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CAPITAL TAX COMPETITION AMONG AN ARBITRARY NUMBER OF ASYMMETRIC COUNTRIES

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Abstract

This paper addresses the issue of capital tax competition among an arbitrary number of countries. Countries are allowed to be asymmetric not only in their population endowment but also in their capital endowment per inhabitant. National governments tax capital and labor in order to finance a public good. Asymmetric capital taxation arises at equilibrium leading to a distortion on the international capital market. We provide conditions for the existence of a Nash Equilibrium. We fully characterize how equilibrium taxes and welfare levels depend upon countries' population and capital endowments.

Keywords: Capital Mobility, Tax Competition, Asymmetric Regions, Nash Equilibrium
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1. Introduction

The ongoing globalization movement allows a superior utilization of resources and a better allocation of risks among countries. However, national economies become more interdependent and fiscal policy affects trade, capital and labor flows. Governments have to take their trade partners' behavior into account when undertaking local redistributive policies or public good supply. A possible consequence of this phenomenon is a downward pressure on the size of the public sector. This concern has given rise to quite an extensive literature (cfr. Cremer et al. (1996) or Wilson (1999) for surveys of the literature). Despite this fact, some interesting questions have been somehow neglected, among which the impact of the asymmetry of regions and the existence of equilibrium.

This paper tackles the problem of international tax competition among national sovereign governments in an integrated market. We use a model with an arbitrary number of asymmetric countries where competitive firms produce a homogeneous good using mobile capital and immobile labor. National governments tax production factors in order to finance a public good. The capital tax we consider here, as it concerns productive capital, is to be understood as **a corporate tax.**[1] We provide conditions for the existence of a Nash Equilibrium. We fully characterize the Nash Equilibrium of the tax game. We identify the precise effects stemming from different population and relative factors endowments in equilibrium tax rates and, consequently, welfare levels.

Contrary to most of the literature, asymmetry is used in a broad sense: countries are allowed to differ not only in population endowment but also in capital endowment per capita. Indeed, apart some exceptions, most models use perfectly symmetric regions, in which case there are no capital movements at equilibrium and hence no gains from trade. It is therefore crucial to consider a setting in which the liberalization of the capital market has a potential welfare increasing role, namely, when countries are asymmetric.

Bucovetsky (1991) and Wilson (1991) both consider a particular kind of asymmetry: regions are symmetric with respect to their capital-labor ratios but differ in population size. The less populated country enjoys a higher level of welfare, a result that is known as the "small region advantage". We obtain the same type of result. Our more general framework allows us to clarify the mechanism through which the small regions advantage emerges. In both previous papers, the

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[1] This view is shared by most of the literature; see, for instance, Person and Tabellini (1992).

advantage stems from the smaller region fixing a smaller tax rate at equilibrium, therefore importing capital from the bigger one. This constitutes a positive externality. In our paper the advantage is there despite the fact that regions are either both importers or both exporters at equilibrium and it turns out that the fiscal externality of higher taxation is not always positive. As pointed out by Wilson (1999), having more available capital is good only for countries taxing capital, and not for the ones subsidizing it. As will be made clear in our analysis, the fact that we allow for more than two regions in our model is crucial to shed light on the nature of the small region advantage.

Two other papers consider the type of asymmetry we use, but in a two-country framework: De Pater and Myers (1994) and Grazzini and van Ypersele (1996). The former shows that, at equilibrium, countries exporting capital subsidize it and countries importing capital tax it, a result that is also present in our setting. The latter considers asymmetry also in the objective functions of the countries, in that both median voters playing the game in tax rates have different endowments.

A crucial feature of our model is that a "rest of the world" sector allowing us to consider the net price of capital as exogenous does not exist. As in De Pater and Myers (1994), asymmetric regions manipulating the international net price of capital in their favor generate a pecuniary externality. We call this pecuniary externality the terms of trade effect, in analogy with the literature on optimal trade tariffs.

We identify sufficient conditions under which an equilibrium exists. Namely, we restrict our game such that no country has a big enough market power to manipulate the net price of capital. To the best of our knowledge, papers dealing with generic production and utility functions have not done such a job so far. (cfr. the section on technical aspects of fiscal competition games in the survey by Delage (2000)).[2] The notable exception is Laussel and Le Breton (1998) who identify a sufficient condition for existence in a symmetric two-region game. Our conditions do compare to theirs to a certain extent, but asymmetry and the presence of N countries make them more cumbersome. Nonetheless, the economic intuition behind them rests quite straightforward.

Delage (2000) qualifies the non-existence of equilibria in a given model as *problematic* and he goes on to say that *these problems of existence and uniqueness are omnipresent* in the tax competition literature. Citing Laussel and Le Breton (1998): *Both the existence and uniqueness issues are difficult in general and have not been up to now dealt with (...).It seems however of primary interest to solve them in order to understand the comparative statics of the equilibrium.* One may

[2] When specific production and utility functions are used (e.g. Bucovetsky (1991) and Grazzini and van Ypersele (1996)) the question of existence is trivial since equilibrium tax rates are explicit functions of the parameters.

argue that the existence of equilibria in the real world is a good reason to lessen the importance of this question in economic modelling. The reverse argument is also true: if there exist equilibria in the real world, then a given model does a poor job at representing it if it does not have equilibria itself.

Game theory has been successfully used as a tool in other areas of economics, as for instance Industrial Organization, where the existence question has not been disregarded. Indeed, if the comparative statics performed on the equilibrium are to be meaningful, we have to be sure that such an equilibrium exists.

The paper is organized as follows. In the next section, we describe the main features of our model. Section 3 is devoted to the description of the agents' preferences and to the derivation of a non-cooperative equilibrium. Section 4 discusses extensions and concludes.

2. The model

Consider N ($i = 1, ...N$) sovereign countries that run a fiscal policy in order to balance their public budget. Fiscal policies consist of per unit taxes levied on capital and labor according to the source-based principle. The economy is described as follows: two production factors, capital K and labor L, are used in the production of a single consumption good. The production technology exhibits constant returns to scale and is described by a homogeneous production function $F(K, L)$: $F(K, L) = Lf(k)$ with $k = K/L$, $f^{'}(k) > 0$ and $f^{''}(k) < 0$. To spare conditions on positive production and positive net remuneration of capital, we assume that $f^{'}(0) = \infty$, $f^{'}(\infty) = 0$, $f(0) = 0$. We also assume that $f''(k)$ is finite for finite and non-zero values of k.

