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Why Do Most Countries Set High Tax Rates on Capital?

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Abstract:

We consider tax competition in a world with tax bases exhibiting different degrees of mobility, modeled as mobile and immobile capital. An agreement among countries not to give preferential treatment to mobile capital results in an equilibrium where mobile capital is nevertheless taxed relatively lightly. In particular, one or two of the smallest countries, measured by their stocks of immobile capital, choose relatively low tax rates, thereby attracting mobile capital away from the other countries, which are then left to set revenue maximizing taxes on their immobile capital. This conclusion holds regardless of whether countries choose their tax policies sequentially or simultaneously. In contrast, unrestricted competition for mobile capital results in the preferential treatment of mobile capital by all countries, without cross-country differences in the taxation of mobile capital. Nevertheless our main result is that the non-preferential regime generates larger global tax revenue, despite the sizable revenue loss from the emergence of low-tax countries. By extending the analysis to include cross-country differences in productivities, we are able to resurrect a case for preferential regimes, but only if the productivity differences are sufficiently large.

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1. Introduction

A theme running through the tax competition literature is that jurisdictions face incentives to compete for mobile capital by reducing their tax rates. As a result, tax competition leads to inefficiently low tax rates and public good provision when governments are welfarist, but may constrain the excessive size of government that act as Leviathans.¹ One might question the tax-reducing effects of tax competition when examining the effective average capital tax rates in the European Union for the year 1991, which we report in Table 1.² Indeed, note that most of the countries are distributed around an average of 32% – with some variance, possibly explained by differences in preferences for publicly provided goods – while on the other hand, a considerably lower tax rate of only 11% is in effect in Ireland.³ An interpretation of such facts is that Ireland was undercutting the other countries, while the rest seemed to act as if it was business as usual. Intuitively, if a country has a comparative advantage at lowering its tax rate to attract mobile capital, it will specialize in this activity. However, the rest of the countries will not attempt to attract mobile capital, and will instead focus on their immobile base to finance their expenditures.

These observations raise questions about the extent to which countries actively compete for capital in an increasingly integrated world economy. Despite increasing capital mobility, Hines (2005) presents evidence showing that in a group of 68 countries, corporate tax collections did not decline as a percentage of GDP between 1982 and 1999.⁴ He attributes this finding to a switch in tax burdens from mobile capital to immobile capital, along with an expansion of domestic tax bases. Such a switch could be brought about by the type of specialization

¹ See Wilson (1999) for a review of the tax competition literature, and Wilson (2005) for a recent analysis of competition with self-interested government officials.

² Effective average tax rates measure total taxes paid as a fraction of the relevant tax base. In the case of the average capital tax rates reported in Table 1, they include corporate tax collection as well as personal taxes on capital income. See Sørensen (2000) or Haufler (2001).

³ Similar patterns can be observed in the 1981 tax rates, except for the fact that Spain and Ireland both have very low tax rates.

⁴ Note however that for the US, corporate tax collections seem to have declined rapidly between 1960 and 1982. On this, see Auerbach (2005).

described above, but it could also signal the use of preferential tax regimes by individual countries, whereby mobile capital is taxed more lightly than immobile capital.

This view that the revenue-reducing effects of tax competition might be mitigated by the differential treatment of mobile and immobile tax bases is not universally shared by economists and policymakers. Recently, the OECD became interested in what it calls “harmful tax practices”. In OECD (1998), in the context of countries engaged in the taxation of mobile tax bases, two sorts of country behaviour are viewed as harmful: (a) To impose no or very low taxes on some bases; and (b) To have some preferential features in the tax system that allow part of a given base to escape taxation. For the second sort of behaviour, the preferential tax regimes often consist in the foreign-owned portion of a tax base being taxed at a lower rate than the domestic-owned portion, a behaviour which is also labeled “discrimination”.⁵

The theoretical literature on preferential versus non-preferential tax regimes is inconclusive. Janeba and Peters (1999) show that the elimination of preferential regimes leads to higher total levels of tax revenue. On the other hand, Keen (2001) reaches the opposite conclusion. They both analyze simultaneous-move Nash games in tax rates, but their models contain important differences. Janeba and Peters consider two countries that differ in their supplies of an immobile “domestic tax base,” whereas a second base is infinitely elastic with respect to differences in tax rates: it locates in the lowest-tax country. In contrast, Keen assumes that both countries are completely identical and have access to two tax bases that are partially-mobile to different degrees. Wilson (2005) observes, however, that if one of the tax bases in Keen’s paper were made infinitely elastic, as in Janeba and Peters, then a symmetric equilibrium in pure strategies would not exist.⁶

⁵ Note that some countries – e.g. Canada and the US – have signed mutually advantageous tax treaties which would be jeopardized if one or the other actor were to start discriminating. And the prohibition of the asymmetric treatment of foreign and domestic firms has been included in treaties in the EU and the OECD. Both the OECD and the EU are active in trying to reduce the extent of discrimination among their members. On this, see OECD (1998).

⁶ Janeba and Smart (2003) generalize both the Janeba-Peters and Keen results to more general settings. But they also must restrict the relevant elasticities to ensure the existence of equilibria in pure strategies. Wilson (2005) analyzes mixed strategies, but he considers only symmetric

In an effort to sort out these competing views, we first develop a model in which countries are first constrained to use a non-preferential regime which imposes the same tax rate on immobile and perfectly mobile capital. This leads to an equilibrium in which there is nevertheless differential taxation of mobile and immobile capital, not within individual countries, but rather because mobile capital locates in countries with low tax rates on all capital. Consistent with the EU case described above, a small number of countries act as “tax havens,” setting their tax rates at relatively low levels and thereby attracting large amounts of the mobile base, leaving the majority of countries to impose higher tax rates on their remaining (immobile) capital. This result suggests that another OECD initiative — to limit tax havens — complements their guidelines for limiting preferential treatment of mobile capital.⁷

When countries are allowed to individually levy different tax rates on immobile and mobile capital, tax havens do not emerge in our model, but tax competition for mobile capital intensifies, causing a large revenue loss in the form of lower tax rates on mobile capital. This comparison raises the intriguing question of whether it is preferable to bring about the differential treatment of mobile and immobile capital through the operation of tax havens in a non-preferential regime, or through preferential treatment without tax havens. We conclude that tax competition in the non-preferential regime leads to a lower aggregate loss in tax revenue, compared with tax competition in the preferential regime. Note, however, that revenue would be higher in the non-preferential regime if there were no tax havens.⁸

equilibria for identical countries, whereas the focus of the current paper is on the emergence of low-tax countries (tax havens).

⁷ In 2000 the OECD published a list of 35 countries called “non-cooperating tax havens,” giving them a year to enact fundamental reform of their tax systems and broaden the exchange of information with tax authorities or face economic sanctions. By 2005 almost all of the blacklisted tax havens had signed the OECD’s Memorandum of Understanding agreeing to transparency and exchange of information.

⁸ The term “tax haven” is being applied here to countries that offer low tax rates on real capital investments, rather than countries that facilitate income-shifting for the purpose of reducing taxable income in high-tax countries, independently of the location of physical investments. Slemrod and Wilson (2006) analyze tax competition in the latter setting and conclude that tax havens worsen the tax competition problem, resulting in lower levels of welfare.

We demonstrate that the superiority of the non-preferential regime in terms of tax revenue does not require assumptions about whether countries choose their tax rates simultaneously or sequentially. Thus, we do not need to justify a particular order of moves, though a case might be made for sequential-move games based on institutional constraints on the ability of countries to adjust tax rates quickly. Our assumption of a highly-mobile tax base precludes the existence of a simultaneous-move pure strategy equilibrium in the non-preferential-regime case, but we are still able to make comparisons by allowing countries to use mixed strategies. In addition, we find that all countries obtain at least the same expected tax revenue under the equilibrium for the sequential-move game as they do when the simultaneous-move game is played, with expected tax revenue higher for some countries when non-preferential treatment is required. As a result, we should not be surprised not to observe mixed strategies being played in practice.

Our analysis of non-preferential regimes also yields the finding that those countries that emerge as "tax havens" are the smallest ones. A similar result is found in the literature on asymmetric tax competition.⁹ The intuition is that smaller countries face a more elastic tax base, giving them incentives to set lower tax rates. In these papers, population is the measure used to describe a small country. But in Table 1, the correlation between the size – population – of a country and its tax rate is not clear. For example, some large countries like Germany and France have below average tax rates. In 1991, it is clearly the smallest country on the list – Ireland – that has the lowest tax rate. However, for 1981, both Ireland and Spain – which has an above average population size – are neck to neck for the lowest tax rate. Note further that if small countries have low tax rates, then they should become importers of capital, giving them relatively high capital/labor ratios, all else equal. But Table 1 also fails to support this prediction. For example, Ireland and Spain have capital/labour ratios below the EU average. In fact, this small set of European data reveals that the 1991 capital taxes and population have a negative correlation factor of -0.108. To summarize, the predictions

⁹ On asymmetric tax competition, see Bucovetsky (1991), Kanbur and Keen (1993), and Wilson (1991).

of the asymmetric tax competition literature do not appear to be realized in the real world equilibrium. Hines (2005) also comments on this lack of correlation between country size and tax rates, noting that it had largely disappeared by 1999.

