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OPTIMAL TAX ADMINISTRATION RESPONSES TO FAKE MOBILITY AND UNDERREPORTING*

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ABSTRACT: In a two-country model, the citizens of a 'big home country' can either fictitiously move residence to a 'small foreign country' where residence-based taxes are lower (external tax avoidance), or under-report the tax base at home (internal tax avoidance). Tax setting is the result of Cournot-Nash competition between revenue maximizing governments, with the home government also setting two types of administration policies, one for each form of tax avoidance. We show that although it is optimal to employ both types of administration policies, which in themselves are both effective at tackling the targeted form of tax avoidance, the optimum is characterized by a tradeoff in terms of policy outcomes: either internal avoidance increases and external avoidance decreases, or the opposite, depending on the characteristics of the fiscal environment.

JEL Codes: H21, H24, H26, H73
Keywords: Personal taxation; Residence principle; Tax avoidance; Tax competition; Tax administration; Tax havens; Taxation of the rich; Leviathan governments

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1 Introduction

Taxation of wealthy individuals is a challenge for tax administrations. On the one hand, these taxpayers are quite skillful at taking advantage of tax loopholes there where they reside, which is favored by the fact that their main source of income is capital, or labor income that can at least partially sheltered as capital income. On the other hand, they can also relocate to low tax jurisdictions relatively easily as long as, under the tax residence principle, they are not attached to a local, regional or even national labor market (Jakobsen et al., 2020; Brülhart et al., 2022; Agrawal et al., 2022). Highly skilled workers or, in general, individuals whose professions involve little location-specific human capital (e.g., individual sportsmen, singers, youtubers or entrepreneurs) might also be equally characterized (de la Feria and Maffini, 2021).

In contrast to what we call internal tax avoidance, mobility (or external tax avoidance) is becoming increasingly important. As Wildasin (2021) argues, mobility of labor depends on technological factors and the possibility of remote work since the Covid-19 pandemic has increased mobility for other segments of the labor market, still composed by high skilled workers. This has, thus, expanded international personal tax competition (IMF, 2022, Chapter 2). Tax competition for wealthy individuals or for high skilled workers materializes into flat or lump sum tax regimes (e.g., Italy or Switzerland), non-dom regimes (UK or Greece), or simply through low tax jurisdictions (e.g., Andorra; see, for exemple, Section 3.2. in Flamant et al., 2021).

Mobility, and thus tax competition, can hold across countries (Kleven et al., 2013; Kleven et al., 2014) or across jurisdictions within a country (Moretti and Wilson, 2017; Martínez, 2022). In any case, it is not limited to tax havens. In absence of tax coordination within a country or at the international level, tax design — as illustrated in the previous paragraph, but also tax enforcement as some relocations are merely on the paper (OECD, 2018, point 96) — has to be adapted in accordance with the increasing importance of mobile taxpayers. Joint with the 'traditional' opportunities of tax avoidance at home, this expands the opportunities of avoidance, and thus it creates a challenge for the design and implementation of tax policy.

The goal of this paper is to address the issues illustrated above by means of a simple two-country theoretical model, in which a 'small foreign country' attracts the residents of a 'big home country' by offering more favorable conditions on a residence-based personal tax (income, or net wealth) than those applied in the home country. Taxpayers keeping residence in the home country can, at a cost, under-declare their personal tax base (internal tax avoidance). Otherwise, they can, at a cost, fictitiously transfer their residence to the foreign country (external tax avoidance), where tax cheating is not feasible because new residents are taxed lump sum. A key element of the model is that taxpayers are heterogeneous along the two dimensions of tax avoidance, being characterized by differing costs of tax cheating at home and of residence shifting abroad. Given taxpayers' heterogeneity, some individuals keep their residence at home, and engage in different levels of tax cheating, while others fictitiously shift their residence to the foreign country. The governments of both countries, which are revenue-maximizing Leviathans, compete on tax rates in a Cournot-Nash game, with the government of the home country also tackling internal and external tax avoidance with two types of administration policies, one for each form of avoidance. Regarding the home country, and with reference to tax revenue maximization, we therefore focus on the characterization of a so called 'optimal tax system' (Slemrod, 1990).

Regarding tax setting, our analysis shows that external tax avoidance and tax competition with the foreign country force the home country to lower its tax rate below the level that would be set in the extreme case — taken as benchmark — in which there is only internal tax avoidance. On the other hand, internal tax avoidance lowers the ratio between the foreign and the home tax rate below the level that would prevail in the other extreme case — taken as second benchmark — in which there is only external tax avoidance.

The model also shows that the Nash equilibrium of the tax competition game determines, in the home country, a one-to-one negative relationship between the two key indicators of fiscal outcomes — the mass of taxpayers moving abroad by cheating on residence (external avoidance) and the average level of tax under-reporting at home (internal avoidance). That is, although the quality of the 'fiscal environment' in the home country is characterized by two independent factors — the taxpayers' opportunities to engage in either internal or external tax avoidance — the corresponding outcomes are not independent, since with taxes optimally set under the pressure of tax competition there exists only one compatible level of internal tax avoidance for any given level of external tax avoidance, and vice versa.

The above result has an important implication for optimal tax administration, which is the following. Although it is in general optimal to employ both types of administration policies to increase net tax revenue collected, and although each policy is effective, *per se*, at restraining the form of tax avoidance toward which is targeted, the optimal tax system, compared to the one with no tax administration, is characterized by a better outcome in one dimension of tax avoidance and a worse outcome in the other dimension. Improvements in both dimensions never occur, in spite of the fact that the optimal tax system, with respect to the one with no tax administration, by definition performs better, under the Leviathan objective, in terms of net tax revenue collected.[1] The terms of the tradeoff are linked to the features of the fiscal environment. In an environment characterized by low opportunities of residence shifting and high opportunities of under-reporting, tax administration, when optimally set, reduces internal tax avoidance — the most pressing problem — while it leaves some room to external tax avoidance — the less pressing problem in relative terms. The opposite outcome holds in a fiscal environment characterized by high opportunities of residence shifting and low opportunities of under-reporting.

When the analysis is extended to the case of correlated personal attributes — in that taxpayers with broad (resp. limited) opportunities of internal avoidance have on average also broad (resp. limited) opportunities of external avoidance — we show that there is an increase, in equilibrium, of tax avoidance, but only of one type, either external or internal — depending of the fiscal environment. Correlation of personal attributes also reduces the pressure of tax competition between the two countries and therefore results in higher taxes in equilibrium. Finally, while with uncorrelated attributes in equilibrium the individuals keeping their residence at home are, on average, those for whom the transfer of residence is relatively more costly but at the same time are also those for whom tax cheating at home is relatively cheaper, in the presence of correlation the individuals staying at home are, on average, those for whom both internal and external tax avoidance are relatively more costly with respect to the individuals shifting residence abroad.

Our paper is closely related to Keen and Slemrod (2017). While Mayshar

[1]This implies that a policy maker — either incumbent or running for election — announcing measures to recover tax revenue by curbing tax avoidance, cannot succeed in terms of both avoidance dimensions.

(1991) originally incorporated tax administration into an optimal tax model, these authors characterize optimal administration by means of a sufficient statistic as in the standard optimal taxation literature (see the review by Piketty and Saez, 2013). Their main finding is the characterization, for tax administration, of the analogue of the elasticity of taxable income, the so-called 'enforcement elasticity of tax revenue', which at the optimum equates to a variation of the (compliance and administrative) costs to revenue ratio. We extend that framework by also considering tax-induced mobility of tax bases both as a consequence of enforcement activities at home and of statutory tax rates differentials across jurisdictions but restrict to taxpayers' avoidance opportunities (see, e.g., Slemrod and Gillitzer, 2014, pp. 53-63, for a typification of the various margins of personal tax avoidance).

Precisely, as Kleven et al. (2020) recently review, there is increasing empirical evidence of higher personal mobility of wealthy and of high-income individuals due to tax rate differentials across countries or within countries at the regional level. Personal mobility is mediated by migration costs, which are not only financial but also related to, in general, the degree of home attachment (Mansoorian and Myers, 1993) or to patriotic feelings (Qari et al., 2012) — a particular type of home attachment. Due to these costs, home countries can set higher taxes in equilibrium, and therefore instilling patriotism can be a strategic policy (Konrad, 2008). Home tax enforcement, though, is also important as long as relocations might be fake (OECD, 2018).

Avoidance, and so tax compliance at home, might also be conditioned by the degree of patriotism (Geys and Konrad, 2020), as it can increase the private incentives to make contributions to the common good. MacGregor and Wilkinson (2012) find some empirical evidence of this hypothesis. That is why in our model we also consider the possibility that personal attributes (patriotism and intrinsic motivation to comply at home) are positively correlated with each other.

Our paper focuses on taxation of high-income or wealthy individuals. Hence, it might provide insights into the design of specific tax enforcement policies for this group of taxpayers or for setting special tax regimes not to lose these tax bases, including exit-taxes.[2] Lehmann et al. (2014) adopt a broader approach as they study the design of nonlinear income tax schedules under Nash tax competition,

[2] https://taxfoundation.org/eu-tax-avoidance-rules-increase-tax-compliance-burden/

but do assume full compliance and so do not consider the simultaneous design of administration policies. Finally, it also differs from Cremer and Gahvari (2000), as they analyze the optimal tax policy (including enforcement) under Nash competition between countries, but in the context of indirect taxes and consumers' cross-border shopping.

The rest of the paper is structured as follows. Section 2 sets up the model by describing taxpayers' choices in terms of internal and external tax avoidance. A general characterization of tax competition and tax administration is presented in Section 3, while specific results are derived in Section 4 for tax policies under tax competition and in Section 5 for tax administration. Section 6 extends the model by allowing the determinants of internal and external tax avoidance to be correlated. Section 7 concludes and an Appendix presents some technical details.

2 Taxpayers' behavior under twofold avoidance

The economy is composed of a 'big' home country H and a 'small' foreign country F (a sort of tax haven), with country H initially populated by a continuum of individuals of unit mass. The analysis focuses on tax cheating in the home country ('internal' tax avoidance) and on fictitious changes of residence from the home to the foreign country ('external' tax avoidance), where taxation is more favorable and tax cheating is not feasible since new residents are taxed in a lump sum form.

2.1 Cheating on income or on residence

All individuals are endowed with one unit of income,[3] exogenously given, which is taxed, on a residence basis, at rate $t \in [0, 1]$ in the home country. The utility of an individual resident in the home country, and reporting income $x \in [0, 1]$, is equal to

$$\tilde{w}^H(x; t, k_j) = 1 - tx - \frac{(1-x)^2}{2k_j}, \qquad (1)$$

[3] Although for the sake of argument we refer to income taxation, the analysis can also be interpreted in terms of wealth taxation under the tax residence principle.

where 1 is income, tx is the tax payment on reported income, and the last term is the cost of tax avoidance,[4] increasing and convex in concealed income, $1-x$, and decreasing in a personal attribute $k_j \geq 0$ that captures the individual's opportunities for tax dodging. Taxpayers' heterogeneity with respect to the cost of tax avoidance, linked to index j (see below), can depend on the source of income, the type of occupation, or the economic sector where income is earned.

By maximizing the utility function (1) with respect to x, income reporting by an individual keeping residence in the home country is equal to

$$x^H(t; k_j) = \max\{1 - tk_j, 0\}. \tag{2}$$

By substituting $x^H(.)$ from Eq. (2) into Eq. (1), the indirect utility is then equal to

$$w^H(t; k_j) = \begin{cases} 1 - t + \dfrac{t^2}{2}k_j, & \text{if} \quad k_j \leq 1/t, \\ 1 - \dfrac{1}{2k_j}, & \text{if} \quad k_j > 1/t. \end{cases} \tag{3}$$

The utility of an individual who transfers the residence to the foreign country is equal to

$$w^F(\tau; p_i) = 1 - \tau - p_i, \tag{4}$$

where $\tau \in [0, t]$ is the lump sum tax[5] applied to new residents and $p_i \geq 0$, linked to index i, is the cost that the individual has to sustain to successfully make a fictitious transfer of residence to the foreign country.

Taxpayers are therefore heterogeneous along two dimensions: with respect to attribute k_j — determining the cost of internal tax avoidance — and with respect to attribute p_i — determining the cost of external tax avoidance. For both forms of tax avoidance, by sustaining the corresponding cost the individual can successfully reduce the tax burden. In the case of internal avoidance, by successfully concealing a share of earned income from the tax authority of the home country. In the case of external avoidance, by successfully pretending to

[4]See, e.g., Slemrod (2001) and Traxler (2012) for throughout treatments of the cost of under-reporting in the context of tax avoidance.