Firms behave competitively and production factors are therefore priced at their marginal productivity: $r = f^{'}(k)$ and $w = f(k) - kf^{'}(k)$ with r and w denoting, respectively, the gross remuneration of capital and labor. The relative factor demand of a particular firm is given by $k(r) = f^{'-1}$ with $dk/dr = k^{'} = 1/f^{''}(k)$.[3] The factor price frontier is $dw/dr = -k$.

We also assume that the demand for capital is convex: $k^{''} \geq 0$. This is equivalent to the sufficient condition for existence used by Laussel and Le Breton (1998).

Countries are assumed to be asymmetric with respect to their factor endowments. $\bar{K}_w$ and $\bar{L}_w$ denote the world aggregate endowment of capital and labor. $\overline{K}_i$ is country i's endowment of capital: $\sum_{i=1}^{N} \overline{K}_i = \overline{K}_w$. $\overline{L}_i$ is the number of inhabitants of country i: $\sum_{i=1}^{N} \overline{L}_i = \overline{L}_w$. We define $\lambda_i = \overline{L}_i/\overline{L}_w > 0$ the share of the aggregate population residing in country i. Note that $\sum_{i=1}^{N} \lambda_i = 1$.

[3] Subscripts and dependent variables will be omitted when not absolutely necessary.

Inhabitants in each country are perfectly homogeneous and supply inelastically one unit of labor to internal firms. Each of them owns $\overline{k}_i = \overline{K}_i / \overline{L}_i$ units of capital, which they can choose to invest in any country. Each individual invests his capital where its net return is higher, which implies that the following arbitrage condition must hold in equilibrium:

$$r_i - t_i = r_j - t_j = \rho \quad \forall i = 1..N$$

where t_i is the per unit capital tax and ρ the net capital remuneration on the international market.

At the Walrasian equilibrium, factor prices adjust to clear markets. A labor market exists in each country and international markets are available for the capital and consumption goods. At equilibrium, labor markets clear in each country. The international capital market clearing condition is given by

$$\bar{L}_w \sum_{i=1}^{N} \lambda_i k(\rho + t_i) = \bar{K}_w$$

As the LHS of this equation is strictly decreasing in ρ, an equilibrium exists,

$$\rho = \rho(t_1, .., t_i, ..t_N) = \rho(t)$$

with

$$\rho_{t_i}(t) = \frac{\partial \rho}{\partial t_i} = -\frac{\lambda_i k' \left(\rho(t) + t_i\right)}{\sum_{j=1}^{N} \lambda_j k' \left(\rho(t) + t_j\right)}$$

where $t = (t_1, ..., t_N)$ is the vector of taxes.

Not surprisingly, ρ is a decreasing function of the taxes in each country: an increase in t_i decreases the national demand for capital and as a consequence international demand for capital. Therefore, for the market to clear, the remuneration has to decrease. Note also that $\rho_{t_i} \geq -1$: in a given country, an increase in the tax rate never decreases the gross remuneration of capital $\left(dr_i/dt_i = 1 + \rho_{t_i} \geq 0\right)$.

The equilibrium wage rate is a function of the capital tax levels via its effect on the capital invested in the country

$$w(\rho + t_i) = f\left(k(\rho + t_i)\right) - k(\rho + t_i) f' \left[k(\rho + t_i)\right]$$

with $\partial w_i / \partial t_i = -k_i(\rho_{t_i} + 1) < 0$ and $\partial w_i / \partial t_j = -k_i \rho_{t_j} > 0$ for $i = 1...N$ and $j \neq i$.[4]

[4] We will use k_i as a shorthand for $k\left(\rho(t) + t_i\right)$ throughout the paper (analogous for other functions).

Capital movements originate from two sources: the difference in factor endowments and the difference in capital taxes. In the absence of capital taxes, capital movements lead to an equalization of the marginal productivities, i.e., to the efficient allocation of factors in the sense that it maximizes overall production per capita. When capital taxes are not equalized across countries, part of the capital movements motivated by fiscal opportunism. This generates a distortion since with different source-based tax rates, arbitrage implies different marginal productivities.

3. Fiscal competition

In this section, we analyze fiscal competition arising between countries. Capital taxes are assumed to be decided simultaneously by each national social planner who maximizes the welfare of its representative consumer. Tax setting is a non-cooperative game whose strategies are tax levels and the payoffs are the countries representative agent's utility.

We begin by describing the public budget constraint and analyzing for each country the effect of its national fiscal policy on the welfare of its representative consumer. We then characterize a non-cooperative equilibrium of the game we have just described.

3.1. The government fiscal policy

Individuals derive utility from the consumption of a private good and of a publicly provided private good g.[5] The government finances g by levying source based taxes on labor τ and capital t. We may thus write utility of country i's representative consumer as:

$$W(c_i, g_i) \text{ with } c_i = \rho\overline{k}_i + w_i - \tau_i \text{ and } g_i = \tau_i + t_i k_i$$

The fiscal choice involves levying public money through a non-distorting tax instrument and/or a distorting one. The labor tax is non-distorting as labor is inelastically supplied and immobile while the capital tax distorts the international price of capital.[6] Since no limits have been imposed on the tax instrument, it is possible to have negative taxes at equilibrium.

[5] Our analysis is also valid for the case of a pure public good. We nonetheless restrict it to the case of a publicly provided private good because welfare comparisons between countries are more straightforward.

[6] We later discuss the effect of the assumption on the elasticity of labor supply. We conclude that is doesn't change the substance of our result.

The fiscal decision is essentially a one dimensional problem since τ_i can be expressed as a function of t_i,

$$\tau_i = g_i - t_i k_i.$$

Using this fact to substitute τ_i in $W(c_i, g_i)$, the government's objective is:

$$\underset{t_i, g_i}{Max} W\left(\rho \overline{k}_i + w_i + t_i k_i - g_i, g_i\right)$$

from which it is clear that the choice of t_i is given by the maximization of $\rho\overline{k}_i + w_i + t_i k_i$, which is in fact the total consumption $(c_i + g_i)$ of the representative consumer in country i.

The decision upon t_i can be thought of as being made separately from the one upon g_i. The presence of a non-distorting tax allows the government to fix g_i at the first best level.[7] τ_i will follow from the budget constraint.