In this paper, we introduce a different measure of country size. Countries are allowed to differ in their endowments of “immobile capital,” and it is the country with the lowest endowment that will choose the lowest tax rate. The intuition is simply that such a country has the least to lose by lowering its tax rate. Our framework therefore suggests that countries with low capital/labour ratios are more likely to set very low tax rates to attract mobile capital. Table 1 provides some evidence on this issue. While some high capital/labour ratio countries – e.g. Sweden and UK – do set high tax rates, it remains that the very low tax rates are found in countries with low capital/labour ratio – e.g. Ireland and Spain. The correlation between the 1991 tax rates and the capital/labor ratio is small but positive (at 0.169).

We later extend the analysis to allow countries to possess different productivities. For non-preferential regimes, an intriguing result is that for countries of equal size, it may be the one with the lowest productivity that will set the lowest tax rate. The same intuition applies: a country with a low productivity generates less tax revenues from its immobile tax base, and can consequently be more aggressive. This implies that mobile capital may have the tendency to inefficiently locate in less productive countries. Depending on the size of these productivity differences, this result could counteract the superior revenue-raising capabilities of non-preferential regimes. Table 1 also reports some data on the productivity of capital. Our explanation could account for the case of Ireland — low productivity and low tax rates, and could also help explain the low tax rate chosen by Spain in 1981. Our explanation is also supported by the fact that as Spain’s productivity rose in the eighties, so did its tax rate.¹⁰ Note that overall, the correlation between the 1981 tax rates and the 1983 capital productivity is strongly positive at 0.848.

¹⁰ Data on total factor productivity for Spain in the eighties can be found in Aiyar and Dalgaard (2001).

The plan of this paper is as follows. In the next section, we first describe the basic model, with countries of different sizes and no productivity differences. For the case where all countries choose their tax rates simultaneously, we show in Section 3 that there exists a simultaneous-move Nash equilibrium in which the smallest two countries play mixed strategies, with their tax rates undercutting the tax rates chosen by the remaining countries. Thus, these two countries obtain all of the mobile capital in equilibrium. We also analyze the case where all countries are identical, finding that there also exist equilibria where more than two countries play mixed strategies and obtain the mobile capital. In Section 4, we introduce a sequential-move game in which each country chooses its tax rate in a specific, randomly determined, order. As noted above, this game produces only a single tax haven and leads to higher global tax revenue than the simultaneous-move game. Section 5 contains the comparison between preferential and non-preferential regimes, along with extending the analysis to the case where countries possess different productivities. Section 6 concludes.

2. The Basic Model

Consider a world in which there are $J \geq 2$ countries indexed by j , $j = 1, \dots, J$. In each country, a representative citizen owns a constant return to scale technology $F(K) = \gamma K$, with $\gamma > 0$, that transforms capital into output. Capital owners can be local or mobile. In country j , there are N_j local capital owners, and they can only invest in their country. The world is also populated by M mobile capital owners who can invest in any of the J countries.¹¹ Capital owners, whether local or mobile, will also choose the size of their investment. Denote by I the investment choice made by all capital owners. If the N_j local capital owners and the M mobile capital owners invest I units of capital in j , then output in j is $F(N_j I + M I) = \gamma(N_j + M)I$. Thus, all capital is perfectly substitutable in production.

Capital bears a per unit tax of t_j in country j . Given the constant return to scale technology in each country, the net return of capital in country j is then simply $(\gamma - t_j)$. The owners of local

¹¹ Note that M (along with some other measure defined below) can be viewed as one of several dimensions of the size of investment.

capital can adjust to taxation by increasing or decreasing the size of their capital investment I . As for the owners of mobile capital, they too can adjust the size of their investment, but they can also adjust by choosing to invest in the country which offers them the highest net return.

The decision of a mobile capital owner as to where to invest is a simple one. The net return they obtain for each unit they invest in country j is $(\gamma - t_j)$, $j = 1, \dots, J$. Obviously, they will choose to invest in the country with the lowest tax rate, i.e. in country g if $\min\{t_j\}_{j=1}^J = t_g$. For now, we assume that if S countries have chosen the same lowest tax rate, then all capital owners invest in a country belonging to this set with probability $1/S$.¹² Thus, all of mobile capital always ends up in a single country (i.e. capital investment is bang-bang), and the other countries obtain nothing.¹³

The general timing of events in this world is as follows. First, countries choose their tax rates t_j , $j = 1, \dots, J$. Note that the tax rate in a given country applies to the two types of capital; discriminating is simply assumed to be impossible. Second, the owners of mobile capital select the country in which they will invest. Third and finally, owners of local and mobile capital choose the size of their investment. We will in turn consider the case where the countries play simultaneously, and that in which they play sequentially, so the first stage will later be decomposed into two sub-stages.

Owners of capital located in i (be it local or mobile) adjust the size of their investment to maximize their net consumption, which is simply the total return on their investment minus the cost of investment, which is given by $c(I)$, with $c' > 0$ and $c'' > 0$. Thus, for capital

¹² For heuristic reasons, we introduce a different breaking rule when the game is sequential.

¹³ Our results would obtain even if the assumption that all investments are bunched were relaxed. In our framework, we simply assume that the marginal product of capital is constant in a given country. Departing from the standard assumption of a declining marginal product of capital is frequent in the literature and simplifies our analysis. For papers which investigate the case in which capital tends to agglomerate because of an increasing marginal product, see Baldwin and Krugman (2004), Boadway, Cuff and Marceau (2004), Kind, Knarvik and Schjelderup (2000).

owners in j , the optimal size of their investment is:

$$I(t_j) = \arg \max_I (\gamma - t_j)I - c(I)$$

Of course, given the owners of mobile capital have decided to invest in j , the problem faced by the owners of local capital and those of mobile capital is identical. The first order condition characterizing the investment decision $I(t_j)$ is $(\gamma - t_j) - c'(I) = 0$. Using it, we easily get that $I'(t_j) = -1/c''(I) < 0$.

Given our focus on the revenue effects of tax competition, it is natural to assume that tax revenue plays a prominent role in government objectives. For simplicity, we assume that governments maximize revenue, but we later argue that our analysis holds more generally.¹⁴ Let m_j be an indicator function which takes a value of 1 if all mobile capital owners invest in country j , and a value of 0 if they have opted for any other country. Thus, tax revenue for country j are $t_j[N_j + Mm_j]I(t_j)$. We denote by $W^j(t, m)$ the tax revenue in country j when it has chosen tax rate t and when the indicator variable takes a value of m . Thus, we have:

$$W^j(t, 1) = t[N_j + M]I(t)$$

$$W^j(t, 0) = tN_jI(t)$$

For future use, denote by \hat{t} the tax rate which maximizes $W^j(t, 0)$ and $W^j(t, 1)$.¹⁵ Also note that both $W^j(t, 0) = W^j(t, 1) = 0$ at both $t = 0$ and some $\bar{t} > \hat{t}$. Finally, we define $\tilde{t}_j < \hat{t}$ as the tax rate solving $W^j(\tilde{t}_j, 1) = W^j(\hat{t}, 0)$, i.e. $\tilde{t}_j I(\tilde{t}_j)(M + N_j) = \hat{t} I(\hat{t})N_j$. This implies that each country has a specific \tilde{t}_j , that $\tilde{t}_j = 0$ when $N_j = 0$, and that \tilde{t}_j increases when N_j increases. The payoff functions of a given country are represented in Figure 1.

— FIGURE 1 —

¹⁴ Note that Janeba and Peters (1999), a paper which is close to ours, considers a world in which governments maximize tax revenues. Edwards and Keen (1996), Kanbur and Keen (1993), Keen (2001), or Wilson (2005) make this same assumption.

¹⁵ Note that given the present formulation of the model, \hat{t} maximizes both $W^j(t, 0)$ and $W^j(t, 1)$.

Irrespective of where mobile capital ends up locating, global tax revenue, summed across all countries, is maximized when tax rates are set at $t_j = \hat{t} \forall j, j = 1, \dots, J$.

3. Equilibrium of the Simultaneous Move Game

Consider first two special cases that are interesting and useful to understand.

