slight abuse of notation, f be the intensive form representation of this technology. Now k is the capital stock as a proportion of the immobile factor L; that is, capital is equal to kL. Referring, for brevity, to the endogenous immobile factor as labour, w is now the wage rate and θ is the labour income tax rate. Let also utility be $H(q)\Phi(\Lambda - L, c, m(1 - \pi))\Gamma(\gamma, g)$, where Λ is the time endowment, $\lambda = \Lambda - L$ is leisure and $\Phi_\lambda > 0$, $\Phi_{\lambda\lambda} < 0$. In this case, the wealth h_j is equal to $h_j = (1 + \rho)e + (1 - \theta)w_j\Lambda = h(\rho, \rho + t_j, \theta)$ and the budget constraint is $(\Lambda - L_j)(1 - \theta)w_j + (1 + \rho)q_j + c_j + m_j(\pi + \rho) = h_j$. Let $\omega_j \equiv (1 - \theta)w_j$ denote the after-tax-wage. Assuming that leisure is a normal good, that first-period consumption and leisure are gross substitutes and that money and leisure are gross substitutes,[33] standard consumer theory then tells us that labour supply in jurisdiction j is given by a function $L(\rho, \pi + \rho, h_j, \omega_j)$ with $L_\rho < 0$, $L_h < 0$, $L_z < 0$ and $L_\omega > 0$. Normalise units for clarity so that $\Lambda = 1$. Note that the effect on labour supply of changes in the net wage has the sign of $L_h + L_\omega$, which captures the balance of the usual income and substitution effects. That is, labour supply is upward sloping if and only if $L_h + L_\omega > 0$. Let us denote with $\tilde{L}_\rho$ the total effect on labour supply of a marginal increase in the real interest rate ρ, i.e. $\tilde{L}_\rho = L_\rho + L_z + L_h[e - (1 - \theta)k] - L_\omega(1 - \theta)k$, and with L_t the effect on labour supply of a marginal change in the capital tax, i.e. $L_t = -[L_h + L_\omega](1 - \theta)k$. Clearly, then, when labour supply is upward sloping we have that $\tilde{L}_\rho < 0$ and $L_t \leq 0$.

Following similar steps to the ones in the previous Section,[34] and after assuming, for expositional, and only, clarity, that in the non-cooperative equilibrium $L = 1$, one can easily see that our discussion above about the implications of taxing the returns to the (endogenous now) immobile factor are still valid. Relative to that case, then, endogeneity of labour and availability of a labour income tax imply that W_t has the additional term $(1 - 1/n)\hat{p}_t H(q)\Phi(1 - L, c, m(1 - \pi))[tk + \theta w]\tilde{L}_\rho > 0$. To understand this term, note that with endogenous labour an increase in capital taxes leads, through a decrease in the interest rate, to higher labour

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[33]The latter assumption can be motivated with reference to the role of money as means of reducing shopping time. A decrease in money holdings would lead to more time spent for shopping, and this would raise the marginal utility of leisure, i.e. $\Phi_{\lambda\delta} < 0$. See also Walsh (2003) pp. 65.

[34]Now in a symmetric equilibrium $L(\rho, \pi + \rho, h, (1 - \theta)w(k(\rho + t)))k(\rho + t) = s(\rho, t, \pi) - \gamma$. So, the interest rate now depends also on the income tax rate, and p_t in the main text denotes, with some abuse of notation, the change in the interest rate of the symmetric equilibrium due to a marginal change in the capital tax. Note that still $p_t < 0$.

supply and capital stock, and thereby higher, capital and labour income, tax revenues in the other jurisdictions (see also Bucovetsky and Wilson (1991)). So, the tax competition effect is reinforced.