It is also true that the choice of t_i which maximizes $\rho\overline{k}_i + w_i + t_i k_i$ is also the one which maximizes $W(c_i, g_i)$. We therefore proceed the analysis by considering only the optimal choice of t_i.

3.2. Effects of the capital tax on welfare

In this subsection, we isolate the different effects of the capital tax on the welfare of a particular country. As discussed above, the objective function of the government may be considered to be:

$$U_i = \rho \bar{k}_i + w_i + t_i k_i \tag{3.1}$$

This is in fact per capita Gross National Product (GNP), i.e., the value of the domestic product minus the net contribution from abroad:

$$U_i = (r_i k_i + w_i) - \rho\left(k_i - \bar{k}_i\right) = f(k_i) - \rho\left(k_i - \bar{k}_i\right)$$

where $\bar{k}_i = \overline{K}_i / \overline{L}_i$ is the aggregate relative endowment of country i and $k_i = K_i / L_i$ is the production factors ratio effectively invested in country i. Note that U_i is continuous in t_i.

[7]

$$\frac{dW}{dg_i} = -W_{c_i}(\bullet) + W_{g_i}(\bullet) = 0$$

yields the Samuelson Rule of optimal public good provision.

We now highlight the effects of a marginal tax increase on U_i, as these are useful to understand the forces at stake when we analyze the tax rate choice.

The capital tax marginal effect can be decomposed into two effects: the *capital movement effect* and the *terms of trade effect.* These are respectively identified in the following expression:

$$\begin{aligned}
\frac{dU_i}{dt_i} &= \frac{\partial U_i}{\partial k_i}\frac{dk_i}{dt_i} + \frac{\partial U_i}{\partial \rho}\frac{d\rho}{dt_i} \\
&= \left(f'(k_i) - \rho\right)\frac{dk_i}{dt_i} - \left(k_i - \overline{k}_i\right)\rho_{t_i} \\
&= t_i\frac{dk_i}{dt_i} - \left(k_i - \overline{k}_i\right)\rho_{t_i}
\end{aligned}$$

The *capital movement effect* has the opposite sign of the tax rate. The intuition behind it has been pointed out by Wilson (1999). The social value of an additional unit of capital is equal to its marginal productivity. Its social cost – what the country pays for that additional unit of capital – is equal to the net price of capital, since a part of the price payed by the firm is collected by the government via the capital tax. Hence there is a wedge, equal to the tax rate, between the social benefit and the social cost of an additional unit of capital. Therefore, when capital flies away, the country is worse off if it taxes capital and best off if it subsidizes it.

The *terms of trade effect* is signed according to the net exporting position of the country. It represents the gain (loss) that a capital-importing (exporting) country makes through the depression of the international remuneration of capital induced by the increase in the capital tax. We call this the *terms of trade effect* as the logic behind it is exactly the one that justifies the optimum tariff in international trade: the tariff is seen as a way to influence the terms of trade. A country that imports capital has an incentive to increase its capital tax in order to decrease its net cost. For the opposite reason, this effect is a disincentive to capital taxation for a capital-exporting country.

3.3. The non-cooperative fiscal decision

It is now possible to formally describe a non-cooperative game played by the different countries. It is a N player game whose players are the national social planners and whose strategies are capital tax levels.

Recalling (3.1), the payoff of country i is given by:

$$U_i(t_1, ..., t_N) = \overline{k}_i\rho(t_1, ..., t_N) + w\left[\rho(t_1, ..., t_N) + t_i\right] + t_i k\left[\rho(t_1, ..., t_N) + t_i\right] \quad (3.3)$$

and its strategy

$$t_i \in (-\infty, \infty) \ . \tag{3.4}$$

The best reply function of country i, $t_i(t_{-i})$ is implicitly defined by the F.O.C of the maximization problem of its social planner:

$$\left(1 + \rho_{t_i}(t)\right) k' \left(\rho(t) + t_i\right) t_i + \left(\overline{k}_i - k(\rho(t) + t_i)\right) \rho_{t_i}(t) = 0 \tag{3.5}$$

which is equivalent to

$$t_i(t) = -\frac{\rho_{t_i}(t)}{1 + \rho_{t_i}(t)} \frac{\overline{k}_i - k(\rho(t) + t_i)}{k'(\rho(t) + t_i)} \tag{3.6}$$

An equilibrium of the non-cooperative game is given by the solution of the system of equations defined by the N best-reply functions as in (3.6).

To ensure the existence of an equilibrium we shall assume that:

Assumption 1. *At any $t = (t_1, ..., t_N)$ such that $\frac{dU_j}{dt_j}(t) = 0$, $\forall j = 1, ...N$, for all i such that $\overline{k}_i - k(\rho(t) + t_i) > 0$:*

1. $\lambda_i k'(\rho(t) + t_i) \geq \sum_{j \neq i} \lambda_j k'(\rho(t) + t_j)$
2. $\left(\sum_j \lambda_j k'(\rho(t) + t_j)\right)^2 - \left(\lambda_i k'(\rho(t) + t_i)\right)^2 \geq \lambda_i \left(\overline{k}_i - k(\rho(t) + t_i)\right) k''_{avg}$

   where $k"_{avg} = \sum_i k''(\rho(t) + t_i)$

These restrict the set of admissible parameters such that both λ and k' are not too large for countries which export capital in equilibrium. Both conditions amount to say that ρ_{t_i} is not too big in absolute value. The first one, in particular, means that one country's tax alone cannot cancel the sum of the effects of all the other countries' taxes on ρ.[8] Note that when $k" = 0$ the second condition is always true. This is the case in Bucovetsky (1991) and Grazzini and van Ypersele (1996), who use a quadratic production function.

[8] There is an intuitive explanation for why one would like to constrain exporters' market power and not importers' one. As shown in Appendix 1, $\frac{d^2\rho}{dt_i^2} \geq 0$: therefore, as t_i increases, changes in both the terms of trade and the capital flight effect caused by the variation in ρ_{t_i} $\left(\frac{d^2\rho}{dt_i^2}\left(\bar{k}_i - k_i\right) \text{ and } \frac{d^2\rho}{dt_i^2} k'_i t_i \text{ respectively}\right)$ are positive for exporters and negative for importers. One would like this positive variation not to be very high, to guarantee the quasi-concavity of the objective function of exporting countries: one therefore needs to constraint their market power on ρ.