In the first special case, there are no mobile capital owners, so $M = 0$. In this case, because there is no mobile factor over which the countries can fight, global tax revenue is maximized. In particular, governments set $t_j = \hat{t} \forall j, j = 1, \dots, J$, and each country obtains revenue $W^j(\hat{t}, 0), j = 1, \dots, J$.

As a second special case, suppose there is some mobile capital but no local capital, so $N_j = 0, j = 1, \dots, J$. In such a case, competition will drive tax rates to zero, and no revenue will be generated in equilibrium. This equilibrium is obviously the worse possible outcome in this world.

Note that the allocation in these two special cases does not depend on the timing of the game or on the relative size of the countries. Obviously, in the absence of mobile capital owners, the timing is irrelevant since the decisions made by the countries are essentially independent. As for the case where there is only mobile capital, the equilibrium features zero revenue regardless of the timing.

The general case we now want to consider is one in which there are J countries differing in their number of local capital owners. Without loss of generality, suppose that $N_1 \geq N_2 \geq \dots \geq N_J$. Three preliminary results turn out to be useful. The proofs of all lemmas and propositions are in the Appendix.

Lemma 1: *Country i never chooses a strategy $t_i > \hat{t}$.*

Note that \hat{t} is independent of the relative size of N_i and M , so that the same upper bound on strategies applies to the countries whether they are identical or different. Lemma 1 simply

states that it does not pay to play a tax rate above \hat{t} , because a lower tax rate can increase tax revenue and the likelihood of attracting mobile capital.

Lemma 2: *Country i never chooses a strategy $t_i < \tilde{t}_i$.*

For a given tax rate $t_i \in [\tilde{t}_i, \hat{t}]$, a country is better off when all mobile capital is invested in it. If the tax rate is lower than \tilde{t}_i , the country prefers to drop off the race and at least get $W^i(\hat{t}, 0)$. Recall that each country has a specific \tilde{t}_i and from Lemma 1 and Lemma 2, we now know that the relevant strategy space for country i is the subset of the real line $[\tilde{t}_i, \hat{t}]$.

Lemma 3: *The game has no pure strategy equilibrium.*

To understand why there is no pure strategy equilibrium, consider an example in which there are only two countries, 1 and 2, with $N_1 > N_2$, implying that $\tilde{t}_1 > \tilde{t}_2$. From this last inequality, it is clear that country 2 can always undercut country 1. Yet, it is impossible to find a pair of tax rates (t_1, t_2) which would constitute an equilibrium. For any $t_1 \in]\tilde{t}_1, \hat{t}[$, country 2's best response is to set t_2 to just undercut t_1 (to attract mobile capital). However, given such a t_2 , country 1's best response is also to undercut country 2. For $t_1 = \tilde{t}_1$, country 2's best response is again to set t_2 arbitrarily close to t_1 ($t_2 \in [\tilde{t}_2, \tilde{t}_1[$ is possible for that). However, given such a t_2 , country 1's best response is to play \hat{t} . Finally, for $t_1 = \hat{t}$, country 2's best response is to set t_2 arbitrarily close to \hat{t} . However, given such a $t_2 = \hat{t}$, country 1's best response is to undercut country 2. Thus, such a game has no pure strategy equilibrium. The argument just developed can be extended to a game with J countries.

We are now in a position to characterize the equilibrium of the game. Note that the framework developed in the current paper bears important similarities with that of an all-pay auction, i.e. an auction in which the highest bidder obtains the object for sale and, more importantly, in which all bidders pay their bid to the auctioneer. As it turns out, our results below have the flavor of those found in Baye *et al.* (1996), which characterizes the equilibria of all-pay auctions.¹⁶ We here present the case in which $N_1 > N_2 > \dots > N_J$ because the general case

¹⁶ Also note that the equilibrium of our game is reminiscent of those of the literature on duopoly

with $N_1 \geq N_2 \geq \dots \geq N_J$ is heavy in terms of notation. However, we present the case in which $N_1 = N_2 = \dots = N_J$ in Proposition 2.

Proposition 1: *In a world with J countries differing in their number of local capital owners (say $N_1 > N_2 > \dots > N_J$), the game has an asymmetric mixed strategy Nash equilibrium in which the equilibrium strategies are as follows.*

◇ Countries $j = 1, \dots, J - 2$: Play \hat{t} with probability $q_j = 1$.

◇ Country $J - 1$: With positive probability $q_{J-1} \in]0, 1[$, plays \hat{t} ; with positive probability $(1 - q_{J-1})$, plays the interval $[\tilde{t}_{J-1}, \hat{t}[$ with continuous probability distribution $H_{J-1}(t)$, with:

$$q_{J-1} = 1 - \left[\frac{W^J(\hat{t}, 1) - W^J(\tilde{t}_{J-1}, 1)}{W^J(\hat{t}, 1) - W^J(\hat{t}, 0)} \right]$$

$$H_{J-1}(t) = \frac{[W^J(t, 1) - W^J(\tilde{t}_{J-1}, 1)] [W^J(\hat{t}, 1) - W^J(\hat{t}, 0)]}{[W^J(t, 1) - W^J(t, 0)] [W^J(\hat{t}, 1) - W^J(\tilde{t}_{J-1}, 1)]}$$

◇ Country J : Plays the interval $[\tilde{t}_{J-1}, \hat{t}[$ with continuous probability distribution $H_J(t)$, with:

$$H_J(t) = \frac{W^{J-1}(t, 1) - W^{J-1}(\hat{t}, 0)}{W^{J-1}(t, 1) - W^{J-1}(t, 0)}$$

To understand Proposition 1, first note that because $N_1 > N_2 > \dots > N_{J-1} > N_J$, we have $0 < \tilde{t}_J < \tilde{t}_{J-1} < \dots < \tilde{t}_2 < \tilde{t}_1 < \hat{t}$. The ranking of the \tilde{t}_j s reflects the capacity of each country to undercut its opponents. This ranking has a straightforward implication: smaller countries can undercut larger countries. Indeed, the equilibrium described in Proposition 1 is one in which all countries but the two smallest ones ($J - 1$ and J) put themselves out of the race to attract mobile capital by taxing at rate \hat{t} with probability one. Country $J - 1$ puts some mass

pricing with capacity constraints, e.g. Levitan and Shubik (1972) and Kreps and Scheinkman (1983). Varian (1980) characterizes a similar equilibrium in his work on Bertrand price competition when some of the firms' customers are captive. Dasgupta and Maskin (1986) examine the existence of equilibrium in general discontinuous economic games. They find the conditions under which the equilibrium is a mixed strategy one similar to that obtained here.

(< 1) on \hat{t} , but it also randomizes over the interval $[\tilde{t}_{J-1}, \hat{t}]$. Finally, country J randomizes on $[\tilde{t}_{J-1}, \hat{t}]$, and it never plays \hat{t} . It follows from these strategies that mobile capital necessarily locates in country $J - 1$ or J (the only countries really participating in the tax competition), and that mobile capital is *never* taxed at the revenue-maximizing tax rate \hat{t} . Global revenue falls short of its maximum level because mobile capital precisely locates in the countries taxing capital at rates below \hat{t} . Of course, there is a revenue loss also because immobile capital is taxed at a rates below \hat{t} in J (for sure) and $J-1$ (with probability $1 - q_{J-1}$). In equilibrium, the expected payoff of all countries (except J) is equal to that they obtain when unable to attract mobile capital and taxing immobile capital at \hat{t} , i.e. the expected payoff for $j = 1, \dots, J - 1$ is $W^j(\tilde{t}_j, 1) = W^j(\hat{t}, 0)$. The sole country which does better is country J , the smallest one. It obtains and expected payoff of $W^J(\tilde{t}_{J-1}, 1) > W^J(\tilde{t}_J, 1) = W^J(\hat{t}, 0)$.

It is useful at this point to introduce a measure of the revenue loss from tax competition. There are of course several ways in which this could be done. We use what we think is a simple and natural measure, expected foregone tax revenue as a proportion of maximum tax revenue, and we denote it by Φ . Maximum revenue is obtained when all countries tax all capital at rate \hat{t} . Thus, maximum revenue is $M\hat{t}I(\hat{t}) + \sum_{i=1}^J W^i(\hat{t}, 0)$. Further, we know from our characterization of the equilibrium that all countries obtain, in expected terms, $W^j(\hat{t}, 0)$, except for country J , which obtains $W^J(\tilde{t}_{J-1}, 1)$. It follows that our measure Φ is given by:

$$\Phi = \frac{W^J(\hat{t}, 1) - W^J(\tilde{t}_{J-1}, 1)}{M\hat{t}I(\hat{t}) + \sum_{i=1}^J W^i(\hat{t}, 0)}$$

It should be clear that although only two countries are effectively competing for mobile capital, all mobile capital is taxed at rates below the revenue-maximizing level, so our measure of revenue loss, Φ , grows larger when M increases relative to the N_j s. Note also that if the size of the economy was doubled (e.g. M and all the N_j s are doubled), then the equilibrium tax rates would not change,¹⁷ but the absolute value of foregone tax revenues would double,

¹⁷ This is because the \tilde{t}_j s do not change when M and all the N_j s are doubled. It follows that the equilibrium remains the same.

leaving Φ unchanged. In next section, we will compare the revenue loss associated with tax competition under sequential play with that under simultaneous play.