[5]The restriction that $\tau \leq t$ is convenient for expositional reasons and innocuous in analytical terms, since strategic tax setting endogenously implies that $\tau < t$ in equilibrium.

have a stable residence in the foreign country, whereas for the most part the everyday activities continue to take place in the home country.

Formally, we assume that a taxpayer's type is characterized by the pair of attributes (i, j), $i \in [0, 1]$, $j \in [0, 1]$, uniformly and independently distributed,[6] which in turn determine the parameters (p_i, k_j) as follows

$$\begin{aligned} p_i &= iP, \quad \text{where} \quad P = 2\bar{p} + a_p, \quad \bar{p} > 0, \quad a_p \geq 0, \\ k_j &= jK, \quad \text{where} \quad K = 2\bar{k} - a_k, \quad \bar{k} > 0, \quad 0 \leq a_k < 2\bar{k}. \end{aligned} \tag{5}$$

In Eq. (5), $\bar{p}$ and $\bar{k}$ are the 'base' mean values of p_i and k_j, respectively. They express the exogenous 'quality' of the fiscal environment, with larger values of $\bar{p}$ and lower values of $\bar{k}$ determining a better environment, one in which tax avoidance is more costly. The variables a_p and a_k represent tax administration policies; i.e., instruments that the government of country H can employ to improve the quality of the fiscal environment, by increasing the costs of external and internal tax avoidance, respectively. These instruments include policies directed at improving tax administration, tax collection, or at closing the so-called 'tax loop-holes'.[7]

2.2 Locational choices

For given tax rates (t, τ) and administration policies (a_p, a_k), a type-(i, j) individual chooses her residential location[8] by comparing the total cost of keeping residence at home, $w^H(t; k_j)$ in Eq. (3), with the total cost of moving abroad, $w^F(\tau; p_i)$ in Eq. (4). Hence, she keeps her residence in the home country if $w^H \geq w^F$. The latter inequality implies that, for given (t, τ) and k_j, the individuals keeping residence at home are those such that $p_i \geq p^*$, with the threshold p^*

[6] In Section 6, we allow for correlation between attributes (i, j).

[7] For both internal and external tax avoidance, we exclude from the analysis audit activities and the possibility to levy monetary or non-monetary sanctions to discovered tax cheaters. With reference to income under-reporting, this would lead to a framework of tax *evasion* (Allingham and Sandmo, 1972), instead of one of tax *avoidance* (on the distinction between tax evasion and tax avoidance, see, e.g, Cowell, 1990; Blaufus and Hundsdoerfer, 2016; Malik et al., 2018).

[8] Note that, although for brevity we refer to individuals' *locational choices*, in fact we refer to *fictitious transfers of residence* to avoid income taxation at home, where most of everyday life continues to occur.

defined by

$$p^*(k_j; t, \tau) \equiv \begin{cases} t - \tau - \dfrac{t^2}{2} k_j, & \text{if} \quad k_j \leq 1/t, \\ \dfrac{1}{2k_j} - \tau, & \text{if} \quad k_j > 1/t. \end{cases} \tag{6}$$

Using Eq. (5), the threshold defined in Eq. (6) can be expressed as a corresponding threshold in terms of attribute i as a function of attribute j, as follows

$$i^*(j; \boldsymbol{\pi}, \boldsymbol{\sigma}) \equiv \begin{cases} \dfrac{t-\tau}{P(\bar{p}, a_p)} - \dfrac{K(\bar{k}, a_k)}{P(\bar{p}, a_p)} \dfrac{t^2}{2} j, & \text{if} \quad j \leq \dfrac{1}{K(\bar{k}, a_k)t}, \\ \dfrac{1}{2P(\bar{p}, a_p)K(\bar{k}, a_k)j} - \dfrac{\tau}{P(\bar{p}, a_p)}, & \text{if} \quad j > \dfrac{1}{K(\bar{k}, a_k)t}, \end{cases} \tag{7}$$

where $\boldsymbol{\pi} = (t, \tau, a_p, a_k)$ denotes the vector of policy instruments and $\boldsymbol{\sigma} = (\bar{p}, \bar{k})$ the vector of the baseline population-average costs of external and internal tax avoidance. For given $\boldsymbol{\pi}$ and $\boldsymbol{\sigma}$, denote with $\mathcal{H}(i, j; \boldsymbol{\pi}, \boldsymbol{\sigma})$ the set of types (i, j) keeping their residence in the home country, with $\mathcal{H}(.)$ defined by

$$\mathcal{H}(i, j; \boldsymbol{\pi}, \boldsymbol{\sigma}) = \{(i, j) \in [0, 1] \times [0, 1] \,|\, i \geq i^*(j; \boldsymbol{\pi}, \boldsymbol{\sigma})\}. \tag{8}$$

The mass of the individuals keeping residence in country H is then equal to

$$m^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = \iint_{\mathcal{H}(i,j;\boldsymbol{\pi},\boldsymbol{\sigma})} \mathrm{d}i \, \mathrm{d}j, \tag{9}$$

while that of the individuals moving abroad is $m^F(\boldsymbol{\pi}, \boldsymbol{\sigma}) = 1 - m^H(\boldsymbol{\pi}, \boldsymbol{\sigma})$.

We undertake some comparative statics analysis about the impact of policy instruments on residential choices in Section 4, where we examine locational choices in detail. We next provide a general analysis of tax policy setting.

3 Tax policy: general analysis

For $t \leq 1/K$, so that — see Eq. (2) — reported income is positive for all taxpayers,[9] the average reported income by taxpayers in the home country is equal to $\bar{x}^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = 1 - t\bar{k}^H(\boldsymbol{\pi}, \boldsymbol{\sigma})$, where $\bar{k}^H(\boldsymbol{\pi}, \boldsymbol{\sigma})$, the average k_j of taxpayers keeping residence in the home country, is equal to

$$\bar{k}^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = (2\bar{k} - a_k) \iint_{\mathcal{H}(i,j;\boldsymbol{\pi},\boldsymbol{\sigma})} \frac{j}{m^H(\boldsymbol{\pi}, \boldsymbol{\sigma})} \mathrm{d}i \, \mathrm{d}j, \tag{10}$$

[9] We show in Section 4 that the Nash equilibrium is always characterized by $t \leq 1/K$.

with $m^H(\boldsymbol{\pi}, \boldsymbol{\sigma})$ defined in Eq. (9).

The tax revenue of the home government is then equal to

$$T^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = t\, \bar{x}^H(\boldsymbol{\pi}, \boldsymbol{\sigma})\, m^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) - C_p(a_p) - C_k(a_k), \tag{11}$$

where $C_p(a_p)$ and $C_k(a_k)$ are the costs of tax administration, $C_p(0) = C_k(0) = 0$, both increasing and strictly convex functions of the policy instruments.[10]

The tax revenue in the foreign country is equal to

$$T^F(\boldsymbol{\pi}, \boldsymbol{\sigma}) = \tau\, m^F(\boldsymbol{\pi}, \boldsymbol{\sigma}). \tag{12}$$

3.1 Tax setting under tax competition

The governments of both countries pursue the Leviathan objective of maximizing their own revenue collected. We start by examining tax setting, assuming Cournot-Nash competition, taking as given the administration policies (a_p, a_k) in the home country. The first order conditions that characterize the Nash equilibrium are[11]

$$\frac{\partial T^H}{\partial t} = \bar{x}^H m^H + t\left(m^H \frac{\partial \bar{x}^H}{\partial t} + \bar{x}^H \frac{\partial m^H}{\partial t}\right) = 0, \tag{13}$$

$$\frac{\partial T^F}{\partial \tau} = m_i^F + \tau \frac{\partial m^F}{\partial \tau} = 0. \tag{14}$$

As is standard in optimal tax theory (see, e.g., Keen and Slemrod, 2017), we define elasticities for the relevant variables with respect to net tax rates as

[10]Note that a_p and a_k represent tax administration policies expressed in *efficiency units*. As such, they impact linearly — with constant returns — on the internal and external tax avoidance costs of taxpayers — see Eq. (5) — while they bear convex costs $C_p(a_p)$ and $C_k(a_k)$ in the revenue function shown in Eq. (11). The equivalent (but less convenient, in analytical terms) alternative is to assume that a_p and a_k represent tax administration policies expressed in *monetary units*, impacting with decreasing returns on the internal and external tax avoidance costs of taxpayers, while bearing linear costs in the government's revenue function.

[11]We show, in Section 4 and Appendix A.2, that the Nash equilibrium is unique and stable, and that the second order condition for revenue maximization holds for both countries.

follows:

$$\varepsilon(\bar{x}^H, 1-t) = -\frac{\partial \bar{x}^H}{\partial t}\frac{1-t}{\bar{x}^H}, \tag{15}$$

$$\varepsilon(m^H, 1-t) = -\frac{\partial m^H}{\partial t}\frac{1-t}{m^H}, \tag{16}$$

$$\varepsilon(m^F, 1-\tau) = -\frac{\partial m^F}{\partial \tau}\frac{1-\tau}{m^F}. \tag{17}$$

Eq. (15) defines the elasticity expressing how strongly the taxpayers with residence in the home country react to higher taxation by reducing reported income; i.e., it is the elasticity of *internal* tax avoidance. Eq. (16) defines the elasticity expressing how strongly taxation in the home country provides incentives to fictitiously move residence to the foreign country; i.e., it is the elasticity of *external* tax avoidance and tax competition. Finally, Eq. (17) defines the elasticity expressing how attractive the foreign tax policy is for home taxpayers; i.e., it is the elasticity representing the 'other side of the coin', for both *external* tax avoidance and tax competition.

Using the above elasticities, it is immediate to express the first order conditions (13)-(14) in terms of standard 'inverse elasticity rules' by which the equilibrium tax rates are implicitly characterized as follows:

$$\frac{t}{1-t} = \frac{1}{\varepsilon(\bar{x}^H, 1-t) + \varepsilon(m^H, 1-t)}, \tag{18}$$

$$\frac{\tau}{1-\tau} = \frac{1}{\varepsilon(m^F, 1-\tau)}. \tag{19}$$

Eq. (18) shows that the home tax rate is determined by elasticities (15) and (16), Eq. (19) that the foreign tax rate is determined by elasticity (17). *Ceteris paribus*, larger elasticities imply lower tax rates in equilibrium. Notice that although Eqs. (18)-(19) show that each equilibrium tax rate is inversely related to the relevant elasticities with respect to the *same* tax rate, each elasticity is also a function of the *other* tax rate, in ways that are related to the type of behavioral responses of taxpayers to both tax rates. Finally, recall that the elasticities on the right hand sides of Eqs. (18)-(19) are also a function of tax administration policies, to which we turn next.

3.2 Tax administration in the home country

The first order condition for maximizing the tax revenue function defined in Eq. (11) with respect to the administration policy $\alpha \in \{p, k\}$ is[12]

$$\frac{\partial T^H}{\partial a_\alpha} = t\left(m^H \frac{\partial \bar{x}^H}{\partial a_\alpha} + \bar{x}^H \frac{\partial m^H}{\partial a_\alpha}\right) - C'_\alpha(a_\alpha) = 0, \quad \alpha = p, k. \tag{20}$$

Defining the elasticities with respect to the administration policies as

$$\varepsilon(\bar{x}^H, a_\alpha) = \frac{\partial \bar{x}^H}{\partial a_\alpha}\frac{a_\alpha}{\bar{x}^H}, \quad \varepsilon(m^H, a_\alpha) = \frac{\partial m^H}{\partial a_\alpha}\frac{a_\alpha}{m^H} \quad \alpha = p, k, \tag{21}$$

the first order condition for optimal tax administration can be expressed as

$$\varepsilon(\bar{x}^H, a_\alpha) + \varepsilon(m^H, a_\alpha) = \frac{a_\alpha C'_\alpha(a_\alpha)}{T^H} \quad \alpha = p, k. \tag{22}$$

Like Eq. (9) in Keen and Slemrod (2017), our Eq. (22) shows that instrument α is optimally set if the sum of the elasticities of income reporting and of residential location of policy α is equal to a linear approximation of the so-called adjusted marginal cost-revenue ratio of policy α.

4 Tax policy: specific analysis

The analysis in the previous section provides a general characterization of tax and administration policies under the incentives of tax competition. We now take a closer look at the properties of such policies, starting, in this section, with tax setting, and then adding, in Section 5, tax administration.