Proposition 1. *(i) Under Assumption 1, the game defined by (3.3) and (3.4) has a non-cooperative equilibrium* $(t_1^{nc}, ..., t_N^{nc})$.

(ii) The equilibrium capital tax levels are such that capital-importing countries set positive capital taxes while capital-exporting countries subsidize capital.

(iii) Moreover, at equilibrium, the capital is almost never efficiently allocated among countries.

Proof. The proof is done in the appendix.

This proposition is rather intuitive at the light of the two effects of taxation. Indeed, if a capital exporting country chooses a positive tax rate, both effects are negative and it has an incentive to decrease the tax rate. For an importer the reverse happens: a negative tax rate makes both effects positive and it therefore has an incentive to increase the tax. The optimum is attained when both effects have opposite signs.

A capital importer taxes capital since taxation induces a decrease in the net price of capital, therefore in its capital bill. Moreover, given that a part of the productive capital is owned by foreign citizens, they support a part of the tax burden. An exporting country subsidizes capital because it gets capital payments from abroad, therefore, the higher the international net price of capital, the better. Moreover, all the tax burden is supported by national citizens, which of course discourages taxation.

This result on exporting countries subsidizing capital has been obtained by De Pater and Myers (1994) in a two country model.

We thus have an inefficient equilibrium, since countries use different tax rates and this distorts the allocation of capital from its overall optimum (the equalization of the marginal productivity of capital in all the countries).

It may seem puzzling why regions choose to use the distorting tax instrument, when they have a non distorting one at hand. However, the non-use of the distorting instrument has been obtained either with a fixed international net remuneration of capital or with symmetric regions. If we drop both these assumptions, then regions will have an interest in manipulating ρ.[9] This can be checked by looking at (3.6), which would simplify to $t_i = 0$ if either $\rho_{t_i} = 0$, or under a symmetric equilibrium, where every country chooses the same tax rate and therefore $k_i = \bar{k}_i$ in equilibrium.[10]

[9] As Eggert and Haufler (1999) recognize, *we emphasize that the symmetry assumption is crucial for our result* [of a zero source-based tax on capital] *because for any non-zero capital export position, regions would use the source tax on capital to shift the terms of trade in their favor.*

[10] When the terms of trade effect does not play a role, we're left with the capital movement effect, which attains a maximum at $t_i = 0$.

Moreover, note that if a residence based capital tax was available to the government, exactly the same effects would be at work. A residence tax on capital and the wage tax are in our model perfect substitutes: they both are non-distorting ways to raise money through inelastic production factors.[11]

To sum up, we have an inefficient non-cooperative equilibrium where asymmetric countries compete for capital and use non-zero tax rates in order to manipulate the terms of trade in their favor.

3.4. Equilibrium tax rates and welfare levels

In this subsection we derive implications from the differences in endowments on equilibrium tax rates and welfare levels attained at equilibrium.

We assume that taxes are strategic complements, that is, $\left.\frac{dt_i}{dt_j}\right|_{\frac{dU_i}{dt_i}=0} \geq 0$, $\forall i$, $\forall j \neq i$.[12] In Laussel and Le Breton (1998) the condition $k'' \geq 0$ is sufficient also for strategic complementary. In our case, nonetheless, it is not, because of the further complication that arises from non-zero net capital exporting positions of countries. We prefer to directly assume strategic complementarity as the sufficient conditions we derived are complicated and not interpretable.

We argue that this assumption is reasonable in our framework. Indeed, the effect of an increase in t_B for country A may be decomposed into two components: the demand for capital k_A increases because its gross price decreases and moreover the sensibility of ρ to t_A also changes. Note that the first effect is of the magnitude of $d\rho/dt_B$ whereas the second one is of the magnitude of $d^2\rho/dt_A dt_B$. We therefore assume that the first effect is more important than the second. Now $d\left(dU_A/dt_A\right)/dk_A$ is positive when country A is on its best reply, so this increase

[11] Since ρ is unaffected by changes in the residence based tax, the FOC on t_i is exactly the same. We would get the same results, but instead of $\tau_i = g_i - t_i k_i$ we would have $\tau_i + \zeta_i \bar{k}_i = g_i - t_i k_i$, where ζ_i stands for the residence-based capital tax.

[12] Note that by the implicit function theorem $\left.\frac{dt_i}{dt_j}\right|_{\frac{dU_i}{dt_i}=0} = -\left.\frac{d^2U_i/dt_i dt_j}{d^2U_i/dt_i^2}\right|_{\frac{dU_i}{dt_i}=0}$ hence it is non-negative if and only if $\left.\frac{d^2U_i}{dt_j dt_i}\right|_{\frac{dU_i}{dt_i}=0}$ is non-negative.

in k_A does suggest strategic complementarity.[13]

In terms of the two effects of taxation, it amounts to say that we ignore the impact on the capital movement effect (which will be a second order one) to concentrate only on the direct increase (equal to $-\rho_{t_A}$) on the terms of trade effect. That is, if demand for capital increases inside an importing country, the decrease in its capital bill induced by its own tax rate is now more important than before; as regards a capital exporter, the decrease in external revenue induced by an increase in its own tax rate is now less heavy. Both are, thus, able to increase their tax rates.

Proposition 2. *In any non-cooperative equilibrium of the game defined by (3.3) and (3.4), there is a cut-off level $\overline{k}_c$ such that $t_c = 0$ and all countries i with $\overline{k}_i < \overline{k}_c$ import capital and choose $t_i > 0$ and all countries e such that $\overline{k}_e > \overline{k}_c$ export capital and set $t_e < 0$.*

Moreover, for any pair of countries i and e such that $\overline{k}_i < \overline{k}_c$ and $\overline{k}_e > \overline{k}_c$, we have $W_e > W_i$.

Proof. The proof is done in the appendix.

This means that two countries with the same relative capital-labor endowment are either both exporters or both importers, irrespective of their labor endowments. Only the relative endowment of a given country matters for determining its net exporting position. In a constant returns to scale world, this is not surprising at all. Moreover, and quite logically, relatively rich countries export capital and relatively poor ones import it.

In terms of welfare, capital exporting countries not only attain higher production levels because they have higher capital in equilibrium, as they receive positive transfers from foreign importing countries. Hence, they enjoy higher welfare.