The special case in which the J countries are identical yields some interesting insights.

Proposition 2: *If the J countries are identical ($N_j = N, \forall j$), the game has a large number of mixed strategy Nash equilibria. An equilibrium entails $0 \leq Q \leq J - 2$ countries playing \hat{t} with probability 1, and $J - Q$ countries playing $t \in [\tilde{t}, \hat{t}]$ according to the continuous cumulative function $H(t)$ and density function $h(t) = H'(t)$ on $[\tilde{t}, \hat{t}]$. For $t \in [\tilde{t}, \hat{t}]$, the mixed strategy $H(t)$ is given by:*

$$H(t) = 1 - \left[\frac{W(\hat{t}, 0) - W(t, 0)}{W(\hat{t}, 1) - W(t, 0)} \right]^{1/(J-Q-1)}$$

In equilibrium, the expected payoff of all countries is $W(\hat{t}, 0)$.

The following points are worth mentioning. First, if there are more than two countries, then a number of them can be playing the revenue-maximizing tax rate, \hat{t} , with probability one. Second, if there are only two countries, then both will play a lower tax rate with a probability approaching one (none will put mass on \hat{t}). Third, the equilibria are all equivalent in terms of revenue. Indeed, our measure of revenue loss, Φ , in the particular context of Proposition 2 yields:

$$\Phi = \frac{[W(\hat{t}, 1) - W(\hat{t}, 0)]}{M\hat{t}I(\hat{t}) + JW(\hat{t}, 0)}$$

All equilibria entail the same Φ as all countries obtain the same expected payoff $W(\hat{t}, 0)$. Note that since, in the context of Proposition 1, country J does better than $W^J(\hat{t}, 0)$, it follows that introducing some heterogeneity in the N_j 's reduces the level of revenue loss, as measured by Φ .

4. Equilibrium of the Sequential Move Game

We now examine the case in which countries play sequentially in the first stage of the overall game. Let \mathcal{J} be the set of countries, containing J countries, each indexed by j , as was the case above. Without loss of generality, suppose that $N_1 \geq N_2 \geq \dots \geq N_{J-1} \geq N_J$. From our

discussion above, it must then be that $\tilde{t}_1 \geq \tilde{t}_2 \geq \dots \geq \tilde{t}_{J-1} \geq \tilde{t}_J$. We assume that countries play sequentially, one after the other, but in an order that is independent of a country index j . It is possible to envision that before the countries play, Nature chooses with probability $1/J!$ an order of play among the $J!$ possible orders of play.

Before going further, it is useful to re-formulate our tie breaking rule for the case in which S countries have chosen the same lowest tax rate. Our assumption is that in such a case, all mobile capital M locates in the country with the largest index j . For example, if countries 2, 3, and 7 have set the lowest tax rate, then M locates in country 7. Such an assumption reflects the fact that because \tilde{t}_j is lower (not larger) for a higher index j (because it has a smaller N_j), the country with the highest index is that which could ultimately undercut every other countries.

In this sequential game, Lemmas 1 and 2 still hold, so for each country, equilibrium strategies must belong to the real line $[\tilde{t}_j, \hat{t}]$. Let a_j , $j = 1, \dots, J - 1$, be an indicator function which takes a value of 1 if country j chooses its tax rate after country J , and a value of 0 if it chooses it before. We denote by $\mathcal{A} \subset \mathcal{J}$ the set of countries who choose their tax rate after J : $\mathcal{A} = \{j \in \mathcal{J} | a_j = 1\}$. The following can be obtained.

Proposition 3: *If $\tilde{t}_J = \min\{\tilde{t}_j, j \in \mathcal{J}\}$, then the subgame perfect equilibrium of the tax competition game is a strategy profile (t_1^*, \dots, t_J^*) in which all countries play the revenue-maximizing tax rate ($t_j^* = \hat{t}$, $\forall j \neq J$), except for country J , which plays $t_J^* = \min\{\tilde{t}_k | k \in \mathcal{A}\}$.*

Thus, in all equilibria, mobile capital locates in country J , the one which can undercut every other country. The presence of smallest country J disciplines all the larger countries, making it useless for them to enter into tax competition and inducing them to maximize the revenue yield of the immobile base. But the tax rates the smallest country must play to attract mobile capital depends on the order of moves. The worse case scenario occurs when country $J - 1$ plays after country J ($J - 1 \in \mathcal{A}$). In this case, of course, $t_J^* = \tilde{t}_{J-1}$, and so t_J^* may be significantly smaller than \hat{t} . The revenue loss stemming from the under-taxation of capital

may therefore be quite large. On the other hand, the best-case scenario occurs when country J plays last ($\mathcal{A} = \emptyset$). In such a case, $t_J^* = \hat{t}$, so global tax revenue is maximized.

Clearly, the nature of the revenue loss in the sequential game is the same as that in the simultaneous game. Our results can therefore be viewed as being robust to changes in the timing of the game. However, there is only one country taxing capital below \hat{t} in the sequential game, and two in the simultaneous game. Also note that in the sequential game, the equilibrium outcome is uncertain *ex ante* because of the uncertainty regarding the order of play, not because the countries play mixed strategies.

It turns out that calculating the appropriate measure of revenue loss in the sequential game in the most general case of J countries is fairly involved. However, we know that in this sequential game, all countries obtain $W^j(\hat{t}, 0)$ for all order of moves, except for J which, in the worse case scenario, when country $J - 1$ plays after country J , obtains a payoff of $W^J(\tilde{t}_{J-1}, 1)$, and which does better for any other scenario in which country $J - 1$ plays before country J . Using our loss measure, Φ , we can immediately recognize two points: (a) The level of loss in the worse case scenario of the sequential game is equal to that in the overall simultaneous game; (b) This level of loss is less than that of the overall simultaneous game in any other scenario of the sequential game. Since the worse case scenario occurs with a probability less than one in the sequential game, it follows from this that there is less revenue loss in the sequential game than in the simultaneous game, a result which is intuitive.

5. Discussion

5.1 Varying Productivities

As an extension to our analysis, we now want to examine the case in which the productivity of investment varies across countries. Thus, suppose that the technology in each country is given by $F_j(K) = \gamma_j K$, with $\gamma_j > 0$ being possibly different across countries. Recall from above that the countries have been indexed by j so that $N_1 \geq N_2 \geq \dots \geq N_J$. Suppose that

the ordering of the γ_j is independent of the index j . Of particular interest to us is the country with the largest γ_j . Let country g be this country: $\max\{\gamma_i\}_{i=1}^J = \gamma_g$.

In this context, full efficiency requires that all countries tax at rate \hat{t}_j (which now differs for different countries) and that mobile capital locates in the most productive country, i.e. in country g .

Consider the case of a sequential move game. From what was shown in Section 4, it should be clear that whatever the order of moves, mobile capital will locate in the country with the largest per unit return $\gamma_j - \tilde{t}_j$ that a country can offer. It follows that capital will locate inefficiently if $\max_j\{\gamma_j - \tilde{t}_j\}_{j=1}^J \neq g$.