As a preliminary step, it is useful to consider two benchmark cases.

4.1 Tax setting under two benchmark cases

In the first benchmark, taxpayers cannot transfer their residence abroad but can avoid the income tax at home.[13]

Proposition 1 *With internal, but no external, tax avoidance, for given* $K = 2\bar{k} - a_k$, $\bar{k} > 0$, $0 \leq a_k < 2\bar{k}$, *the home-country revenue-maximizing tax rate*

[12] Second order conditions have been checked with a wide range of numerical simulations. See Section 4 for details.

[13] Formally, no residence shifting can be obtained by letting $\bar{p} \to \infty$.

is equal to $t_1^* = \min\left(\frac{1}{K}, 1\right)$*. If* $0 < K \leq 1$*, average reported income is equal to* $\bar{x}_1^{H*} = 1 - \frac{K}{2} > 0$*. If* $K > 1$*, it is equal to* $\bar{x}_1^{H*} = \frac{1}{2}$*.*

Proof. With immobile taxpayers, $m^H = 1$ and $\bar{x}^H = 1 - t\frac{K}{2}$. By maximizing $T^H = t\bar{x}^H$ with respect to t one gets $t_1^* = \min\left(\frac{1}{K}, 1\right)$. If $0 < K \leq 1$, by substituting $t_1^* = 1$ into $\bar{x}^H$ one obtains $\bar{x}_1^{H*} = 1 - \frac{K}{2}$. If $K > 1$, by substituting $t_1^* = \frac{1}{K}$ into $\bar{x}^H$ one obtains $\bar{x}_1^{H*} = \frac{1}{2}$. ■

Note that, at the optimal tax policy t_1^*, individual income reporting is at an interior solution $x_1^{H*} = 1 - t_1^* jK \geq 0$ for all types $j \in [0, 1]$, for all $K > 0$.

In the second benchmark, taxpayers can make fictitious residence relocations but cannot conceal income at home.[14]

Proposition 2 *With external, but no internal, tax avoidance, for given* $P = 2\bar{p} + a_p$, $\bar{p} \geq 0$, $a_p \geq 0$*, the Nash equilibrium tax rates are* $t_2^* = \min\left(\frac{2}{3}P, 1\right)$, $\tau_2^* = \min\left(\frac{1}{3}P, \frac{1}{2}\right)$*. If* $0 \leq P \leq \frac{3}{2}$*, the mass of taxpayers keeping residence in the home country is equal to* $m_2^{H*} = \frac{2}{3}$*. If* $P > \frac{3}{2}$*, it is equal to* $m_2^{H*} = 1 - \frac{1}{2P}$*.*

Proof. With no internal avoidance, $\bar{x}^H = 1$, $p^* = t - \tau$, $m^H = 1 - (t - \tau)/P$. By maximizing $T^H = t[1 - (t - \tau)/P]$ with respect to t, for given τ, one gets the best response function $t = \frac{\tau + P}{2}$ of the home government. By maximizing $T^F = \tau(t - \tau)/P$ with respect to τ, for given t, one gets the best response function $\tau = \frac{t}{2}$ of the foreign government. By combining the best response functions, the unique Nash equilibrium is $t_2^* = \frac{2}{3}P$, $\tau_2^* = \frac{1}{3}P$. If $0 \leq P \leq \frac{3}{2}$, it is $t_2^* \leq 1$ and $\tau_2^* < 1$. If $P > \frac{3}{2}$, it is $t_2^* = 1$ and $\tau_2^* = \frac{1}{2}$. The mass of taxpayers keeping residence in the home country is equal to $m_2^{H*} = 1 - (t_2^* - \tau_2^*)/P = \frac{2}{3}$ if $0 \leq P \leq \frac{3}{2}$. It is equal to $m_2^{H*} = 1 - \left(1 - \frac{1}{2}\right)/P = 1 - \frac{1}{2P}$ if $P > \frac{3}{2}$. ■

Propositions 1 and 2 are illustrated in Figure 1. Without loss of generality, assume no administration policies, so that $K = 2\bar{k}$ in Proposition 1 and $P = 2\bar{p}$ in Proposition 2. Then, in an economy with no external tax avoidance and low levels of internal avoidance ($K \leq 1$), the tax rate is set at 100%, since income is exogenous. It is instead less than 100%, decreasing in K, in economies with large opportunities of internal tax avoidance ($K > 1$). At the other end, in an economy with no internal tax avoidance and high levels of external tax avoidance ($P \leq \frac{3}{2}$),

[14] Formally, this situation can be obtained by letting $\bar{k} \to 0$.

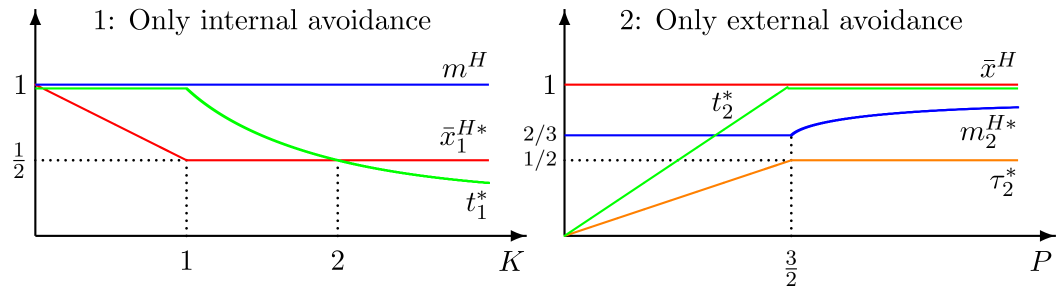


Figure 1: Tax setting under two benchmark cases.

tax competition forces both governments to set tax rates below 100%, and the more so the less costly is for taxpayers to shift residence (i.e., the lower is P). The home tax rate is instead 100%, while the foreign one is 50%, in economies with low opportunities for residence relocations ($P \geq \frac{3}{2}$).

We now go back to the general case in which both internal and external tax avoidance practices can be undertaken by the citizens of the home country.

4.2 Locational choices in the taxpayers' types space

The equation $i = i^*(j; \boldsymbol{\pi}, \boldsymbol{\sigma})$, with $i^*(.)$ defined in Eq. (7), separates the individuals keeping their residence at home — the types (i, j) for whom $i \geq i^*(j; \boldsymbol{\pi}, \boldsymbol{\sigma})$ — from those moving it abroad — those for whom $i < i^*(j; \boldsymbol{\pi}, \boldsymbol{\sigma})$. Clearly, depending on the way the separating equation $i = i^*(j; \boldsymbol{\pi}, \boldsymbol{\sigma})$ crosses the support set of attributes (i, j), different types of locational equilibria can emerge. Here we consider only one type of locational equilibrium that we label as 'standard' type. The reason for focusing on this type only is that the tax competition game we examine in Section 4.4 always admits a unique Nash equilibrium such that, at the given equilibrium tax rates, the locational equilibrium is of standard type.

A standard locational equilibrium is represented in Figure 2 and is formally characterized in Definition 1.

Definition 1 *Standard locational equilibria* (SLE) *are characterized by the following conditions:* (i) $t \leq 1/K(\bar{k}, a_k)$, (ii) $i^*(0; \boldsymbol{\pi}, \boldsymbol{\sigma}) \leq 1$, (iii) $i^*(1; \boldsymbol{\pi}, \boldsymbol{\sigma}) \geq 0$.

In SLE, for all $j \in [0, 1]$ there are some taxpayers keeping residence at home — those with $i \geq i^*(j; \boldsymbol{\pi}, \boldsymbol{\sigma})$ — and some others shifting it abroad — those with

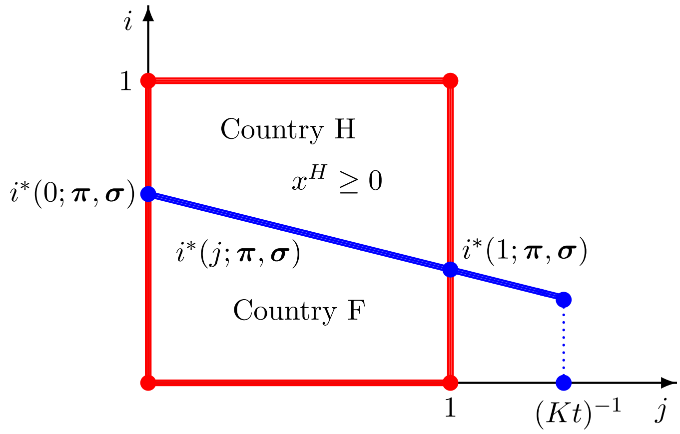


Figure 2: A 'standard' locational equilibrium in the (i, j) space

$i < i^*(j;\boldsymbol{\pi},\boldsymbol{\sigma})$. Moreover, all separating values $i^*(j;\boldsymbol{\pi},\boldsymbol{\sigma})$ belong to the linear part of the piecewise function defined in Eq. (7), since the maximum value of j, $j = 1$, is less than $(Kt)^{-1}$.

Figure 3 illustrates the comparative statics properties of SLE. An increase in the home tax rate t, by making the line $i = i^*(j;\boldsymbol{\pi},\boldsymbol{\sigma})$ to shift upward and to rotate clockwise, increases the transfers of residence $m^F(.)$. The opposite occurs in response to an increase in the foreign tax rate τ, causing the line to shift downward. An increase of $\bar{p}$ or a_p reduces the transfers of residence, since the separating line shifts downward and rotates anti-clockwise. Finally, a decrease of $\bar{k}$, or an increase of a_k, increases the transfers of residence, since the separating line rotates anti-clockwise keeping fixed the intercept at $j = 0$.

Note also, from Figures 2 and 3, that, as expected, the individuals characterized by relatively high values of i — those with lower opportunities for external tax avoidance — tend to stay in the home country. That is, $\bar{\imath}^H > 1 > \bar{\imath}^F$, where $\bar{\imath}^H$ and $\bar{\imath}^F$ are the mean values of i for the individuals staying at home and fictitiously moving abroad, respectively. The opposite situation arises with respect to the attribute j. Since the separating line $i = i^*(j;\boldsymbol{\pi},\boldsymbol{\sigma})$ is negatively sloped, and since we are currently assuming that i and j are uncorrelated, then the individuals keeping their residence at home tend to be, on average, more inclined to internal tax avoidance than those falsely transferring their residence abroad; that is, $\bar{\jmath}^H > 1 > \bar{\jmath}^F$. We return to this issue in Section 6, where we consider correlated attributes (i, j), and in the concluding Section 7.

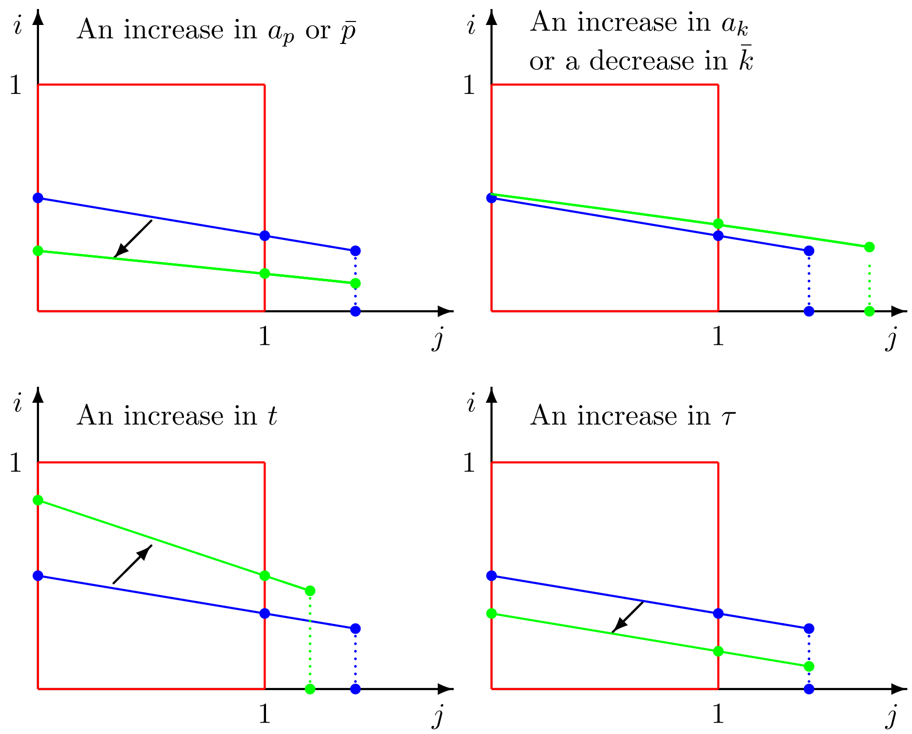


Figure 3: Comparative statics on Standard Locational Equilibria (SLE)

4.3 Locational choices in the tax rates space

Definition 1 characterizes the set of SLE in the (i, j) space for given policy parameters $\boldsymbol{\pi} = (t, \tau, a_p, a_k)$ and baseline average costs $\boldsymbol{\sigma} = (\bar{p}, \bar{k})$. In order to examine tax competition, we now characterize the set of SLE in the tax rates space (t, τ), for given (a_p, a_k) and $(\bar{p}, \bar{k})$. The formal characterization is in Lemma 1. Figure 4 illustrates.