Proposition 3 (Small country advantage). *In any non-cooperative equilibrium of the game defined by (3.3) and (3.4), take any two countries i and j, such that $\overline{k}_i = \overline{k}_j \neq \overline{k}_c$ and $\lambda_i > \lambda_j$. Then $|t_i| > |t_j|$ and, moreover, $W_i < W_j$.*

[13] We may write the FOC (see appendix) as

$$\frac{dU_A}{dt_A} = \frac{dk_A}{dt_A}\left(t_A + \lambda_A \frac{k_A - \overline{k}_A}{\sum_{j\neq A}\lambda_j k_j'}\right)$$

and hence

$$\left.\frac{d^2U_A}{dt_A dk_A}\right|_{\frac{dU_A}{dt_A}=0} = \frac{dk_A}{dt_A}\left(\frac{\lambda_A}{\sum_{j\neq A}\lambda_j k_j'}\right) > 0$$

Proof. The proof is done in the appendix.

The small region advantage had already been obtained by Wilson (1991) and Bucovetsky (1991).[14]

The capital movement effect explains the welfare differences in the above proposition. Country i having a higher tax than j, there is more capital available to j and this means more welfare if j is an importer and less if it is an exporter.

The difference in tax rates are quite intuitive, in the light of both effects of taxation: the net price of capital is more sensitive to changes in the tax rate of a bigger country. On the one hand, this country has a bigger incentive to manipulate the terms of trade, therefore it will choose an higher tax in absolute value. On the other hand, the gross price of capital increases less (and therefore capital flight is smaller), which means a low cost of taxing for a big importer and a low benefit of taxing for a big exporter: both choose smaller taxes than their less populated counterparts.

One may ask why doesn't the bigger country (say, an importer) decrease its tax rate to increase its utility. Its bigger weight in the international capital market makes it such that ρ is too sensitive to its tax rate. Therefore, were the country to decrease its tax rate, the corresponding increase in ρ associated with the increase in k would hurt too much its capital bill, more than compensating for the increase in production. This may seem puzzling at first sight, since usually in economics agents are able to profit (and not suffer) from their market power. As pointed out by Wilson (1991), this stems from the fact that in tax competition models the externality imposed by one region on the other is positive and not negative as, e.g., in a tariff war.

Another interesting question is how do tax rates compare between two countries with the same population and different endowment of capital per inhabitant. The factor ratio endowment induces a downward pressure in the tax rate, since countries which own relatively a lot of capital dislike low ρ.[15]

Figure 3.1 summarizes our findings about tax levels and welfare. The arrows represent the direction of change in endowments that is needed to move to a country with a higher tax rate (welfare level). Note that at the cut off level $\overline{k}_c$, population size does not have an influence on the tax rate nor on welfare levels.

Take the left panel. The tax rate in country A' is bigger than the one in A because of the small region effect. By the same reason, in a country with a smaller population than B (an exporter) the tax will be higher (smaller subsidy). The

[14] Both Bucovetsky and Wilson got this result in a 2 country setting. However, in our model the presence of N countries is crucial for the result. In fact, it can be checked that if $N = 2$ with $\overline{k}_1 = \overline{k}_2$ the only equilibrium is $t_1 = t_2 = 0$. If, say, $t_1 < t_2$ then 1 should be importing capital and 2 exporting but then $t_1 > 0$ and $t_2 < 0$, one reaches a contradiction.

[15] See end of Appendix 2 for details.

effect of capital endowment per inhabitant is the same at both A and B: countries with less endowment will have higher tax rates (e.g., A" has a higher tax rate than A).

We now turn to the right panel of the figure, namely, welfare comparisons.

At a given equilibrium, all the countries face the same ρ and therefore welfare comparisons are based only upon the capital movement effect. That is, an importer is better off the smaller its tax rate and an exporter is better off the smaller its subsidy. One of the consequences of this fact is the small region advantage: welfare is higher in countries with smaller populations, a result which is common to countries C, D and E.

The capital endowment per capita has a direct positive effect on welfare - each citizen receives ρ for unit of capital he owns. That's what the arrows departing from countries C and D show us. But it also has a negative impact on the tax rate, therefore, for exporting countries, its total effect may become negative (as at country E, for instance) after a certain threshold, which will depend upon λ.[16]

4. Conclusion and possible extensions

In this paper we have analyzed fiscal competition between N asymmetric countries when the international capital market is liberalized. We have focused our analysis on the effect of this competition on the allocation of capital among countries, i.e., on production efficiency. We decompose the impact of fiscal policy into two effects: the *capital movement effect* and *the terms of trade effect.*

We have shown that, when countries behave non-cooperatively, at equilibrium, the capital tax level differs between countries leading to an inefficient allocation of resources. We characterized how tax rates and welfare levels depend upon population and capital endowments of countries.

As we pointed out already, the source-based capital tax would be used even if a residence-base version were available to the government. One possible extension would be to consider three available tax instruments and factor supplies

[16]Note that the total effect of $\overline{k}_i$ on U_i, at a given equilibrium is given by:

$$\left.\frac{dU_i}{d\overline{k}_i}\right|_{\rho} = \frac{\partial U_i}{\partial \overline{k}_i} + \frac{\partial U_i}{\partial t_i}\frac{\partial t_i}{\partial \overline{k}_i} = \rho + t_i k_i' \rho_{t_i}$$

And

$$\left.\frac{d^2U_i}{d\overline{k}_i^2}\right|_{\rho} = \left(\rho_{t_i}\right)^2 k_i' + \left(\rho_{t_i}\right)^2 t_i k_i' + t_i k_i' k_i'' \frac{\partial \rho_{t_i}}{\partial k_i'} < 0$$

Hence there may exist a value of $\overline{k}_i$ after which $\left.\frac{dU_i}{d\overline{k}_i}\right|_{\rho}$ becomes negative.