To see how this can happen, let $\Delta_{gj} = \gamma_g - \gamma_j \geq 0$ be the difference in productivity between the most productive country g and any other country j . Note that countries never set a negative tax rate ($t_j \geq 0$) otherwise their payoff would be negative. It follows that if a country is so unproductive that $\Delta_{gj} > \tilde{t}_g$, then this country will never be able to attract mobile capital at positive tax rate t_j . This is reminiscent of the analysis of Cai and Treisman (2005) in which countries of too low productivity are simply unable to compete for mobile capital. Thus, we focus on countries that are sufficiently productive and for which $\Delta_{gj} \leq \tilde{t}_g$. Let $\mathcal{J}' \subseteq \mathcal{J}$ be the set of such countries. Now recall that the smaller the N_j of a country, the lower the smallest tax rate \tilde{t}_j it can offer. It should therefore be clear that some countries belonging to \mathcal{J}' , despite being less productive than country g , may be small enough to attract mobile capital. Indeed, let \bar{N}_{gj} , $j \in \mathcal{J}'$, $j \neq g$, be the solution to the following implicit equation:

$$\hat{t}_g \frac{N_g}{N_g + M} \frac{I(\gamma_g - \hat{t}_g)}{I(\gamma_g - \tilde{t}_g)} - \hat{t}_j \frac{\bar{N}_{gj}}{\bar{N}_{gj} + M} \frac{I(\gamma_j - \hat{t}_j)}{I(\gamma_j - \tilde{t}_j)} - \Delta_{gj} = 0$$

It can then be shown that if $\exists j \in \mathcal{J}'$, $j \neq g | N_j < \bar{N}_{gj}$, then there is a country that is small enough to attract mobile capital despite being less productive than country g . In such a case, all countries tax choose their revenue-maximizing tax rate, \hat{t}_j (including country g), except the country in which mobile capital ends up locating. Thus, there is now not only the revenue

loss from taxing mobile capital at too low a rate, but also the potential inefficiency from capital possibly ending up locating in a country where it is not the most productive.

To summarize, the presence of small and less productive countries generates two effects. On the one hand, small and less productive countries discipline productive and large countries and induce them to maximize the revenue yield of their immobile tax bases. On the other hand, these small and less productive countries, by taxing capital at lower tax rates, may end up with a disproportionately large share (all of it in our analysis) of mobile capital because they are the ones who have less to lose from low taxes.

5.2 Preferential versus Non-Preferential Regimes

We now turn to a comparison of bilateral preferential regimes – i.e. regimes in which competing countries can set different tax rates on bases of differing mobility – with bilateral non-preferential regimes – i.e. regimes in which tax rates are constrained to be the same on all bases. The main advantage of a preferential regime resides in the fact that governments can avoid losing tax revenue on immobile tax bases by setting an appropriately high tax rate on them, while competing more aggressively on the more mobile ones. On the other hand, a non-preferential regime has the advantage of reducing competition on the mobile tax bases by tying them to the more immobile ones. In other words, a non-preferential regime makes it more costly for governments to lower their tax rates and so reduces harmful tax competition. Depending on the environment, one or the other regime may be desirable. Janeba and Peters (1999), in an environment entailing one perfectly mobile base and one perfectly immobile base, show that a non-preferential regime dominates a preferential regime. On the other hand, Keen (2001) obtains the opposite result when two bases are at least partially mobile. Wilson (2005) generalizes and attempts to reconcile these results within a unified framework.

It turns out that the framework developed in this paper can be used to contribute to this literature. We focus on the simple case in which one tax base is perfectly mobile and the other one is perfectly immobile. Since the equilibrium properties depend on whether countries set

their tax rates simultaneously or sequentially, we have to study each case in turn.

In the case of a simultaneous game, the non-preferential regime equilibrium tax rates are the outcome of a mixed strategy Nash equilibrium in which countries choose their tax rates in the manner stated in Proposition 1. In equilibrium, the expected tax revenue of each country is given by $W^j(\hat{t}, 0)$ (the same amount they would obtain by maximizing tax revenue from their immobile base only) except for smallest country J which does better, obtaining $W^J(\tilde{t}_{J-1}, 1) > W^J(\hat{t}, 0)$. In the case of a preferential regime, the characterization of the equilibrium is a lot simpler. Since tax rates on mobile and immobile capital are disconnected, our framework can be viewed as a simple first-price auction¹⁸. Thus, each country sets the revenue maximizing tax rate \hat{t} on its immobile base, and competition drives the tax rate on the mobile base to zero. Tax revenue in that case is given by $W^j(\hat{t}, 0)$ for all countries. It follows that in the case of a simultaneous game, a non-preferential regime dominates a preferential one since at least one country (country J) does better in the non-preferential one.

For the case of a sequential game, Proposition 3 establishes that in a non-preferential regime, all countries obtain $W^j(\hat{t}, 0)$ except for country J which obtains at least $W^J(\tilde{t}_{J-1}) \geq W^J(\hat{t}, 0)$ (with a strict inequality if $N_J > N_{J-1}$) and even better in a potentially large number of order of moves. The analysis of the preferential regime in the sequential game is identical to that in the simultaneous case. All countries set a tax rate \hat{t} on immobile capital, but for the mobile base, intense competition implies that the only subgame perfect equilibrium is for all countries to set their tax rate at zero. The expected payoff for all countries is therefore $W^j(\hat{t}, 0)$. Thus, because at least one country (country J) does better in the non-preferential regime, we again conclude that a non-preferential regime dominates a preferential one.

But there are also, within our framework, arguments in favour of preferential regimes. Clearly, since tax rates on mobile capital are driven down to zero in a preferential regime, the location decision of mobile capital owners is unaffected by tax considerations and it must then be

¹⁸ Recall that in the case of a non-preferential regime, in which tax rates are tied, our framework can be interpreted as an all-pay auction.

that mobile capital will locate in the most productive country. Recall from the previous Subsection that mobile capital could locate inefficiently in a non-preferential regime. It follows from this that non-preferential regimes are better at reducing the under-taxation of capital, but that preferential regimes are better at eliminating the inefficiency associated with the wrong location of mobile capital.

6. Conclusion

The current analysis could be extended in a few directions. First, we could assume that governments care about new investment not only because of the resulting rise in tax revenue, but also because of various external benefits such as employment gains in desirable occupations. Keen (2001) discusses such an extension in his analysis of preferential and non-preferential regimes, showing that his analysis can be generalized to encompass these additional benefits. Similarly, we may amend the objective function to read

$$W^j(t, 1) = (t + b)[N_j + M]I(t)$$

$$W^j(t, 0) = (t + b)N_j I(t),$$

where b represents the external benefit per unit of investment. This extension reduces the tax rate that is optimal for a country in the absence of mobile capital: countries no longer wish to maximize revenue, because the investment loss resulting from a marginal increase in the tax rate now not only lowers the tax base, but also reduces the external benefits associated with investment. But the previous analysis goes through with \hat{t} now redefined in this manner. In particular, countries other than the two smallest decide not to compete for capital and instead set their tax rates equal to this \hat{t} (Proposition 1), and the other results are similarly extended.

Alternatively, the objective function may be specified as a weighted sum of tax revenue and the producers' surplus received by the suppliers of capital to a region. This extension recognizes that higher tax rates harm capital owners by reducing their income from capital. Once again, the analysis goes through with \hat{t} reduced below its revenue-maximizing level to reflect this

harm. Presumably, the weight given to producers' surplus would reflect the political influence of capital owners, perhaps through lobbying activities. A more complex extension would be to allow the benefits of additional capital to differ between mobile and immobile capital. This asymmetry complicates the calculation of mixed strategies and is therefore left to future research.

Two other extensions appear to us as likely to generate interesting results. The first one would be to introduce labour and political economy considerations in the analysis. Suppose that workers in each country benefit from the presence of productive capital because of the associated larger output and wages, but also because capital is taxed to finance the provision of a public good. Then, if capital is highly mobile and unevenly owned by the workers of various countries, then the choice of tax rates on capital in a given country will be driven by strategic international considerations — as in the current paper, but also by the distribution of capital ownership within the country.

A second extension of the current analysis would be to use the framework of Section 4 as the within-period game of a multi-period dynamic game. To simplify, assume that both investors and governments are myopic. Also assume that the countries have the same productivity, but that they differ in terms of their number of local capital owners. Further, suppose that M_t new mobile investors are born each period and that the location decision they make at that time is irreversible – in effect, mobile investors locate and transform themselves into local capital investors. Hence, suppose that at time t , the countries have local capital $(N_{1,t}, \dots, N_{\ell,t}, \dots, N_{J,t})$. Then, from our previous analysis, and whatever the order of moves within period t , if country ℓ is that with the smallest amount of local capital investors, capital investors M_t then end up locating in country ℓ at time t . Assuming investors are infinitely-lived, it follows that at time $t + 1$, the countries will have local capital investors $(N_{1,t+1} = N_{1,t}, \dots, N_{\ell,t+1} = N_{\ell,t} + M_t, \dots, N_{J,t+1} = N_{J,t})$. Of course, it will again be the country with the smallest number of local capital investors that will attract mobile capital investors M_{t+1} . If this process continues, the smaller countries will become larger – while the

large ones will stagnate – and all countries will evolve to be approximately of the same size.¹⁹ Thus, the environment considered in this paper can generate convergence in the amount of capital located in all countries. However, such a convergence does not seem to be happening in the real world – e.g. see Table 1. We speculate that if investors and/or governments were forward-looking – instead of being myopic – then convergence would not necessarily obtain. These extensions of the current paper will be examined in future work.