Lemma 1 *For given (a_p, a_k) and $(\bar{p}, \bar{k})$, the set $S(a_p, a_k, \bar{p}, \bar{k})$ of tax rates (t, τ), $0 \leq \tau \leq t \leq 1$, such that the locational equilibria are of standard type is characterized by the following conditions:* (i) $t \leq 1/K(\bar{k}, a_k)$, (ii) $\tau \geq t - P(\bar{p}, a_p)$, (iii) $\tau \leq t - \frac{1}{2}t^2 K(\bar{k}, a_k)$.

Proof. By Definition 1, point (ii), SLE are characterized by $i^*(0; \boldsymbol{\pi}, \boldsymbol{\sigma}) \leq 1$. Since, by Eq. (7), $i^*(0; \boldsymbol{\pi}, \boldsymbol{\sigma}) = \frac{t-\tau}{P(.)}$, the condition can be written as $\tau \geq t - P(.)$, which is point (ii) in Lemma 1. By Definition 1, point (iii), SLE are characterized by $i^*(1; \boldsymbol{\pi}, \boldsymbol{\sigma}) \geq 0$. Since, by Eq. (7), $i^*(1; \boldsymbol{\pi}, \boldsymbol{\sigma}) = \frac{t-\tau}{P(.)} - \frac{K(.)t^2}{2P(.)}$, the condition can be written as $\tau \leq t - \frac{1}{2}t^2 K(.)$, which is point (iii) in Lemma 1. Finally, point (i) in Lemma 1 simply follows from point (i) in Definition 1. ■

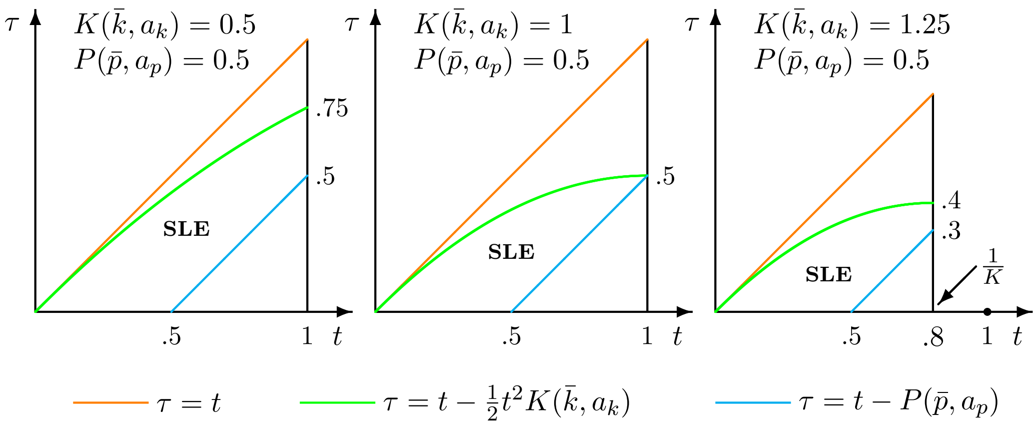


Figure 4: Standard locational equilibria (SLE) in the (t, τ) space

Setting three specific pairs of values (P, K) to exemplify, Figure 4 shows the region in the tax rates space in which the locational equilibria are of standard type. Condition (iii) in Lemma 1 is delimited by the quadratic function drawn in green. Condition (ii) is delimited by the line depicted in blue. For all pairs of tax rates (t, τ) that are included in the area delimited by the green curve (from above) and by the blue line (fom below), the locational equilibrium is of standard type. Note that as K increases, for given P, the region containing SLE shrinks, since the quadratic green curve moves downward while, but only if $K > 1$, the maximum admissible value of t, $1/K$, lowers. Also a decrease in P, for given K (not represented in Figure 4), shrinks the region of SLE, since the blue line shifts upwards.

4.4 Tax competition: technical analysis

We are now ready to characterize the Nash equilibrium of the tax competition game, already defined in Section 3 in general terms. Focusing, as remarked above, on SLE, we first characterize the key variables of the model.

Lemma 2 *For* $(t, \tau) \in S(a_p, a_k, \bar{p}, \bar{k})$*, the mass, the average value of* k_j*, and the* *average income reporting, of taxpayers keeping residence at home, are equal to*

$$m^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = 1 - \frac{4K(t-\tau) - (Kt)^2}{4PK}, \tag{23}$$

$$\bar{k}^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = K \frac{3PK - 3K(t-\tau) + (Kt)^2}{6PKm^H(\boldsymbol{\pi}, \boldsymbol{\sigma})}, \tag{24}$$

$$\bar{x}^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = 1 - t\,\bar{k}^H(\boldsymbol{\pi}, \boldsymbol{\sigma}), \tag{25}$$

respectively.

Proof. See Appendix A.1. ■

The next step is to employ the variables defined in Lemma 2 to specify the tax revenue functions of the home and the foreign governments — Eqs. (11) and (12), respectively — and then to compute, by solving the first order conditions shown in Eqs. (13) and (14), the best response functions of each policy maker. The result is in the following proposition.

Proposition 3 *For $(t, \tau) \in S(a_p, a_k, \bar{p}, \bar{k})$, the best response function of country F, $\tau = b_F(t)$, and the inverse best response function of country H, $\tau = b_H^{-1}(t)$, are equal to*

$$\tau = b_F(t) \equiv \frac{t}{2} - \frac{Kt^2}{8}, \tag{26}$$

$$\tau = b_H^{-1}(t) \equiv \frac{(8K^2t^2 - 27Kt + 24)t}{12(1-Kt)} - P. \tag{27}$$

Proof. Differentiate Eq. (12) with respect to τ, using Eq. (23), and then solve for τ to obtain Eq. (26). Differentiate Eq. (11) with respect to t, using Eqs. (23), (24) and (25), and then solve for τ to obtain Eq. (27). ■

The best response τ of the foreign government, shown in Eq. (26), is a simple quadratic increasing function of t. Instead, there is no explicit solution to express the best response t of the home government to the tax rate τ. However, its inverse function, with τ expressed as a function of t, can be computed, which is shown in Eq. (27).

From the best response functions shown in Proposition 3, we obtain the Nash equilibrium characterized in the following proposition.

Proposition 4 *If, for given* (a_p, a_k) *and* $(\bar{p}, \bar{k})$*, the set* $S(a_p, a_k, \bar{p}, \bar{k})$ *defined in Lemma 1 is non empty, and if there exists a Nash equilibrium* (t^*, τ^*) *of the tax competition game such that* $t^* \in (0,1)$ *and* $\tau^* \in (0,1)$*, then* $t^* > \tau^*$*, equal to*

$$t^* = \frac{z^*(PK)}{K}, \quad \tau^* = \frac{t^*}{2} - \frac{z^*(PK)^2}{8K}, \tag{28}$$

where $P = 2\bar{p} + a_p$*,* $K = 2\bar{k} - a_k$*,*

$$z^*(PK) \equiv \begin{cases} 1 - \dfrac{\phi(PK)}{26}(1 - I\sqrt{3}) + \dfrac{8PK - 1}{2\phi(PK)}(1 + I\sqrt{3}), & \text{if} \quad PK < \dfrac{1}{8}, \\ 1 + \dfrac{\phi(PK)}{13} - \dfrac{8PK - 1}{\phi(PK)}, & \text{if} \quad PK > \dfrac{1}{8}, \end{cases} \tag{29}$$

and where

$$\phi(PK) = \left(-845 + 26\sqrt{1664(PK)^3 - 624(PK)^2 + 78PK + 1053}\right)^{1/3}. \tag{30}$$

Proof. Multiplying both sides of Eqs. (26) and (27) by K, we have

$$K\tau = \frac{4Kt - (Kt)^2}{8}, \tag{31}$$

$$K\tau = \frac{8(Kt)^3 - 27(Kt)^2 + 24Kt}{12(1 - Kt)} - PK. \tag{32}$$

Making the change of variable $z = Kt$, combining Eqs. (31)-(32), and solving for z, we obtain the unique solution $z^*(PK)$ in Eq. (29).[15] By the definition of z, t^* is then equal to z^*/K and, finally, by substituting t^* into Eq. (26) we get τ^*. ■

Proposition 4 states that, if an interior Nash equilibrium in the region of SLE exists, then the equilibrium tax rates are those shown in Eq. (28). The proposition does not provide existence, uniqueness and stability conditions of the equilibrium, or conditions for the solution to be interior (i.e., with tax rates strictly positive and below 100%). Since the formal derivation of such conditions turns out to be analytically complex (without providing additional insights about tax policy), our strategy is that of checking for the above properties and conditions by numerically computing the equilibrium over a wide range of values of the key parameters of the model. Referring for the details to Appendix A.2, here we

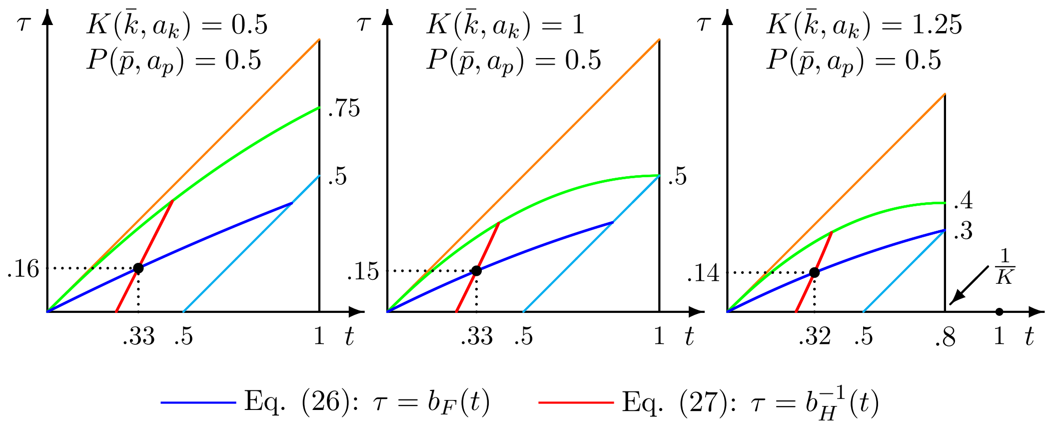


Figure 5: Nash equilibria in SLE

summarize the main results with the help of Figure 5, which employs the same three numerical examples considered in Figure 4. The blue curve is Eq. (26), the best response function of the foreign government. According to this function, τ is an increasingly concave quadratic function of t, starting at $(t, \tau) = (0, 0)$ and then lying strictly below the increasingly concave quadratic green curve delimiting from above the set of SLE. The red curve is Eq. (27), the best response function of the home government. This function is such that $\tau = -P$ at $t = 0$. It is then increasing in t, with slope greater than that of the blue curve, and it tends asymptotically to $\tau \to +\infty$ for $t \to 1/K$ (clearly, this is the case only if $K > 1$, as in the third panel of Figure 5; otherwise, if $K < 1$, as in the first two panels, the asymptote is not reached because its value $1/K > 1$ is outside the admissible range of values for t). Hence, the best response of the home government — the red curve — has a positive intercept on the t axis and then it crosses once, from below (implying stability of the equilibrium), the best response of the foreign government — the blue curve. The crossing point is the unique Nash equilibrium in the set of SLE. A further result derived from the numerical analysis in Appendix A.2 is that, in general, the Nash equilibrium tax rates defined in Proposition 4 always determine a standard locational equilibrium. We summarize the above discussion in the following remark.[16]

[15] The solution in Eq. (29) has been obtained with the mathematical software Maple. Note that the imaginary unit is denoted by I, in place of the usual i, in order to avoid confusion with the personal attribute i.

[16] We label Lemma or Proposition the results of which we provide formal proofs. We label Remark the results that are derived from numerical analysis.