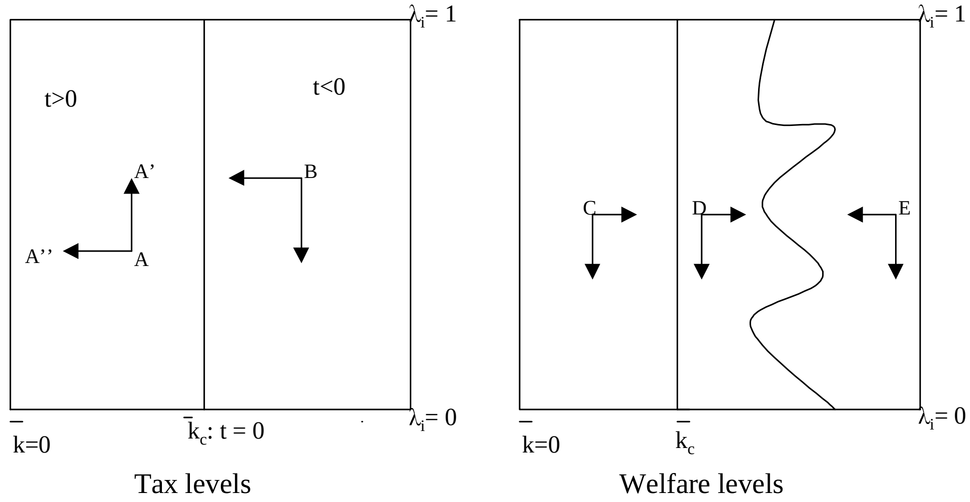

Figure 3.1: Tax and welfare levels

not perfectly (but fairly) inelastic. We conjecture that the conclusions of our model as regards the non-zero source-based tax on capital wouldn't change, because the other tax instruments are not as effective in manipulating the terms of trade. Factor supplies being quite inelastic, the labor and capital residence-based taxes would not be too different from the non distorting labor tax in our model. That is, they could still fulfil the role of equilibrating the public budget, but the residual tax burden would then be split among the capital income and the labor residence-based taxes in the combination which minimizes the distortions due to the factor supply elasticity.

This paper helps to identify how asymmetry between a large number of countries plays an important role in fiscal competition, giving important insights as to how population size and capital ownership affects the capital importing/exporting position of a country, its tax rate and its welfare.

Appendices

A1: The non-cooperative equilibrium

Proposition 1. *(i) Under Assumption 1, the game defined by (3.3) and (3.4) has a non-cooperative equilibrium* $(t_1^{nc}, ..., t_N^{nc})$.

(ii) The equilibrium capital tax levels are such that capital-importing countries set positive capital taxes while capital-exporting countries subsidize capital.

(iii) Moreover, at equilibrium, the capital is almost never efficiently allocated among countries.

Proof.

(ii). We know that, at equilibrium, countries are on their best-reply functions(3.5). $t_i \geq (<)0$ when $(\overline{k}_i - k_i) \leq (>)0$.

(iii). The capital is efficiently allocated across countries when its cost is equalized. Since the cost is given by the international price of capital plus the national capital tax rate, costs are equalized only when all countries set the same level of capital tax. This is the case only when countries are symmetric.

(i). In this type of game, the following conditions are sufficient for existence. For any i, :

- U_i is continuous on $\{t_{1,...,}t_N\}$ and quasi-concave on t_i.
- Strategy sets are compact and convex.

We start with the **strategy sets**. They are trivially convex. As capital tax rates are unidimensional strategy sets, they are compact if they are bounded from below and above. We show that we can compactify the strategy set. The demonstration is done by contradiction for the upper and lower limit. Imagine a country i sets an infinite tax at equilibrium: $r_i = \infty$ and, by the assumptions on the production function, $k_i = 0$ and therefore the country is exporting capital. This is impossible since we showed in (ii). that only capital-importing countries set a positive capital tax. Now suppose a country j sets a tax rate $t_j = -\infty$ then $r_j = -\infty$ which is impossible since by assumption $f'(k) > 0$ for any k.

We now look at **payoff functions**.

The payoff functions are continuous on $\{t_{1,...,}t_N\}$ by assumption.

We use the following definition of quasi-concavity:

Definition 1. *A C^1 function $g(x)$ is quasi-concave iff:*
$g(x) \geq g(x_0) \Rightarrow g'(x_0)(x - x_0) \geq 0$ *for any* x, x_0

It is easily seen that:

(i) $g'(x)$ changes sign only once

(ii) $g'(x) > 0$ at the lower bound of the domain of x

Imply the above condition[17].

Also note that for continuous $g'(x)$ if for any $\widehat{x}$ such that $g'(\widehat{x}) = 0$ we have the same sign for $g''(\widehat{x})$ then $g'(x)$ changes sign only once.

We now show that in our case:

(i) $\frac{dU_i}{dt_i}$ is continuous

(ii) $\frac{dU_i}{dt_i} > 0$ at the lower bound of the strategy set

(iii) $\frac{d^2U_i}{dt_i^2}\left(\widehat{t}_i\right) \leq 0$ at any $\widehat{t}_i$ such that $\frac{dU_i}{dt_i}\left(\widehat{t}_i\right) = 0$

After some manipulations, the first order condition on t_i, (3.5), may be written as

$$\frac{dU_i}{dt_i} = \frac{dk_i}{dt_i}\left(t_i + \lambda_i \frac{k_i - \overline{k}_i}{\sum_{j\neq i} \lambda_j k_j'}\right) \tag{4.1}$$

Which is continuous ($\sum_{j\neq i} \lambda_j k_j' \neq 0$ by our assumptions on f'').

Let's call

$$t_i + \lambda_i \frac{k_i - \overline{k}_i}{\sum_{j\neq i} \lambda_j k_j'} = \phi_i(t_i)$$

Obviously, $\frac{dU_i}{dt_i} = 0$ iff $\phi_i(t_i) = 0$.

A country can always set a tax rate so low that he imports capital. That is, for low tax rates $\phi_i(t_i) < 0$[18]. Also, a country can always set a tax rate so high that he ends up exporting capital. Then, for high tax rates, $\phi_i(t_i) > 0$[19]. That means (4.1) is positive on the lower bound of the strategy set and negative on its upper bound.

Taking into account that

$$\frac{d^2\rho}{dt_i^2} = -\frac{\rho_{t_i}^2 \sum_{j\neq i} \lambda_j k_j'' + \left(1+\rho_{t_i}\right)^2 \lambda_i k_i''}{\sum_j \lambda_j k_j'}$$

[17]Indeed, call $\overline{x}$ the value at which $g'(x)$ changes sign. Then the following three possibilities exhaust the cases for which $g(x) \geq g(x_0)$: either (a) $x_0 < x < \overline{x}$ or (b) $\overline{x} < x < x_0$ or (c) $x < \overline{x}$ and $x_0 > \overline{x}$.