¹⁹ The difference between the size of the largest country and that of the smallest of course depends on the size of the elements of the sequence $\{M_t, M_{t+1}, \dots\}$.

7. Appendix: Proofs

Proof of Lemma 1: For any $t'_i > \hat{t}$, there exists a $t''_i < \hat{t}$ such that $W^i(t''_i, m) = W^i(t'_i, m)$, for $m \in \{0, 1\}$. Of course, since under t''_i , the country is more likely to attract the mobile capital, it will always prefer to play t''_i . QED.

Proof of Lemma 2: If a country plays $t_i < \tilde{t}_i$ and all the mobile capital locates on its territory, it will get a payoff which is less than it gets when it taxes at rate \hat{t} and no mobile capital locates on its territory: $W^i(t_i < \tilde{t}_i, 1) < W^i(\hat{t}, 0)$. QED.

Proof of Lemma 3: (A) We first study the case of two identical countries. For $N_i = N_j$, we first show that there is no symmetric ($t_i = t_j$) pure strategy Nash equilibrium and then show that there is no asymmetric ($t_i > t_j$) pure strategy Nash equilibrium.

(i) There is no symmetric ($t_i = t_j$) pure strategy Nash equilibrium.

Consider a strategy profile (t, t) , with $t \in [\tilde{t}, \hat{t}]$ (from Lemma 1 and Lemma 2).

If $t > \tilde{t}$, then the payoff of each country is $W^1 = W^2 = \frac{1}{2}W(t, 1) + \frac{1}{2}W(t, 0)$. Clearly, this cannot be an equilibrium as any country, say 1, has an incentive to deviate to $t'_1 = t - \varepsilon \geq \tilde{t}$, causing all the capital to locate in 1, and ensuring itself a payoff $W^{1'} = W(t - \varepsilon, 1) > W^1$.

If $t = \tilde{t}$, then the payoff of each country is $W^1 = W^2 = \frac{1}{2}W(\tilde{t}, 1) + \frac{1}{2}W(\tilde{t}, 0)$. Clearly, this cannot be an equilibrium as any country, say 1, has an incentive to deviate to $t'_1 = \hat{t}$, ensuring itself a payoff $W^{1'} = W(\hat{t}, 0) > W^1$.

(ii) There is no asymmetric ($t_i > t_j$) pure strategy Nash equilibrium.

Consider any strategy profile (t_1, t_2) , with $\hat{t} \geq t_1 > t_2 \geq \tilde{t}$.

If $\hat{t} \geq t_1 > t_2 > \tilde{t}$, then $W^1 = W(t_1, 0)$ and 1 has an incentive to deviate to $t'_1 = t_2 - \varepsilon > \tilde{t}$ to obtain $W^{1'} = W(t_2 - \varepsilon, 1) > W^1$.

If $\hat{t} > t_1 > t_2 = \tilde{t}$, then $W^1 = W(t_1, 0)$ and 1 has an incentive to deviate to $t'_1 = \hat{t}$ to obtain $W^{1'} = W(\hat{t}, 0) > W^1$.

If $\hat{t} = t_1 > t_2 = \tilde{t}$, then $W^2 = W(\tilde{t}, 1)$ and 2 has an incentive to deviate to $t'_2 = \hat{t} - \varepsilon > \tilde{t}$ to obtain $W^{2'} = W(\hat{t} - \varepsilon, 1) > W^2$.

This completes part (A) of the proof.

(B) We now turn to the case in which there are two countries with $N_i > N_j$.

From above, we know that $\tilde{t}_i > \tilde{t}_j$. As Lemma 1 and Lemma 2 apply when $N_i > N_j$, it follows that the strategies of the countries must belong to the following intervals: $t_i \in [\tilde{t}_i, \hat{t}]$ and $t_j \in [\tilde{t}_j, \hat{t}]$.

We first show that there is no symmetric ($t_i = t_j$) pure strategy Nash equilibrium and then show that there is no asymmetric ($t_i \neq t_j$) pure strategy Nash equilibrium.

(i) There is no symmetric ($t_i = t_j$) pure strategy Nash equilibrium.

Since $\tilde{t}_j < \tilde{t}_i < \hat{t}$, a symmetric equilibrium is a pair (t, t) such that $t \in [\tilde{t}_i, \hat{t}]$. Consider such a strategy profile (t, t) .

If $t > \tilde{t}_i$, then the payoff of country i is $W^i = \frac{1}{2}W^i(t, 1) + \frac{1}{2}W^i(t, 0)$ and that of j is $W^j = \frac{1}{2}W^j(t, 1) + \frac{1}{2}W^j(t, 0)$. Clearly, this cannot be an equilibrium as any country, say i , has an incentive to deviate to $t'_i = t - \varepsilon \geq \tilde{t}_i$, causing all the capital to locate in i , and ensuring itself a payoff $W^{i'} = W^i(t - \varepsilon, 1) > W^i$.

If $t = \tilde{t}_i$, then the payoff of country i is $W^i = \frac{1}{2}W^i(\tilde{t}_i, 1) + \frac{1}{2}W^i(\tilde{t}_i, 0)$ and that of j is $W^j = \frac{1}{2}W^j(\tilde{t}_i, 1) + \frac{1}{2}W^j(\tilde{t}_i, 0)$. Clearly, this cannot be an equilibrium as i has an incentive to deviate to $t'_i = \hat{t}$ ensuring itself a payoff $W^{i'} = W^i(\hat{t}, 0) > W^i$.

(ii) There is no asymmetric ($t_i \neq t_j$) pure strategy Nash equilibrium.

Without loss of generality, assume that $N_1 > N_2$ so that $\tilde{t}_2 < \tilde{t}_1 < \hat{t}$.

Consider a strategy profile (t_1, t_2) with $\tilde{t}_1 \leq t_1 < t_2 \leq \hat{t}$. Given those strategies, $W^1 = W^1(t_1, 1)$ and $W^2 = W^2(t_2, 0)$. Then, 2 has an incentive to deviate to $t'_2 = t_1 - \varepsilon$ to obtain $W^{2'} = W^2(t_1 - \varepsilon, 1) > W^2$.

Consider a strategy profile (t_1, t_2) with $\tilde{t}_2 < \tilde{t}_1 < t_2 < t_1 \leq \hat{t}$. Given those strategies, $W^1 = W^1(t_1, 0)$ and $W^2 = W^2(t_2, 1)$. Then, 1 has an incentive to deviate to $t'_1 = t_2 - \varepsilon$ to obtain $W^{1'} = W^1(t_2 - \varepsilon, 1) > W^1$.

Consider a strategy profile (t_1, t_2) with $\tilde{t}_2 \leq t_2 \leq \tilde{t}_1 < t_1 < \hat{t}$. Given those strategies, $W^1 = W^1(t_1, 0)$ and 1 has an incentive to deviate to $t'_1 = \hat{t}$ to obtain $W^{1'} = W^1(\hat{t}, 0) > W^1$.

Consider a strategy profile (t_1, t_2) with $\tilde{t}_2 \leq t_2 < \tilde{t}_1 \leq t_1 < \hat{t}$. Given those strategies, $W^1 = W^1(t_1, 0)$ and 1 has an incentive to deviate to $t'_1 = \hat{t}$ to obtain $W^{1'} = W^1(\hat{t}, 0) > W^1$.

Consider a strategy profile (t_1, t_2) with $\tilde{t}_2 \leq t_2 \leq \tilde{t}_1 < t_1 = \hat{t}$. Given those strategies, $W^2 = W^2(t_2, 1)$ and 2 has an incentive to deviate to $t'_2 = \hat{t} - \varepsilon$ to obtain $W^{2'} = W^2(\hat{t} - \varepsilon, 1) > W^2$ for ε small.

This completes part (B) of the proof.

(C) The generalization of (A) and (B) to the case of J countries with $N_1 \geq N_2 \geq \dots \geq N_J$ is tedious but straightforward.

This completes the proof. QED.

Proof of Proposition 1: Because $N_1 > N_2 > \dots > N_{J-1} > N_J$, we have $0 < \tilde{t}_J < \tilde{t}_{J-1} < \dots < \tilde{t}_2 < \tilde{t}_1 < \hat{t}$. The equilibrium strategies are as follows.

◇ Countries $j = 1, \dots, J - 2$: Play \hat{t} with probability $q_j = 1$.