Remark 1 *In general, the Nash equilibrium of the tax competition game, characterized in Proposition 4, exists, is unique and stable, and it determines a standard locational equilibrium of residential choices.*

It is instead possible, see again Appendix A.2 for the details, that the Nash equilibrium is not interior. In particular, for values of K close to zero and values of P sufficiently large, it is possible that the equilibrium is such that $t^* = 1$, a result which is accordance with those emerging from the two benchmark cases examined in Propositions 1 and 2.

4.5 Tax competition: economic interpretation

Proposition 4 and Remark 1 deal with the *analytical* properties of the Nash equilibrium resulting from tax competition. In order to gain insights about its *economic* properties, it is crucial to examine the properties of the function $z^*(PK)$ defined in Eq. (29). Since z^* is obtained by solving the cubic equation in Kt resulting by equating Eqs. (31) and (32), the solution shown in Eq. (29) has a real root for $PK > 1/8$ (since the argument of the cubic root in Eq. (30) is positive) and a complex root for $PK < 1/8$ (since the argument is negative), while there is no solution for $PK = 1/8$ (since the argument is zero). However, in practice z^* is continuous at $PK = 1/8$, since $\lim_{PK\to(1/8)^-} z^* = \lim_{PK\to(1/8)^+} z^*$; moreover, for $PK < 1/8$ the imaginary part of the complex root is negligible, so that the real part can be taken as a real solution. The remaining properties are stated in the following remark.

Remark 2 *The function $z^*(PK)$, $PK > 0$, defined in Eq. (29), has the follwing properties:* $\lim_{PK\to 0} z^* = 0$, $\lim_{PK\to\infty} z^* = 1$, *continuous, monotonically increasing and strictly concave,* $0 < \frac{dz^*}{d(PK)} < 1$.

By combining Remark 2 with Eq. (28) in Proposition 4, we can see that, provided that the Nash equilibrium is interior, $t^* = z^*/K < 1/K$, since $z^* < 1$. That is, external tax avoidance lowers the home tax rate below the level, $1/K$, prevailing with only internal tax avoidance (Proposition 1). Moreover, since $t^*/\tau^* = \frac{1}{2} - \frac{z^*}{8}$, internal tax avoidance lowers the ratio between the foreign and the home tax rate below the level of 1/2 prevailing with only external tax avoidance (Proposition 2). The results are summarized in the following remark.

Remark 3 *If the Nash equilibrium is interior, then*

$$0 < t^* < \frac{1}{K}, \qquad \frac{3}{8} < \frac{\tau^*}{t^*} < \frac{1}{2}, \tag{33}$$

with t^* increasing in P for given K, decreasing in K for given P, and τ^*/t^* decreasing in PK.

By combining Lemma 2 and Proposition 4, we obtain the following result.

Proposition 5 *For any given pair (P, K) such that the Nash equilibrium of the tax competition game is as defined in Proposition 4, the mass of taxpayers keeping residence at home in equilibrium, and the average income reporting in equilibrium, are both functions of the product PK only, as follows*

$$m^{H*}(PK) = 1 - \frac{z^*(PK)[4 - z^*(PK)]}{8PK}, \tag{34}$$

$$\bar{x}^{H*}(PK) = 1 - z^*(PK)\frac{5z^*(PK)^2 - 12z^*(PK) + 24PK}{48PKm^{H*}(PK)}, \tag{35}$$

with the function $z^*(PK)$ defined in Eq. (29).

Proof. From Eq. (28) in Proposition 4, we see that the products Kt^* and $K\tau^*$ are a function of the product PK through the function $z^*(PK)$. By Lemma 2, we see that $m^H(.)$, the fraction $\bar{k}^H(.)/K$ and $\bar{x}^H(.) = 1 - (Kt)\left[\bar{k}^H(.)/K\right]$ are a function of Kt, $K\tau$ and PK. Hence, for $t = t^*$, $\tau = \tau^*$, the equilibrium values of m^H and $\bar{x}^H$, denoted by m^{H*} and $\bar{x}^{H*}$ and shown in Eqs. (34) and (35), respectively, are functions of the product PK only. ■

Proposition 5 shows an important result. Namely, that the two key indicators of fiscal outcomes, the mass of people keeping residence in the home country (its complement to one expressing the degree of external tax avoidance), and the average level of tax reporting at home (its complement to one expressing the degree of internal tax avoidance), do not depend separately — through the Nash equilibrium of the tax competition game — on P and K, but only on their product PK.

Leaving aside tax administration policies, on which we focus in Section 5, with $a_p = a_k = 0$, it is $P = 2\bar{p}$ and $K = 2\bar{k}$. That is, and as already remarked, the values taken by P and K express the 'quality' of the fiscal environment, since high (low) values of P (K) mean that taxpayers have, on average, not

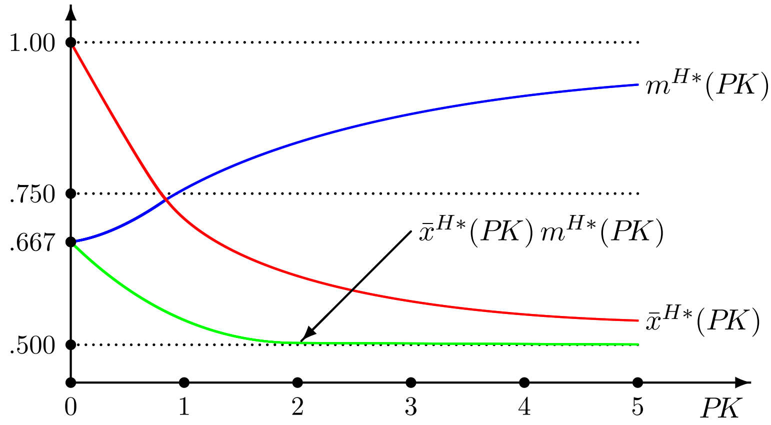


Figure 6: Internal and external tax avoidance as a function of PK

many opportunities to cheat on residence (income reporting). Proposition 5 then shows that although P and K are, by modeling assumption, independent drivers of tax avoidance, the corresponding outcomes are not independent, since there is a one-to-one relation, via the Nash equilibrium of the tax competition game, between m^{H*} and $\bar{x}^{H*}$ that is a function of the product PK.

Using Remark 2, and numerical analysis, the following remark lists the properties of the functions shown in Eqs. (34) and (35) of Proposition 5.

Remark 4 *The function $m^{H*}(PK)$, defined in Eq. (34), has the follwing properties:* $\lim_{PK\to 0} m^{H*} = \frac{2}{3}$, $\lim_{PK\to\infty} m^{H*} = 1$, *continuous and monotonically increasing. The function $\bar{x}^{H*}(PK)$, defined in Eq. (35), has the follwing properties:* $\lim_{PK\to 0} \bar{x}^{H*} = 1$, $\lim_{PK\to\infty} \bar{x}^{H*} = \frac{1}{2}$, *continuous and monotonically decreasing.*

Figure 6 illustrates and highlights three economic implications resulting from the Nash equilibrium of the tax competition game. The first is that even very different fiscal environments, in terms of P and K, can determine the same outcomes m^{H*} and $\bar{x}^{H*}$, provided that the value of the product PK is the same. The second is that there is a clear tradeoff between internal and external tax avoidance outcomes, since any given fiscal environment (P_1, K_1) cannot outperform another environment (P_2, K_2) on both outcomes, since $m_1^{H*} \lesseqgtr m_2^{H*}$ and $\bar{x}_1^{H*} \gtreqless \bar{x}_2^{H*}$ if $P_1K_1 \lesseqgtr P_2K_2$. Finally, for any given feasible value of m^{H*} there is only one corresponding value of $\bar{x}^{H*}$.

Note that for values of PK tending to zero one obtains the benchmark case derived in Proposition 2, in which there is external but not internal tax avoid-

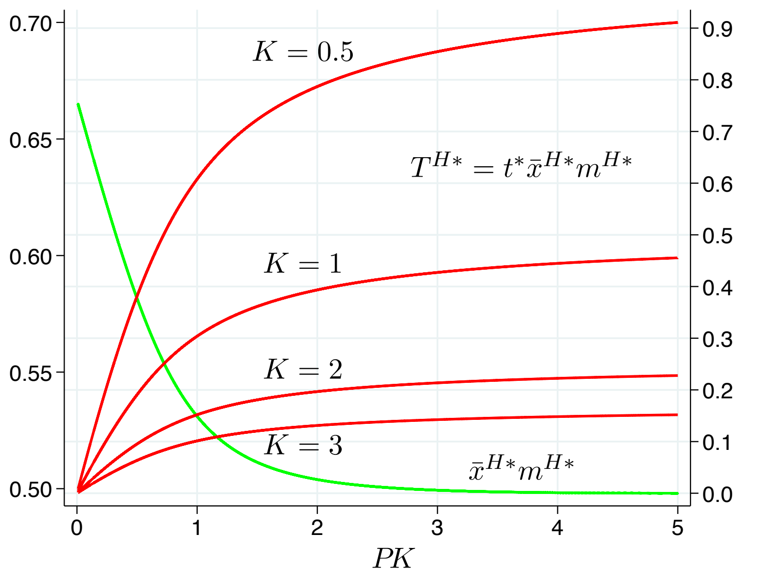


Figure 7: Taxable income and tax revenue in the home country.

ance, with 2/3 of taxpayers keeping residence at home in equilibrium. Instead, for values of PK tending to infinity one obtains the benchmark case derived in Proposition 1, in which there is internal but not external tax avoidance, with average income reporting equal to 50% in equilibrium.

The last comment concerns the green curve in Figure 6, representing *taxable income*.[17] The graph shows that taxable income $m^{H*}\bar{x}^{H*}$, which is equal to 2/3 when PK is close to zero, is a monotonically decreasing and convex function of PK, approaching, for values of PK around 2, its asymptotic value of 1/2. Note, however, that a constant value of taxable income of 1/2 for $PK > 2$ does not imply that tax revenue in the home country is constant, since tax revenue results from the product of taxable income and the equilibrium tax rate t^*, which is decreasing in K, for given PK, and increasing in PK, for given K. Figure 7 illustrates. The green curve represents (on the left axis) taxable income as a function of PK. Tax revenue in the home country, as a function of PK and for given values of K is represented (on the right axis) by the red curves. As we can see, tax revenue $T^{H*} = t^* \bar{x}^{H*} m^{H*}$ is increasing in PK, for given K, since the increase in the home tax rate t^* more than outweighs the reduction in taxable

[17] In defining *taxable income*, we follow Keen and Slemrod (2017), footnote 6. Taxable income is what is effectively taxed, not what in principle should be taxed. In our case, taxable income is $m^{H*}\bar{x}^{H*} < 1$ whereas full income is 1.

income $\bar{x}^{H*}m^{H*}$. Moreover, it is decreasing in K, for given PK, since taxable income is constant but the tax rate decreases.

5 Optimal tax system under twofold avoidance

We examine tax administration by the home government in two steps. First, we ask which policy instrument, a_p or a_k, is more effective at recovering tax revenue, by comparing the marginal tax revenue associated to a small increase in each instrument, evaluated at the 'starting point' of no tax administration $a_p = a_k = 0$. This *local* approach, which is useful in that it delivers analytical results, is then complemented by the second step, presenting a numerical analysis of the *global* optimum in tax administration.

5.1 Local analysis

Proposition 6 *Let (t^*, τ^*) be the Nash equilibrium tax rates derived in Proposition 4. Starting from $a_p = a_k = 0$, an infinitesimal increase in one of the policy instruments (a_p, a_k) impacts on tax revenue at home as follows*

$$\left.\frac{\partial T^H}{\partial a_p}\right|_0^* = \frac{2(Kt^*)^4 - 9(Kt^*)^3 + 6[(K\tau^*) + 2](Kt^*)^2 - 12(Kt^*)(K\tau^*)}{12(PK)^2}, \quad (36)$$

$$\left.\frac{\partial T^H}{\partial a_k}\right|_0^* = \frac{4(Kt^*)^4 - 9(Kt^*)^3 + 6[(PK) + (K\tau^*)](Kt^*)^2}{12(PK)K^2}, \quad (37)$$

where $|_0^*$ denotes that the partial derivatives are evaluated at $a_p = a_k = 0$, $t = t^*$, $\tau = \tau^*$.