[18]Note that if all other countries fix t at the lower bound of the strategy set, there may exist a country i who is incapable of importing capital. But we may choose the lower bound as small as we want it to make it such that $\phi_i(t_i) < 0$ even if $\overline{k_i} - k_i > 0$ (remember that Assumption 1 places an upper bound on $\overline{k_i} - k_i$ and moreover $\sum_{j\neq i} \lambda_j k_j'$ is finite).

[19]A similar comment as the one on the lower bound applies here.

Note that, as in Laussel and Le Breton (1998), $k_i'' > 0$ for all i is sufficient for $\frac{d^2\rho}{dt_i^2} > 0$.

The second derivative of U_i may be written as

$$\begin{aligned}\frac{d^2U_i}{dt_i^2} &= -\rho_{t_i}^2 \left[\frac{\sum_{j\neq i}\lambda_j k_j''}{\sum_j \lambda_j k_j'}\left(\overline{k}_i - k_i + t_i k_i'\right)\right] + \\ &+ \left(1+\rho_{t_i}\right)^2 \left[t_i k_i'' - \frac{\lambda_i k_i''}{\sum_j \lambda_j k_j'}\left(\overline{k}_i - k_i + t_i k_i'\right)\right] + k_i'\left(1-\rho_{t_i}^2\right)\end{aligned}$$

And taking its value where the first order condition is nil:

$$\left.\frac{d^2U_i}{dt_i^2}\right|_{\phi_i(t_i)=0} = -\rho_{t_i}^2 \left[\frac{\sum_{j\neq i}\lambda_j k_j''}{\sum_{j\neq i}\lambda_j k_j'}\left(\overline{k}_i - k_i\right)\right] + k_i'\left(1-\rho_{t_i}^2\right) \tag{4.2}$$

Clearly, the second term on (4.2) is always negative. As long as $\overline{k}_i - k_i \leq 0$, so is the first one. Hence, for importers, we're done: $\left.\frac{d^2U_i}{dt_i^2}\right|_{\phi_i(t_i)=0} < 0$.

Now for exporters we need

$$-\rho_{t_i}^2 \left[\frac{\sum_{j\neq i}\lambda_j k_j''}{\sum_{j\neq i}\lambda_j k_j'}\left(\overline{k}_i - k_i\right)\right] \leq -k_i'\left(1-\rho_{t_i}^2\right) \tag{4.3}$$

which substituting $\rho_{t_i}^2$ and after trivial manipulation boils down to:

$$\frac{\lambda_i^2 k_i' \sum_{j\neq i}\lambda_j k_j''}{\sum_{j\neq i}\lambda_j k_j'}\left(\overline{k}_i - k_i\right) \leq \left[\left(\sum_j \lambda_j k_j'\right)^2 - \left(\lambda_i k_i'\right)^2\right]$$

Under Assumption 1,

$$0 \leq \frac{\lambda_i k_i'}{\sum_{j\neq i}\lambda_j k_j'} \leq 1$$

Hence:

$$0 \leq \frac{\lambda_i^2 k_i' \sum_{j\neq i}\lambda_j k_j''}{\sum_{j\neq i}\lambda_j k_j'}\left(\overline{k}_i - k_i\right) \leq \lambda_i(\overline{k}_i - k_i)\sum_{j\neq i}\lambda_j k_j''$$

Noting that $\sum_{j\neq i}\lambda_j k_j'' = k_{avg}'' - \lambda_i k_i'' \leq k_{avg}''$, a sufficient condition for (4.3) to be true is

$$\left(\sum_j \lambda_j k_j'\right)^2 - (\lambda_i k_i')^2 \geq \lambda_i k_{avg}''(\overline{k}_i - k_i)$$

which is always true under Assumption 1. Hence, also for exporting countries $\left.\frac{d^2U_i}{dt_i^2}\right|_{\phi_i(t_i)=0} \leq 0.$ ■

A2: Equilibrium tax rates and welfare levels

Proposition 2. *In any non-cooperative equilibrium of the game defined by (3.3) and (3.4), there is a cut-off level $\overline{k}_c$ such that $t_c = 0$ and all countries i with $\overline{k}_i < \overline{k}_c$ import capital and choose $t_i > 0$ and all countries e such that $\overline{k}_e > \overline{k}_c$ export capital and set $t_e < 0$.*

Moreover, for any pair of countries i and e such that $\overline{k}_i < \overline{k}_c$ and $\overline{k}_e > \overline{k}_c$, we have $W_e > W_i$.

Proof.

Suppose such a cut-off level does not exist. Then there is at least one pair of countries A and B such that $\overline{k}_A \geq \overline{k}_B$ and A is an importer and B an exporter, or $t_A > 0$ and $t_B < 0$.

This implies $k_A < k_B$ and hence $\overline{k}_A - k_A > \overline{k}_B - k_B$ which contradicts the fact that $\overline{k}_A - k_A < 0$ and $\overline{k}_B - k_B > 0$.

For the second result, write $U_l = f(k_l) + \rho(\overline{k}_l - k_l)$. Since $t_e < t_i$ we have $k_e > k_i$ and $f(k_e) > f(k_i)$ and also $\rho(\overline{k}_e - k_e) > 0 > \rho(\overline{k}_i - k_i)$. ■

Proposition 3 (Small country advantage). *In any non-cooperative equilibrium of the game defined by (3.3) and (3.4), take any two countries i and j, such that $\overline{k}_i = \overline{k}_j \neq \overline{k}_c$ and $\lambda_i > \lambda_j$. Then $|t_i| > |t_j|$ and, moreover, $W_i < W_j$.*

Proof.

Let's call $Z_l = Z(\lambda_l, \overline{k}_l, t_l, t_{-l}) = (1+\rho_{t_l}(t))k'\left(\rho(t) + t_l\right) t_l + \left(\overline{k}_l - k(\rho(t) + t_l)\right) \rho_{t_l}(t)$, country i's FOC.