◇ Country $J - 1$: With positive probability $q_{J-1} \in]0, 1[$, plays \hat{t} ; with positive probability $(1 - q_{J-1})$, plays the interval $[\tilde{t}_{J-1}, \hat{t}[$ with continuous probability distribution $H_{J-1}(t)$, with:

$$q_{J-1} = 1 - \left[\frac{W^J(\hat{t}, 1) - W^J(\tilde{t}_{J-1}, 1)}{W^J(\hat{t}, 1) - W^J(\hat{t}, 0)} \right]$$

$$H_{J-1}(t) = \frac{[W^J(t, 1) - W^J(\tilde{t}_{J-1}, 1)] [W^J(\hat{t}, 1) - W^J(\hat{t}, 0)]}{[W^J(t, 1) - W^J(t, 0)] [W^J(\hat{t}, 1) - W^J(\tilde{t}_{J-1}, 1)]}$$

- Country J : Plays the interval $[\tilde{t}_{J-1}, \hat{t}]$ with continuous probability distribution $H_J(t)$, with:

$$H_J(t) = \frac{W^{J-1}(t, 1) - W^{J-1}(\hat{t}, 0)}{W^{J-1}(t, 1) - W^{J-1}(t, 0)}$$

Thus, all countries except the two smallest ones ($J - 1$ and J) put themselves out of the race to attract mobile capital by taxing at rate \hat{t} with probability one. Mobile capital locates in country $J - 1$ or J .

In equilibrium, the expected payoff of all countries (except J) is equal to that they obtain when unable to attract mobile capital and taxing immobile capital at the revenue-maximizing tax rate, \hat{t} , i.e. the expected payoff for $j = 1, \dots, J - 1$ is $W^j(\tilde{t}_j, 1) = W^j(\hat{t}, 0)$. The sole country which does better is country J , the smallest one. It obtains an expected payoff of $W^J(\tilde{t}_{J-1}, 1) > W^J(\tilde{t}_J, 1) = W^J(\hat{t}, 0)$.

The proof that these strategies constitute an equilibrium is simply that given the other countries' strategy, Country j has no desire to deviate.

To determine q_{J-1} , $H_{J-1}(t)$, and $H_J(t)$, the procedure is as follows.

(A) Consider first the payoffs for country J for some of its pure strategies, given the strategy of country $J - 1$. Note that since the other countries always play \hat{t} , they have no impact on the payoff of country J .

A.1 When country J plays \tilde{t}_{J-1} , it obtains $W^J(\tilde{t}_{J-1}, 1)$:

$$q_{J-1}W^J(\tilde{t}_{J-1}, 1) + (1 - q_{J-1})[H_{J-1}(\tilde{t}_{J-1})W^J(\tilde{t}_{J-1}, 0) + (1 - H_{J-1}(\tilde{t}_{J-1}))W^J(\tilde{t}_{J-1}, 1)]$$

$$= W^J(\tilde{t}_{J-1}, 1)$$

A.2 For any $t \in]\tilde{t}_{J-1}, \hat{t}[$, country J obtains:

$$q_{J-1}W^J(t, 1) + (1 - q_{J-1})[H_{J-1}(t)W^J(t, 0) + (1 - H_{J-1}(t))W^J(t, 1)]$$

Imposing that this last expression equals $W^J(\tilde{t}_{J-1}, 1)$ to ensure that all pure strategies yield the same payoff, we can solve for $H_{J-1}(t)$:

$$H_{J-1}(t) = \frac{W^J(t, 1) - W^J(\tilde{t}_{J-1}, 1)}{(1 - q_{J-1})[W^J(t, 1) - W^J(t, 0)]}$$

It is easily checked that $H_{J-1}(\tilde{t}_{J-1}) = 0$. Using the fact that $\lim_{t \rightarrow \hat{t}} H_{J-1}(t) = 1$, we can solve for q_{J-1} and obtain:

$$q_{J-1} = 1 - \left[\frac{W^J(\hat{t}, 1) - W^J(\tilde{t}_{J-1}, 1)}{W^J(\hat{t}, 1) - W^J(\hat{t}, 0)} \right]$$

Substituting this value of q_{J-1} in $H_{J-1}(t)$ above we get the following:

$$H_{J-1}(t) = \frac{[W^J(t, 1) - W^J(\tilde{t}_{J-1}, 1)] [W^J(\hat{t}, 1) - W^J(\hat{t}, 0)]}{[W^J(t, 1) - W^J(t, 0)] [W^J(\hat{t}, 1) - W^J(\tilde{t}_{J-1}, 1)]}$$

And it is easily checked that $H_{J-1}(\tilde{t}_{J-1}) = 0$ and $\lim_{t \rightarrow \hat{t}} H_{J-1}(t) = 1$.

(B) Consider now the payoffs for country $J - 1$ for any of its pure strategies given the strategy of country J and that of the other countries.

For any $t \in]\tilde{t}_{J-1}, \hat{t}[$, country $J - 1$ obtains:

$$H_J(t)W^{J-1}(t, 0) + (1 - H_J(t))W^{J-1}(t, 1)$$

In equilibrium, this last expression must equal $W^{J-1}(\hat{t}, 0)$ and we can solve for $H_J(t)$:

$$H_J(t) = \frac{W^{J-1}(t, 1) - W^{J-1}(\hat{t}, 0)}{W^{J-1}(t, 1) - W^{J-1}(t, 0)}$$

Note that given $H_J(t)$, country $J - 1$ is indifferent between all its pure strategies (it always obtains $W^{J-1}(\hat{t}, 0)$). In particular, country $J - 1$ obtains the same expected payoff for any

value of q_{J-1} . Country $J - 1$ is therefore indifferent between putting and not putting some mass on \hat{t} . In the equilibrium constructed here, country $J - 1$ does put mass q_{J-1} on \hat{t} so that it is possible to increase the payoff of country J from $W^J(\tilde{t}_J, 1)$ to $W^J(\tilde{t}_{J-1}, 1)$. QED

Proof of Proposition 2: We present the proof for the case of two identical countries. The case of $J > 2$ countries is a straightforward extension.

If the countries have the same number of local capital owners ($N_i = N_j$), Proposition 2 states that the game has a symmetric mixed strategy Nash equilibrium in which the two countries play $t \in [\tilde{t}, \hat{t}]$ according to the continuous cumulative function $H(t)$ and density function $h(t) = H'(t)$ on $[\tilde{t}, \hat{t}]$. For $t \in [\tilde{t}, \hat{t}]$, the mixed strategy $H(t)$ is given by:

$$H(t) = \frac{W(t, 1) - W(\hat{t}, 0)}{W(t, 1) - W(t, 0)}$$

In equilibrium, the expected payoff of the two countries is $W(\hat{t}, 0)$.

We show that when j plays the mixed strategy $H(t)$, i has no incentive to deviate from $H(t)$.

Suppose j plays the mixed strategy $H(t)$. Then, if i plays t' , $m_i = 0$ with probability $H(t')$ and $m_i = 1$ with probability $1 - H(t')$.

Before solving for the mixed strategy equilibrium, first note that there are no point masses in equilibrium when there are only two identical countries. The intuition is simple: if the level of tax t' was played with positive probability, there would be a tie at t' with positive probability. Imagine then that country j decides to play $t' - \varepsilon$ (instead of t') with the same probability. The cost of such a deviation would be of the order of ε , but if the two countries were to tie, then country j would gain a fixed positive amount. The formal proof of this is as follows. Imagine that country i plays t' with positive probability ω , and country j deviates from t' to $t' - \varepsilon$ with the same positive probability. The payoff for country j will change by a factor of:

$$\begin{aligned}
& \left\{ \Pr(t^i < t' - \varepsilon)W(t' - \varepsilon, 0) - \Pr(t^i < t')W(t', 0) \right\} \\
& + \left\{ \Pr(t^i > t' - \varepsilon)W(t' - \varepsilon, 1) - \Pr(t^i > t')W(t', 1) \right\} \\
& + \left\{ \omega W(t' - \varepsilon, 1) - \frac{\omega}{2}[W(t', 1) + W(t', 0)] \right\}
\end{aligned}$$

The first terms in curly brackets represent the difference between losing with a tax level $t' - \varepsilon$, and losing with a tax level t' . As for the second terms in curly brackets, they represent the difference between winning with a tax level $t' - \varepsilon$, and winning with a tax level t' . It is easy to see that the sum of those terms goes to zero when ε goes to zero. Now, the last terms in curly brackets represent the difference between winning alone with $t' - \varepsilon$, and sharing the win with t' . Since the sum of these terms is strictly positive when ε goes to zero, it pays to deviate to $t' - \varepsilon$ when there is a probability mass at t' . This implies that $H(t)$ cannot have a probability mass.²⁰ And because the cumulative function is continuous, cases in which the countries play $t_i = t_j$ (a tie) occur with probability 0.