Proof. By differentiating Eq. (11) with respect to a_p and a_k, using Eqs. (23), (24) and (25), and then evaluating at $a_p = a_k = 0$, we obtain

$$\left.\frac{\partial T^H}{\partial a_p}\right|_0 = \frac{2K^2t^4 - 9Kt^3 + 6(K\tau + 2)t^2 - 12t\tau}{12P^2}, \quad (38)$$

$$\left.\frac{\partial T^H}{\partial a_k}\right|_0 = \frac{4Kt^4 - 9t^3 + 6(P + \tau)t^2}{12P}. \quad (39)$$

Multiplying and dividing Eq. (38) by K^2, and Eq. (39) by K^3, and then evaluating at $t = t^*$, $\tau = \tau^*$, we obtain Eqs. (36) and (37). ■

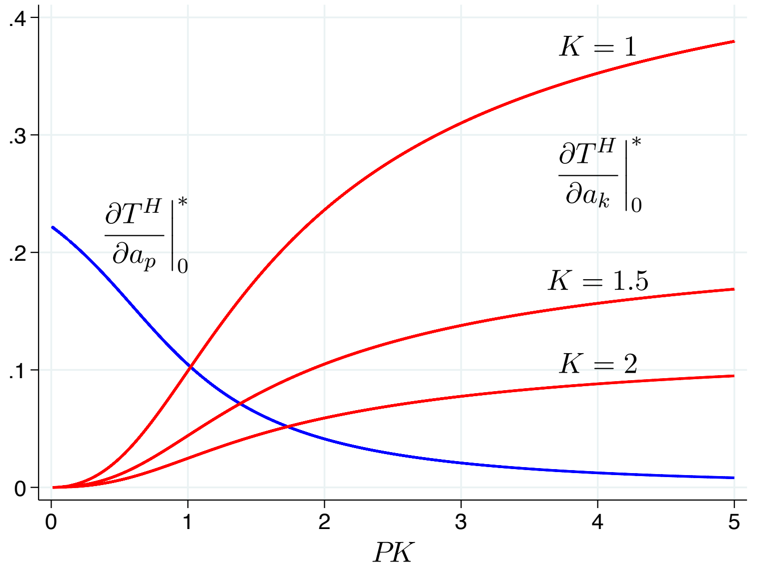


Figure 8: Tax administration: Local analysis.

Recalling, from Eq. (28), that $Kt^* = z^*$ and $K\tau^* = z^*/2 - z^{*2}/8$, we see that the derivatives in Eqs. (36) and (37) are both a direct and an indirect function (through z^*) of the product PK. The derivative in Eq. (37) is also a function of K. Then, recalling the properties of the function $z^*(PK)$ listed in Remark 2, by means of numerical analysis we obtain the following results.

Remark 5 *The derivatives in Eqs. (36) and (37) have the following properties:*

$$\lim_{(PK)\to 0} \frac{\partial T^H}{\partial a_p}\bigg|_0^* > 0, \qquad \lim_{(PK)\to 0} \frac{\partial T^H}{\partial a_k}\bigg|_0^* = 0, \tag{40}$$

with $\frac{\partial T^H}{\partial a_p}\Big|_0^*$ *monotonically decreasing in* PK*,* $\frac{\partial T^H}{\partial a_k}\Big|_0^*$ *monotonically increasing in* PK*, for given* K*, and monotonically decreasing in* K*, for given* PK*. Hence, for given* $K > 0$*, there exists a threshold value* $\widetilde{PK}$*, increasing in* K*, such that*

$$\frac{\partial T^H}{\partial a_p}\bigg|_0^* \gtrless \frac{\partial T^H}{\partial a_k}\bigg|_0^* \qquad \text{if } PK \lesseqgtr \widetilde{PK}. \tag{41}$$

Figure 8 illustrates. The blue curve is $\frac{\partial T^H}{\partial a_p}\Big|_0^*$, the red curves are $\frac{\partial T^H}{\partial a_k}\Big|_0^*$ for three different values of K. For low values of PK, below the threshold $\widetilde{PK}$ (at the intersection of the blue curve with a red curve), the introduction of administrative measures that render more costly for taxpayers fictitious residence shifting is more productive, in terms of recovered tax revenue, than the introduction of measures that make internal tax avoidance more costly. The opposite for values of PK above the threshold $\widetilde{PK}$. Therefore, low values of PK — easy residence shifting or difficult tax cheating, or both — imply that it is more productive to limit external tax avoidance, whereas high values of PK — for the opposite reasons— imply that it is more productive to limit internal tax avoidance. Of course, the productivity in terms of recovered tax revenue must be confronted with the associated costs, which in general differ across types of policies. However, in the case of fixed-cost lump-sum policies, and under the constraint of a limited budget, the comparison of marginal revenues represents a sufficient statistic for deciding which type of intervention is more effective to implement.

5.2 Global analysis

We now examine the optimal tax system by characterizing the revenue maximizing tax administration policy. We assume that the cost of administration policy α, $\alpha \in \{p, k\}$, takes a strictly convex quadratic form, $C(a_\alpha) = (c_\alpha/2)a_\alpha^2$, with the parameter $c_\alpha > 0$ measuring how steep is the linear increase of marginal costs of instrument α.

As we describe in Appendix A.2 by means of numerical analysis, the results shown in Remark 1 about the Nash equilibrium of the tax competition game extend to the case in which tax administration is optimally set.[18]

Remark 6 *In general, there exists a well defined optimum of tax administration policies, which implies a unique and stable Nash equilibrium of the tax competition game, with a standard locational equilibrium of residential choices.*

Denote with (a_p^*, a_k^*) the optimal administration policy. Then, from Eq. (5), $P^* = 2\bar{p} + a_p^*$, $K^* = 2\bar{k} - a_k^*$, and, by substituting $P = P^*$ and $K = K^*$ into Eq. (28), we obtain the Nash equilibrium tax rates under optimal tax administration, denoted (t^{**}, τ^{**}). Moreover, denote with m^{H**} and $\bar{x}^{H**}$ the mass of individuals and the average tax reporting in country H, respectively, under the optimal administration policy, and recall that m^{H*} and $\bar{x}^{H*}$ denote the corresponding

[18] As in the case of no tax administration, it is possible that the optimum is not interior (see Appendix A.2).

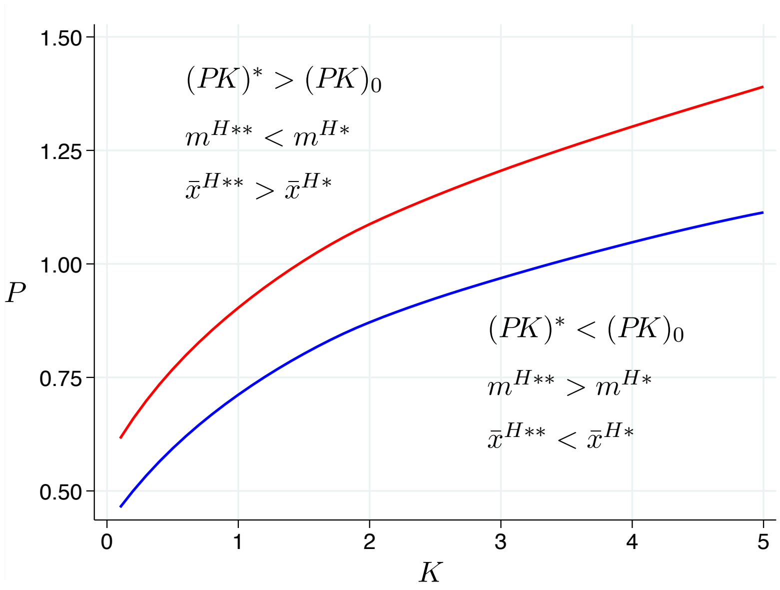
variables in the absence of tax administration. The following result is then a direct consequence of Proposition 5.

Proposition 7 *If tax administration policy has a well defined interior global optimum $a_p^* > 0$, $0 < a_k^* < 2\bar{k}$, then if $m^{H**} \gtreqless m^{H*}$ then $\bar{x}^{H**} \lesseqgtr \bar{x}^{H*}$.*

Proof. From Proposition 5, for given administration policies $a_p \geq 0$, $0 \leq a_k \leq 2\bar{k}$, m^{H*} and $\bar{x}^{H*}$ are function of the product PK only, with m^{H*} monotonically increasing and $\bar{x}^{H*}$ monotonically decreasing, and where $P = 2\bar{p} + a_p$ and $K = 2\bar{k} - a_k$. Hence, for $a_p = a_k = 0$ it is $(PK)_0 = 4\bar{p}\bar{k}$, while for $a_p = a_p^*$, $a_k = a_k^*$ it is $(PK)^* = (2\bar{p} + a_p^*)(2\bar{k} - a_k^*)$. Hence, depending on the specific values a_p^* and a_k^*, it is either $(PK)^* > (PK)_0$, $(PK)^* = (PK)_0$ or $(PK)^* < (PK)_0$. In the first case it is $m^{H**} > m^{H*}$ and $\bar{x}^{H**} < \bar{x}^{H*}$, in the second it is $m^{H**} = m^{H*}$ and $\bar{x}^{H**} = \bar{x}^{H*}$, in the third it is $m^{H**} < m^{H*}$ and $\bar{x}^{H**} > \bar{x}^{H*}$. ∎

In terms of Figure 6, Proposition 7 recognizes that changes in tax administration policies determine a 'motion', either to the right or to the left, along the curves $m^{H*}(PK)$ and $\bar{x}^{H*}(PK)$. If the impact of a_k — that reduces K — prevails over that of a_p — that increases P, then the movement is to the left, with m^{H*} decreasing and $\bar{x}^{H*}$ increasing. The opposite if it is the impact of a_p that prevails over that of a_k. This means that, although it is in general optimal to employ both tax administration policies to increase net tax revenue, in terms of tax avoidance indicators, m^{H*} and $\bar{x}^{H*}$, the optimal policy faces a tradeoff.

The terms of the tradeoff are illustrated in Figure 9. For given (c_k, c_p), there exists an increasingly concave curve in the space (P, K) such that the product PK is not affected by optimal tax administration. The graph shows two of such curves: one in red (for $c_k = 1$, $c_p = 1$) and one in blue (for $c_k = 0.5$, $c_p = 1$). Along a given curve, it is $P_0 = 2\bar{p}$, $K_0 = 2\bar{k}$, in the absence of tax administration, $P^* = 2\bar{p} + a_p^*$, $K^* = 2\bar{k} - a_k^* > 0$, with tax administration optimally set, with $P^* > P_0$, $K^* < K_0$, $P^*K^* = P_0K_0$. As a result, for combinations (P, K) along a given curve, tax revenue increases with no apparent improvements in external and internal tax avoidance outcomes. Above the curve, the optimal administration policy increases the product PK, and hence increases internal, but reduces external, tax avoidance. The opposite below the curve. The overall economic implications are clear. Consider a pair (P, K) situated, for instance, on the red curve, since $c_k = 1$, $c_p = 1$. This means that, by optimally setting tax administration one obtains an improvement in net tax revenue collected with no impact



Blue curve: $c_k = 0.5$, $c_p = 1$. Red curve: $c_k = 1$, $c_p = 1$

Figure 9: The impact of adding optimal tax administration on fiscal outcomes.

on either components of taxable income, m^{H*} and $\bar{x}^{H*}$. Revenue increases because improved tax administration allows to increase the tax rate t^*, obtaining a gain that more than outweighs the increased expenditure in administration. Now suppose to increase P, keeping K constant, so that we move above the red curve. Since increasing P reduces the opportunities of external tax avoidance, this means that, in relative terms, now internal tax avoidance becomes a more pressing problem than internal tax avoidance. As a result, by optimally setting tax administration one obtains an improvement in terms of declared average income, with $\bar{x}^{H**} > \bar{x}^{H*}$, at the cost of higher mobility, with $m^{H**} < m^{H*}$. Similar considerations can be made if we move above the red curve by reducing K, with P fixed, or if we consider changes in either P or K determining movements below the curve.

6 Correlated personal attributes

In the model examined so far, the personal attributes i and j (determining p_i and k_j, respectively) were assumed to be uncorrelated. However, it is clearly possible that individuals characterized by low costs of internal avoidance (a high value of

k_j) are also characterized by low costs of external avoidance (a low value of k_j), and vice versa, which implies a *negative* correlation between traits i and j.

Note that the issue of correlation becomes more prominent if one moves from the approach followed so far of treating attributes p_i and k_j as indicators of the 'objective' costs of tax avoidance to that of treating them as indicators of the 'subjective' costs of tax avoidance, with p_i expressing the degree of 'patriotism in taxation' (Geys and Konrad, 2020) and $1/k_j$ expressing the degree of 'tax morality' (Luttmer and Singhal, 2014). If p_i expresses not only the objective costs of external tax avoidance, but also the psychological cost of 'betraying' the native country by cheating on residence, and if $1/k_j$ expresses not only the objective costs of internal tax avoidance, but also the psychological cost of cheating on taxes, then it is clear that a certain degree of correlation is quite likely to exist between the two personal traits.