$Z_l = 0$ defines implicitly the best reply $t_l(t-_l)$.

$$\frac{dZ}{d\lambda_l} = k_l' t_l \frac{d\rho_{t_l}}{d\lambda_l} + (\overline{k}_l - k_l)\frac{d\rho_{t_l}}{d\lambda_l} = (\overline{k}_l - k_l + k_l' t_l)\frac{\sum_{h\neq l} \lambda_h k_h'}{\left(\sum_h \lambda_h k_h'\right)^2}(-k_l')$$

$\frac{dZ}{d\lambda_l} < 0$ when $\overline{k}_l - k_l > 0$ and $t_l < 0$ and it is positive otherwise. At $t_l = 0$ and $\overline{k}_l - k_l = 0$, $\frac{dZ}{d\lambda_l} = 0$

Moreover, the fact that taxes are strategic complements is ensured by:

$$\frac{dZ_l}{dt_h} > 0 \quad \text{for } h \neq l$$

We now look at the Z functions of each country in a given equilibrium, that is, taking ρ and t_{-i-j} as given.

By lemma 1, we are sure that the countries are either both importers or both exporters. Suppose i and j are importers and $0 \leq t_i \leq t_j$. We have $Z_i = Z(\lambda_i, \overline{k}_i, t_i, t_j, t_{-j-i}) = 0$ and $Z_j = Z(\lambda_j, \overline{k}_i, t_j, t_i, t_{-j-i}) = 0$.

Quasi-concavity of the objective function implies: $Z(\lambda_i, \overline{k}_i, t_j, t_j, t_{-j-i}) \leq 0$. Strategic complementarity implies $Z(\lambda_j, \overline{k}_i, t_j, t_j, t_{-j-i}) \geq 0$. This implies $Z(\lambda_j, \overline{k}_i, t_j, t_j, t_{-j-i}) \geq Z(\lambda_i, \overline{k}_i, t_j, t_j, t_{-j-i})$. Since $t_j > 0$ and $\overline{k}_i - k(t_j) > \overline{k}_i - k(t_j) > 0$ we have in this case $\frac{dZ}{d\lambda_l} > 0$ and we reach a contradiction. Hence, it must be the case that $t_i > t_j$.

A similar argument holds for the case of exporters.

For the welfare comparison, note that

$$\left.\frac{dU_i}{dt_j}\right|_{\frac{dU_i}{dt_i}=0} = \left(\overline{k}_i - k_i + t_i k_i'\right) \rho_{t_j}\Big|_{t_i = -\frac{\overline{k}_i - k_i}{k_i'} \frac{\rho t_i}{1+\rho_{t_i}}} = -t_i \frac{\rho_{t_j}}{\rho_{t_i}} k_i'$$

which has the same sign as t_i. At equilibrium, given $\{t_l\}_{l \neq j, l \neq i}$, we may write $U_i(t_i, t_j)$.

Take i and j importers. We know that $0 < t_j < t_i$ and we have:

$$U_i = U(t_i, t_j) < U(t_i, t_i) \leq U(t_j, t_i) = U_j$$

where the last inequality follows from the definition of a Nash equilibrium.

A similar argument holds for the case of exporters. ■

Result on the effect of $\overline{k}$ on equilibrium t:

Note that $\frac{dZ_i}{d\overline{k}_i} = \rho_{t_i} < 0$ and take two counties such that $\lambda_i = \lambda_j$ and $\overline{k}_i > \overline{k}_j$. Now suppose $t_i \geq t_j$ and apply the same kind of reasoning that was used to demonstrate the previous proposition.

A5: An example

In this appendix, considering a particular example, we show, with some lemmas, that the analysis we undertook in this paper is not vain, i.e. we were not reasoning on an empty set.

Consider the following constant returns to scale production function in intensive form:

$$f(k) = (a - bk)k$$

This function has been used by Bucovetsky and Grazzini and van Ypersele. It perfectly fits in the assumptions we impose except for two technical conditions i.e. $f'(0) = \infty$, $f'(\infty) = 0$. These conditions have to be replaced by $\overline{k}_i < \frac{a\gamma_i}{2b}$, in order to ensure positive marginal productivity, where $\gamma_i = \frac{\overline{K_w}}{K_i}$.

Lemma 1. *Payoff functions are concave and taxes are strategic complements:* $\frac{d^2U_i}{dt_i^2} < 0$ *and* $\frac{d^2U_i}{dt_j dt_i} > 0$.

Proof. Mutatis mutandis equation (3.5),

$$\frac{dU_i}{dt_i} = 2b\lambda_i(\overline{k}_w - \overline{k}_i) + \lambda_i \sum_{j=1}^{N} \lambda_j t_j - t_i = 0 \tag{4.4}$$

It directly follows that $\frac{d^2U_i}{dt_i^2} = (\lambda_i^2 - 1) < 0$ and $\frac{d^2U_i}{dt_j dt_i} = \lambda_j \lambda_i > 0$. ■

Lemma 2. *The non-cooperative equilibrium exists and is unique.*

Proof. The Nash equilibrium solves the system of equations defined by (4.4) for the N countries. This system is linear and of full rank. The solution is then unique and given by

$$t_i = \frac{2b\lambda_i}{1 - \sum\limits_{j=1}^{N} \lambda_j^2} \left(\overline{k}_w - \overline{k}_i \left(1 - \sum_{j \neq i} \lambda_j^2 \right) - \sum_{j \neq i} \overline{k}_j \lambda_j^2 \right) \quad \text{or}$$

$$t_i = \frac{2b\overline{k}_w}{1 - \sum\limits_{j=1}^{N} \lambda_j^2} \left(\lambda_i \left(1 - \sum_{j \neq i} \gamma_j \lambda_j \right) - \gamma_i \left(1 - \sum_{j \neq i} \lambda_j^2 \right) \right) \quad \text{for all } i = 1...N$$

■

Equilibrium tax rates

We now show how equilibrium tax rates depend upon $\overline{k}$ and λ.

First note that the tax rate has the same sign as $\overline{k}_w - \overline{k}_i \left(1 - \sum_{j \neq i} \lambda_j^2\right) - \sum_{j \neq i} \overline{k}_j \lambda_j^2$

As we would expect:

$$\frac{dt_i}{d\overline{k}_i} = -\frac{2b\lambda_i}{1 - \sum\limits_{j=1}^{N} \lambda_j^2} \left(1 - \sum_{j \neq i} \lambda_j^2 \right)$$

is negative.

Moreover,

$$\frac{dt_i}{d\lambda_i} = \left(\overline{k}_w - \overline{k}_i \left(1 - \sum_{j \neq i} \lambda_j^2 \right) - \sum_{j \neq i} \overline{k}_j \lambda_j^2 \right) 2b \left(1 - \sum_{j \neq i} \lambda_j^2 \right)$$

has the sign of the tax rate.

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