We now solve for $H(t)$ knowing that it must be continuous on $[\tilde{t}, \hat{t}]$. Thus, given j plays $H(t)$, when i plays the mixed strategy $H(t)$, its expected payoff is:

$$\int_{\tilde{t}}^{\hat{t}} [H(z)W(z, 0) + (1 - H(z))W(z, 1)] dH(z)$$

For $(H(t), H(t))$ to be a mixed strategy Nash equilibrium, it has to be that all pure strategies played with positive probability yield the same payoff. We construct the equilibrium so that the expected payoff of the two countries is $W(\hat{t}, 0)$. Thus, it has to be that:

$$H(t)W(t, 0) + (1 - H(t))W(t, 1) = W(\hat{t}, 0) \quad \forall t \in [\tilde{t}, \hat{t}]$$

²⁰ Note that a different argument is required to show that there cannot be a probability mass at \tilde{t} . The argument goes as follows. Suppose that each country plays \tilde{t} with probability ω . There is then a positive probability that the countries will tie at \tilde{t} and earn a strictly dominated payoff: $1/2[W(\tilde{t}, 1) + W(\tilde{t}, 0)] < W(\hat{t}, 0)$. Thus, $H(t)$ cannot have a mass at \tilde{t} .

It follows that for $t \in [\tilde{t}, \hat{t}]$, $H(t)$ is given by:

$$H(t) = \frac{W(t, 1) - W(\hat{t}, 0)}{W(t, 1) - W(t, 0)}$$

When j plays the mixed strategy $H(t)$, i has no incentive to deviate from $H(t)$ because:

- Changing the probability of playing any $t \in [\tilde{t}, \hat{t}]$ would not affect its payoff as all pure strategies are equivalent by construction.
- Playing $t \in [0, \tilde{t}[$ or $t \in]\hat{t}, \infty]$ with positive probability would decrease i 's expected payoff as these strategies are all dominated (Lemma 1 and Lemma 2).

This completes the proof for the case of two identical countries. It is easily shown that for the case of $J > 2$ countries, either all countries play a modified $H(t)$ given by

$$H(t) = 1 - \left[\frac{W(\hat{t}, 0) - W(t, 0)}{W(t, 1) - W(t, 0)} \right]^{1/(J-Q-1)}$$

or some of them ($Q \leq J - 2$) put a unit mass on \hat{t} . QED.

Proof of Proposition 3: (A) We first study the case of two countries, 1 and 2, with $N_1 \geq N_2$. We start by examining the case in which country 2 plays first. In that case, the game has a pure perfect Nash equilibrium in which country 2 sets $t_2 = \tilde{t}_1$ and country 1 sets $t_1 = \hat{t}$. In equilibrium, mobile capital locates in 2 and the payoff of country 1 is $W^1(\hat{t}, 0)$ while that of country 2 is $W^2(\tilde{t}_1, 1) > W_2(\hat{t}, 0)$.

To see that this must be true, note that because country 2 has a lower N_2 , it has a lower \tilde{t} : $\tilde{t}_2 \leq \tilde{t}_1$. Consequently, country 2 can always and does undercut country 1 by setting $t_2 = \tilde{t}_1$ (recall our breaking rule). Country 1 then chooses the best tax rate available given it is unable to compete, i.e the tax rate it chooses when isolated: \hat{t} .

Consider now the case in which country 1 plays first. In that case, the game has a pure perfect Nash equilibrium in which both countries play \hat{t} . In equilibrium, mobile capital locates in 2

and the payoff of country 1 is $W^1(\hat{t}, 0)$ while that of country 2 is $W^2(\hat{t}, 1)$. To see that this must be true, recall that country 1 can always be undercut by country 2. Country 1 thus sets $t_1 = \hat{t}$ and country 2, benefiting from the breaking rule, plays $t_2 = \hat{t}$.

This completes part (A) of the proof.

(B) The generalization of (A) to the case of J countries with $N_1 \geq N_2 \geq \dots \geq N_J$ is straightforward. QED.

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9. Table and Figure

Table 1

*Effective average tax rate on capital, Productivity of capital,
Capital stock per worker, and Population, for the EU and US*

	Effective average tax rate on capital (%)		Productivity of capital (as % of that in US)	Capital stock per worker (US dollars)	Population (millions)
	1981	1991	1983	1985	1990
Austria	21.5	22.7	0.56	28245	7.7
Belgium	39.5	36.0	0.66	42670	9.9
Denmark	47.8	40.0	0.72	30878	5.1
Finland	35.2	45.2	0.66	46451	4.9
France	28.4	24.8	0.63	38093	56.7
West Germany	31.0	26.5	0.68	38261	63.2
Ireland	11.4	11.1	0.49	22741	3.5
Italy	25.3	34.5	0.53	32968	56.7
Netherlands	29.7	31.9	0.77	N/A	14.9
Spain	13.9	20.3	0.53	26221	39.3
Sweden	47.4	53.1	0.97	25256	8.5
United Kingdom	66.5	45.3	0.84	22600	56.7
EU average	33.1	32.6	0.67	32217	27.2
United States	40.9	41.1	1.00	32046	285.1

Notes: Except for the effective tax rate on capital income, EU average is that of the countries listed in this table.

Sources: Effective tax rate on capital income: Sørensen (2000, Table 2) or Haufler (2001, Table 4.1). Productivity of Capital: Treffer (1993, Table 1). Capital stock per worker: Summers and Heston (1991, Table II). Population: United Nations Population Division website (<http://esa.un.org/unpp/>).

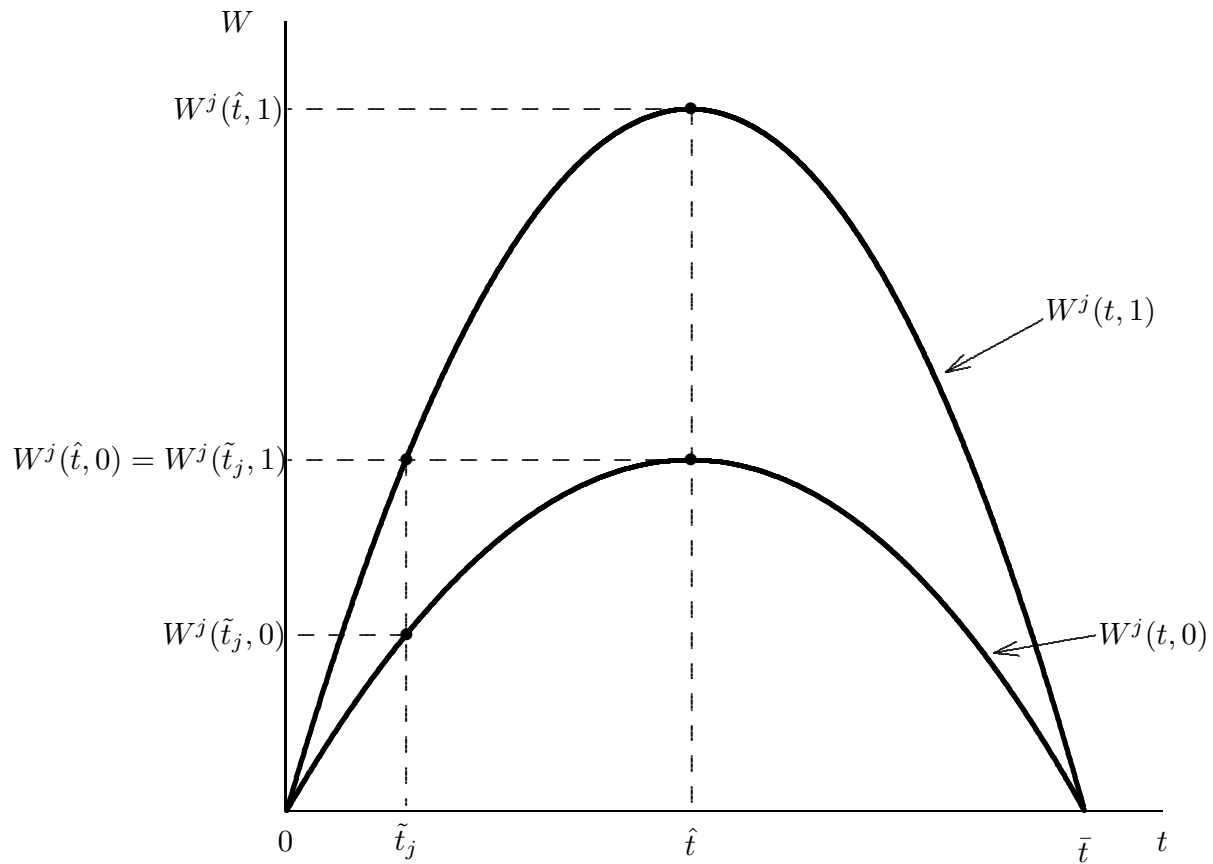


Figure 1: The Payoffs