We introduce correlation by assuming that i and j are distributed on the closed set $[0,1] \times [0,1]$ according to the following density function

$$f(i, j; \delta) = 1 - \delta + 2\delta[(1 - j)i + (1 - i)j], \tag{42}$$

where $\delta \in [0,1]$ is a parameter determining the degree of negative correlation. For $\delta = 0$, there is no correlation and we are back to the situation examined in the previous sections. For $\delta = 1$, the correlation coefficient is equal to $-1/3$, which is then limited in the range $[0, -1/3]$. We employ this density function because of its relative simplicity that makes the computations of our model tractable. The marginal distributions of i and j are both uniform on the unit interval. For $\delta > 0$, the conditional distribution of i is linearly increasing for $0 \leq j < \frac{1}{2}$, it is flat for $j = \frac{1}{2}$, and it is linearly decreasing for $\frac{1}{2} < j \leq 1$, which is what determines the negative correlation.

In order to highlight the role of correlated personal attributes, we limit the analysis to the maximum degree of correlation allowed by the density function defined in Eq. (42), by setting $\delta = 1$. All the results are given in the form of remarks since they are mainly obtained through numerical analysis.

We start by showing that our main results — those given in Remark 1 and Proposition 5 — extend to the case of correlated attributes.

Remark 7 *Assume $\delta = 1$. In general, there exists a unique and stable Nash equilibrium of the tax competition game, determining a standard locational equilibrium of residential choices. In the equilibrium, both the mass of taxpayers*

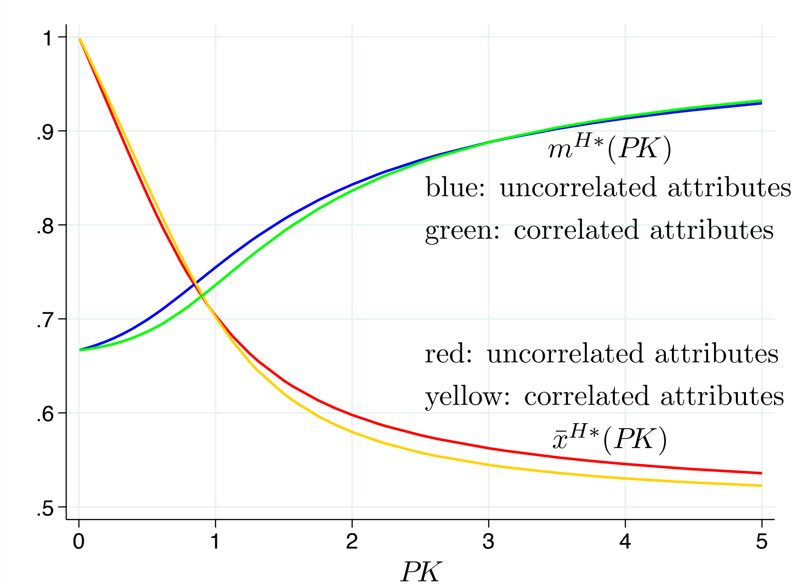


Figure 10: Fiscal outcomes with and without correlation of personal attributes.

keeping residence at home and the average income reporting are functions of the product PK only.

As for the second part of Remark 7, although it is not possible to obtain explicit solutions for $m^{H*}(PK)$ and $\bar{x}^{H*}(PK)$ like in Proposition 5, in Appendix A.3 we show that they are functions of PK only.

Figure 10 compares internal and external tax avoidance as a function of PK without correlation (hence replicating Figure 6) and with correlation of personal attributes. The blue and the red curves refer to $\delta = 0$, the green and the yellow ones to $\delta = 1$. For low values of PK there is more external tax avoidance under correlation than without it, while there is no significant difference in internal tax avoidance. For high values of PK there is more internal tax avoidance under correlation than without it, while there is no significant difference in external tax avoidance. All in all, therefore, we can conclude that correlation of personal attributes increases, in equilibrium, tax avoidance, but only one type, either internal or external, not both at the same time.

Figure 11 compares the Nash equilibrium tax rates with and without correlated attributes. The red curve shows, for country H, the ratio between the equilibrium tax rate under correlation and the one under no correlation, in the absence of tax administration. Correlated attributes allow for higher taxation,

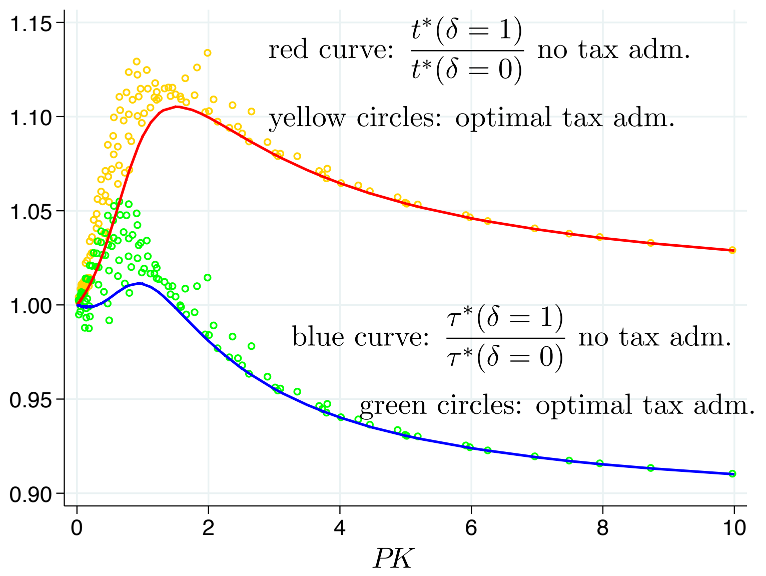


Figure 11: The impact of correlated attributes on equilibrium tax rates.

since the ratio — which is a non-monotonic function of PK — is greater than one. The corresponding blue curve for country F shows that, except for a small interval around $PK = 1$, correlation determines lower taxation, since the ratio is below one. Hence, all in all, correlated attributes reduce the pressure of tax competition. The scattered circles in Figure 11 show the same tax-ratios when tax administration is optimally set, in yellow for country H, in green for country F. Most circles are located above the corresponding curves, indicating that optimal tax administration determines a wider mark-up between taxation under correlation of personal attributes and taxation under no correlation than without tax administration. However, the tax rates ratios under optimal tax administration are no longer a function of PK only.

Finally, we show, in Figure 12, how correlation impacts on the distribution of personal attributes in the two countries. As already noted in Section 4.2, if attributes (i, j) are uncorrelated, then in equilibrium the individuals keeping their residence at home are, on average, those for whom the transfer of residence is relatively costly but at the same time are also those for whom tax cheating at home is relatively cheap. In fact, as the left panel of Figure 12 shows, the ratio between the average p_i of the individuals staying at home, $\bar{p}^H$, and the overall average $\bar{p}$, is greater than one, as well as the ratio $\bar{k}^H/\bar{k}$. Conversely, for the

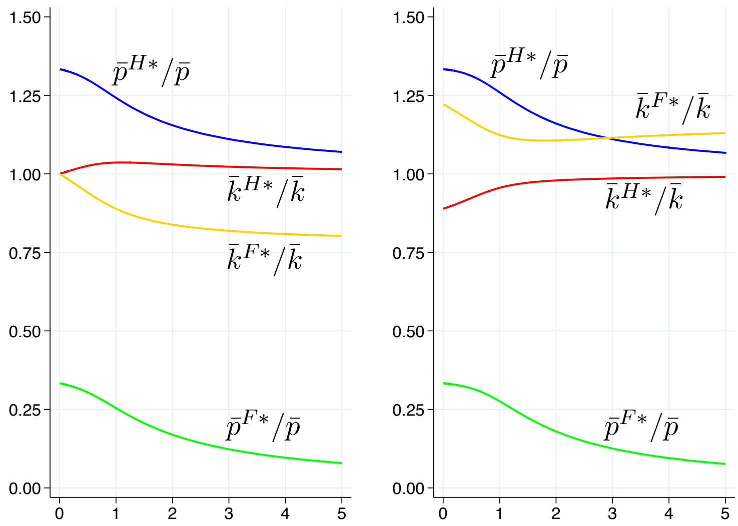


Figure 12: Average personal attributes with and without correlation.

individuals shifting the residence abroad, it is $\bar{p}^F/\bar{p} < 1$ and $\bar{k}^F/\bar{k} < 1$. With uncorrelated attributes, taxpayers specialize in the form of tax avoidance, internal or external, in which they have a comparative advantage. Things are different in the presence of correlation,[19] as shown in the right panel of Figure 12. In this case, the individuals staying at home are, on average, those for whom both internal and external tax avoidance are relatively costly with respect to the individuals shifting residence abroad, and the reverse for those who shift residence.

7 Conclusions

In a globalized world, wealthy and high-income individuals' opportunities of avoidance expand: they can relocate. Some of these relocations are fictitious and favored by special advantageous tax regimes elsewhere. Tax administrations, thus, have to deal with twofold avoidance: that coming from tax loopholes at home, and that arising from fake relocations. This paper has analyzed personal avoidance and tax administration policies in this context under a Cournot-Nash tax competition model.

[19]Note that the result emerges even if the degree of correlation, equal to $-1/3$, is quite low.

Our analysis has shown that there is a tradeoff, in equilibrium, between internal and external tax avoidance outcomes, implying that no fiscal environment can outperform another one on both outcomes. This in turn implies that, by optimally setting tax administration, it is not possible to reduce both internal and the external tax avoidance. The analysis has also been extended to the case of correlated personal attributes, showing that in this case there is a reduction, in equilibrium, of tax avoidance, but only of one type, external or internal — depending of the fiscal environment. Correlation of personal attributes also reduces the pressure of tax competition between the two countries and therefore results in higher taxes in equilibrium.

There are extensions of this theoretical framework we leave for further research. First, we can consider a tax competition model with countries of equal or similar size and in which the flow of taxpayers can go in both directions. Second, an interesting extension is to examine the social signalling role of the choice of residential location, in the spirit of the theoretical framework by Bénabou and Tirole (2006). In our model, individuals moving their residence abroad, a largely observable choice, signal themselves as non-patriotic types, and to the extent that individuals and society care for this negative signal, mobility choices can be influenced. Moreover, since mobility alters the characteristics of the taxpayers keeping their residence in the home country, it can also bear indirect socially relevant signals about tax cheating. In addition to these positive issues about the impact of social signalling for tax competition, it is also interesting to examine in normative terms how signals can be exploited by governments to improve their policies (see, e.g., Perez-Truglia and Troiano, 2018). A third extension is to examine the benefits of tax coordination and harmonization. Finally, one can analyze a Stackelberg type competition, in which there is a first mover (a big country) and a follower (a small country). These other avenues of research should shed further light on the optimal design of taxes in an imperfect world where wealthy individuals have a myriad of opportunities to avoid taxes and the public sector has, thus, important challenges ahead.

Only Tax Competition			Tax Competition and Administration				
			c_p	1	1	1	1
			c_k	1	1	0.5	0.5
δ	0	1	δ	0	1	0	1
$0 < \tau^* < t^* < 1$	133	131	$0 < \tau^{**} < t^{**} < 1,\ a_k^* < 2\bar{k}$	125	125	117	120
$0 < \tau^* < t^* = 1$	10	12	$0 < \tau^{**} < t^{**} = 1,\ a_k^* < 2\bar{k}$	9	13	10	11
			$0 < \tau^{**} < t^{**} < 1,\ a_k^* = 2\bar{k}$	2	1	6	3
			$0 < \tau^{**} < t^{**} = 1,\ a_k^* = 2\bar{k}$	7	4	10	9
SLE	143	143	SLE	143	143	143	143
Nash stable	143	143	Nash stable	143	143	143	143
soc H	143	143	soc H	143	143	143	143
soc F	143	143	soc F	143	143	143	143

11 values of $\bar{p} = 0.025, 0.05, 0.1, 0.125, 0.25, 0.375, 0.5, 0.625, 0.75, 0.875, 1$
13 values of $\bar{k} = 0.05, 0.1, 0.125, 0.25, 0.375, 0.5, 0.625, 0.75, 1, 1.25, 1.5, 2, 2.5$

Table A.1: Description and properties of the numerical analysis.