However, now, changes in the labour supply affect also disposable income and thereby demand for money. To see the implications, note first that disposable income now is $y_j = (1+\rho)s_j + (1-\theta)w_j L_j$. Next, suppose, for expositional clarity, that utility $\Phi(1-L, c, m(1-\pi))$ is separable in leisure, i.e. $\Phi(1-L, c, m(1-\pi)) = \hat{\Phi}(1-L)V(c, m(1-\pi))\Gamma(g)$. It follows that money demand is still given by the function $m(\pi_j + \rho, y_j, 1 - \pi_j)$. However, we now have that $l_\rho = m_z + m_y[\theta e + \gamma + s_\rho(1+\rho)] + m_y(1-\theta)w\tilde{L}_\rho < m_z + m_y[\theta e + \gamma + s_\rho(1+\rho)]$. That is, endogeneity of labour leads, ceteris paribus, to too low taxes - relative to the case of the internationally immobile factor being exogenous and taxable at a rate θ; the reason is that with endogenous labour an increase in capital taxes leads, through a decrease in the interest rate, to higher labour supply and thereby, all other things equal, disposable income, money demand and seignorage in the other jurisdictions. So the seignorage effect is dampened.

With endogenous labour, one may also wonder what are the efficiency properties of an endogenous labour income tax θ. In fact, if tax authorities can choose freely income taxes, one can very easily see that an externality emerges. This externality works through the negative effect of income taxes on the interest rate ρ. Essentially, this externality is qualitatively similar to the net externality that emerges from the effect of capital taxes on the interest rate, which we have discussed above.

What is crucial for our results is that real money balances are increasing with disposable income and, for any given income, decreasing with the real interest rate ρ. These would also be the characteristics, in any equilibrium with positive nominal interest rate, of a demand for liquidity due to a cash-in-advance constraint $m_j(1-\pi_j) \geq c_j$. This is the most popular variant of liquidity constraints, requiring that money holdings must be at least as high as the value of purchases.[35] Thereby deploying a cash-in-advance model would not affect qualitatively the

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[35]If $\rho + \pi_j > 0$ then holding money is costly. If real money balances provide no utility, i.e. if $V_r = V_{cr} \equiv 0$, then the cash-in-advance constraint binds. It follows, then, from the budget constraint that $m_j = y_j/(1+\rho)$. After using the definition of disposable income, we can see that real money holdings are decreasing with both the real interest rate and the capital tax. Note, furthermore, that money holdings are independent of inflation. Introducing such dependence can be achieved by postulating that bonds are credit goods that can provide some liquidity (see, for instance, Lucas and Stokey, 1987). In this case, the cash-in-advance constraint becomes

main insights of our paper.

6   Conclusions

This paper shows that taxes on mobile capital may not be too low when governments have access to seignorage. Our explanation is based on a simple ingredient: capital taxes provide an externality by affecting the revenues of foreign central banks from issuing currency. This externality may lead, ceteris paribus, to too high national capital taxes. This additional effect, of capital taxes, may more than offset the usual effects of tax competition. In this case, and contrary to conventional wisdom, non-cooperative capital taxes will be too high.

In fact, we emphasise that the relative strength of the various effects depends on the interest-elasticity of the demands for capital and real money balances, on income-elasticity of money demand, on the extend to which countries exploit immobile factors, on the responsiveness of labour supply to changes in the interest rate, on the responsiveness of savings to changes in the future-income, on the level of seignorage and total tax receipts, and on whether policies are discretionary. Future research that incorporates, for instance, asymmetric regions or foreign ownership of the fixed production factor will improve our understanding of capital tax competition in the presence of seignorage.

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$(\xi b + m)(1 - \pi) \geq c$ where $\xi > 0$ is the degree of liquidity provided by non-monetary assets. If $\pi_j + \rho > 0$ and $\xi \leq 1$ then again the cash-in-advance constraint binds, and thereby $m_j = [y_j - \xi e (1 - \pi_j)] / (1 + \rho - \xi (1 - \pi_j))$, which is a decreasing function of inflation, capital tax and real interest rate.

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