Appendix

A.1 Proof of Lemma 2

In a SLE — see Definition 1 and Figure 2 — the separating line $i = i^*(j; \boldsymbol{\pi}, \boldsymbol{\sigma})$ of the support set of personal attributes (i, j) is such that $0 \leq i^*(0; \boldsymbol{\pi}, \boldsymbol{\sigma}) \leq 1$ and $0 \leq i^*(1; \boldsymbol{\pi}, \boldsymbol{\sigma}) \leq 1$. Hence, $m^H(.)$ in Eq. (23) is obtained by computing the integral

$$m^H(.) = \int_0^1 \int_{i^*(j;\boldsymbol{\pi},\boldsymbol{\sigma})}^1 \mathrm{d}i\, \mathrm{d}j, \tag{A.1}$$

while $\bar{k}^H(.)$ in Eq. (24) is obtained by computing the integral

$$\bar{k}^H(.) = \frac{1}{m^H(.)} \int_0^1 \int_{i^*(j;\boldsymbol{\pi},\boldsymbol{\sigma})}^1 j\, \mathrm{d}i\, \mathrm{d}j. \tag{A.2}$$

Finally, $\bar{x}^H(.)$ in Eq. (25) is simply equal to its definition.

A.2 Numerical analysis of the model

The numerical analysis is summarized in Table A.1. We first computed the Nash

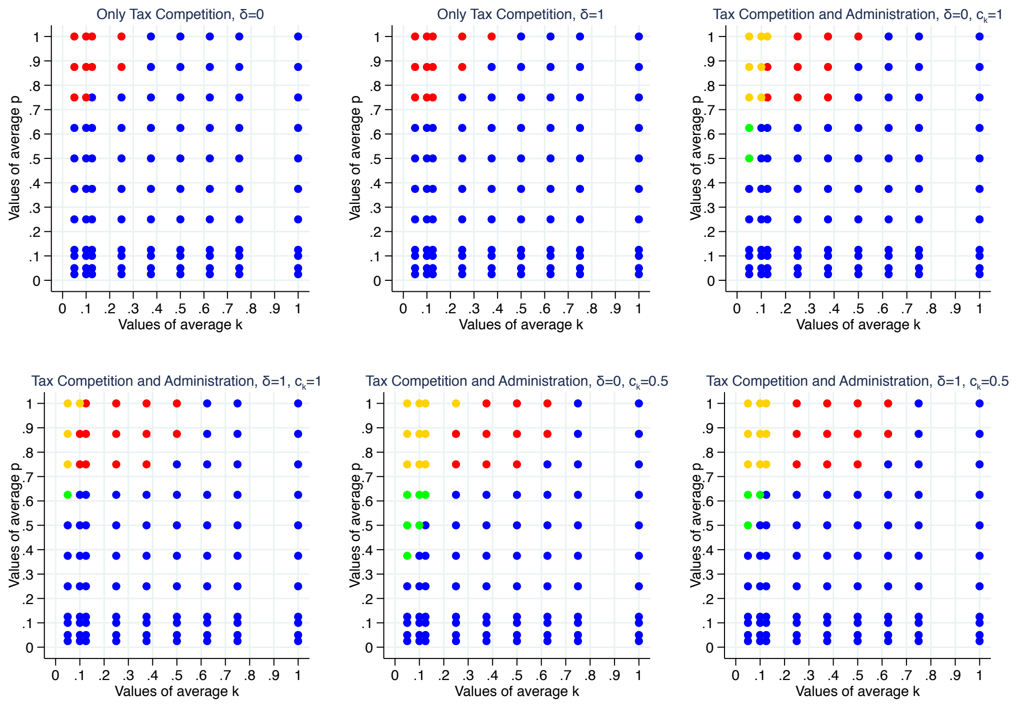


Figure A.1: Type of solutions: Interior (blue), Corner with $t^* = 1$ or $t^{**} = 1$ (red), Corner with $a_k^* = 2\bar{k}$ (green), Corner with $t^* = 1$ or $t^{**} = 1$ and $a_k^* = 2\bar{k}$ (yellow).

equilibrium tax rates with no tax administration for all combinations of 11 values of $\bar{p}$ and 13 values of $\bar{k}$, both with uncorrelated ($\delta = 0$) and with correlated ($\delta = 1$) attributes (part of the table under the heading *Only Tax Competition*). We then computed the Nash equilibrium tax rates and the optimal tax administration for the same 143 pairs $(\bar{p}, \bar{k})$, for $\delta = \{0, 1\}$, $c_k = \{0.5, 1\}$, $c_p = 1$ (part of the table under the heading *Tax Competition and Administration*).

For each set of 143 simulations, Table A.1 reports the number of cases in which the solution is interior or presents corner solutions. For instance, when only tax competition is considered, for $\delta = 0$, in 133 cases the Nash equilibrium is interior, with $0 < \tau^* < t^* < 1$, while in 10 cases it is a corner solution with $0 < \tau^* < t^* = 1$. The 'location' of corner solutions in the $(\bar{p}, \bar{k})$ space is shown in Figure A.1 for all 6 sets of simulations (the graphs consider only values $\bar{k} \leq 1$ since otherwise solutions are always interior). Corner solutions with $t^* = 1$ or $t^{**} = 1$ occur only when $\bar{p}$ is large while $\bar{k}$ is low, in line with the benchmark

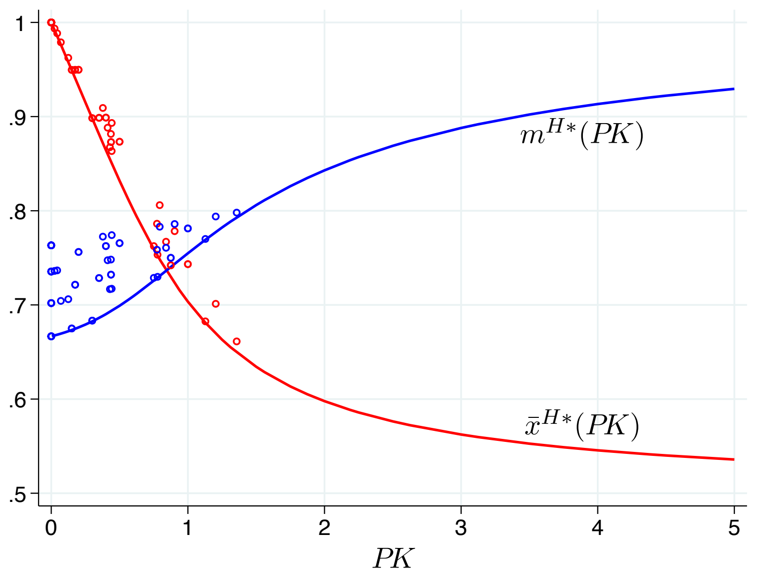


Figure A.2: Internal and external tax avoidance: interior and corner solutions.

cases examined in Propositions 1 and 2.

Figure A.2 replicates Figure 6 considering also corner solutions. Along the curves, the values of $m^{H*}(PK)$ and $\bar{x}^{H*}(PK)$ when the solution is interior with $0 < t^* < 1$. On the circles, the values of $m^{H*}(PK)$ and $\bar{x}^{H*}(PK)$ when the solution is corner with $t^* = 1$.

Table A.1 also reports that in all numerical computations: the locational equilibrium is of standard type (SLE), the Nash equilibrium is stable (Nash stable), for both the home and the foreign governments the second order conditions of tax revenue maximization are satisfied (soc H and soc F, respectively).

Figure A.3 considers 9 pairs of values (P, K) to show that a Nash equilibrium exists, is unique and stable, and located in the region of the tax rates space in which the locational equilibrium is of standard type (the region colored in cyan color). The equilibria shown refer to tax competition without administration.

A.3 Correlated attributes: Remark 7

That a Nash equilibrium of the tax competition game in general exists, is unique and stable, and determines a standard locational equilibrium when $\delta = 1$ (first part of Remark 7) has already been proven numerically in Section A.2. As for

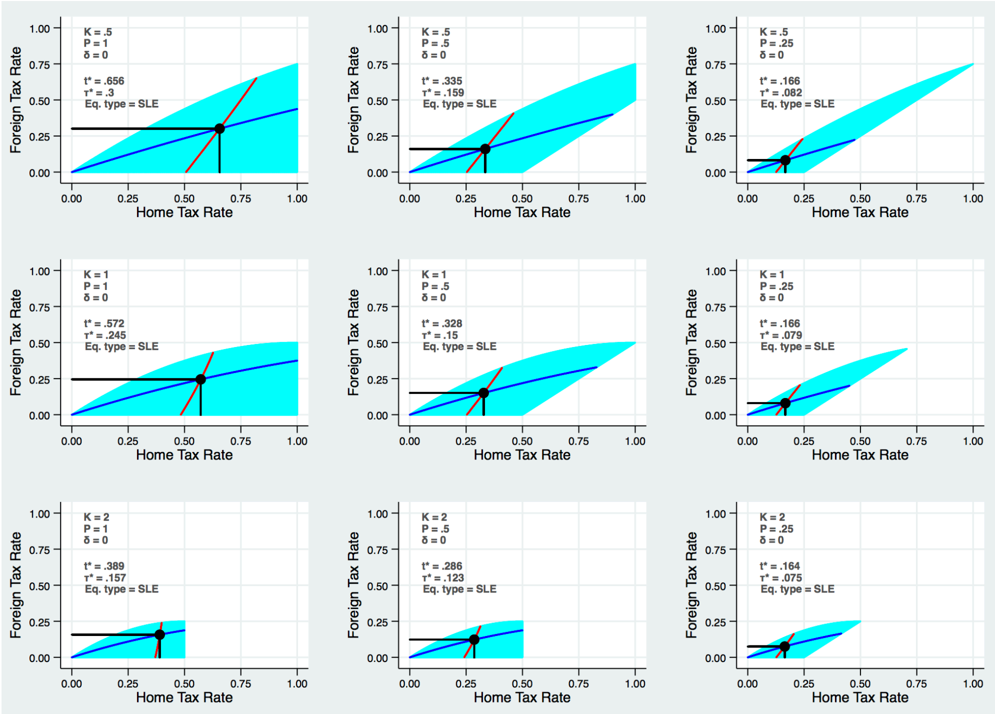


Figure A.3: Nash equilibria for 9 pairs of values (P, K).

the second part of Remark 7, for $(t, \tau) \in S(a_p, a_k, \bar{p}, \bar{k})$ and $\delta = 1$, we have that

$$m^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = 1 - \frac{(t-\tau)K}{PK} - \frac{4(Kt)^3 - (Kt)^4 - 4(2PK + K\tau)(Kt)^2}{24(PK)^2}, \quad \text{(A.3)}$$

$$\bar{k}^H(\boldsymbol{\pi}, \boldsymbol{\sigma}) = K\frac{\Omega}{240(PK)^2 m^H(\boldsymbol{\pi}, \boldsymbol{\sigma})}, \quad \text{(A.4)}$$

where

$$\Omega = 9(Kt)^4 - 40(Kt)^3 + 20(3PK + 2K\tau + 2)(Kt)^2 +$$

$$-80(2PK + K\tau) + 40(PK + K\tau)(3PK + K\tau).$$

These equations show that $m^H(\boldsymbol{\pi}, \boldsymbol{\sigma})$ and $\bar{k}^H(\boldsymbol{\pi}, \boldsymbol{\sigma})/K$ are a function of PK, Kt and $K\tau$.

Also the best response function of the foreign country,

$$K\tau = \frac{Kt}{2} - \frac{(Kt)^4 + 8(Kt)^2 PK}{8(Kt)^2 + 48PK}, \quad \text{(A.5)}$$

as well as the inverse best response function of the home country,

$$K\tau = \frac{45(Kt)^2 + 30PK - 20(Kt)^3 - 40(Kt)PK - \sqrt{K^2\Psi}}{20(Kt)}, \quad \text{(A.6)}$$

where

$$K^2\Psi = 130(Kt)^6 + 400(Kt)^4PK - 550(Kt)^5 + 400(Kt)^2(PK)^2 +$$

$$-1200(Kt)^3PK + 425(Kt)^4 - 1200Kt(PK)^2 + 300(Kt)^2PK + 900(PK)^2,$$

are a function of PK, Kt and $K\tau$. Hence, for $\delta = 1$ the Nash equilibrium tax rates are such that Kt^* and $K\tau^*$ are function of the product PK only, and therefore also m^{H*}, $\bar{k}^{H*}/K$ and $\bar{x}^{H*} = 1 - t^*\bar{k}^{H*}$.

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