Journal of International Economics 81 (2010) 253–264

Contents lists available at ScienceDirect

Journal of International Economics

journal homepage: www.elsevier.com/locate/jie

Imperfect tax competition for profits, asymmetric equilibrium and beneficial tax havens

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ARTICLE INFO

Article history:
Received 13 June 2008
Received in revised form 30 March 2010
Accepted 6 April 2010

JEL classification:
F23
F21
H26
H87

Keywords:
Tax competition
Profit shifting
Tax havens

ABSTRACT

We present a model of tax competition for real investment and profits and show that the presence of tax havens in some cases increases the tax revenue of countries. In the first part of the paper, we argue that tax competition for profits is likely to be imperfect in the sense that the jurisdiction with the lowest tax rate does not necessarily attract all shifted profits. Under this assumption, tax competition between a large number of identical countries may lead to either a symmetric equilibrium with no profit shifting or an asymmetric equilibrium where firms shift profits from high-tax to low-tax countries. In the second part of the paper, we introduce tax havens. Starting from a symmetric equilibrium, tax havens unambiguously reduce the tax revenue of countries due to a 'leakage effect' — tax havens attract tax base from countries — and a 'competition effect' — the optimal response to the increased tax sensitivity of tax bases involves a reduction of tax rates. Starting from an asymmetric equilibrium, however, tax havens also raise the tax revenue of countries through a 'crowding effect' — tax havens make it less attractive to compete for profits and thus induce low-tax countries to become high-tax countries. We demonstrate that the latter effect may dominate the former effects so that countries, on balance, benefit from the presence of tax havens.

1. Introduction

While most of the theoretical literature on tax competition has focused on competition for mobile real capital, there is now ample empirical evidence that multinational firms also respond to tax differences by shifting profits between jurisdictions. Bartelsman and Beetsma, (2003) and Clausing, (2003) demonstrate that multinational firms manipulate transfer prices in order to minimize global tax costs whereas Desai et al., (2004), Huizinga et al. (2008) and a number of studies reviewed by Hines (1999) report results consistent with profit shifting through finance structures.

A number of recent papers have contributed to the emerging understanding that profit shifting fundamentally reshapes the incentives underlying optimal taxation of capital. Haufler and Schjelderup (2000) find that profit shifting introduces an incentive to reduce tax rates and broaden tax bases.[1] Mintz and Smart (2004) show that profit shifting lowers the tax sensitivity of real investment, which suggests that profit shifting softens tax competition for real investment. Hong and Smart (2010) demonstrate that high-tax countries may benefit from profit shifting since it allows them to establish a *de facto* differentiated corporate tax system with mobile multinational firms facing a lower effective tax rate than immobile domestic firms.[2]

In the first part of the paper, we contribute to the literature on profit shifting by setting up a model of tax competition for real investment and profits between a large number of identical countries. Assuming that tax competition for profits is imperfect in the sense that the jurisdiction with the lowest tax rate does not necessarily attract all shifted profits, we show that the equilibrium may be either symmetric with all countries applying the same tax rate t^S or asymmetric with an endogenous fraction of countries applying a low tax rate t^L and the remaining countries applying a high tax rate t^H. The possibility of asymmetric equilibrium provides an explanation for the observed heterogeneity in capital taxes across countries and for the somewhat weak empirical evidence of convergence in capital tax rates (Slemrod, 2004). Our contribution thus compliments a number of earlier papers that attribute asymmetric outcomes in capital taxation to differences in country size (Bucovetsky, 1991), industrial clusters sustained by agglomeration forces (Baldwin and Krugman, 2004) and specialization in goods with different capital intensities (Wilson, 1987).

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[1] A similar point is made by Fuest and Hemmelgarn (2005) in a context where the corporate tax acts as a backstop to the personal income tax.

[2] Much in a similar spirit, Peralta et al. (2006) show that countries may optimally decide not to enforce transfer pricing rules since this works as a means to attract mobile multinational firms while maintaining a high tax rate on immobile domestic firms.

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doi:10.1016/j.jinteco.2010.04.002

The evidence that multinational firms engage in profit shifting has spurred an increased interest in the role of tax havens. Slemrod and Wilson (2009) present an elaborate model of profit shifting to tax havens and show that tax havens unambiguously reduce the welfare of countries due to wasteful use of resources by tax havens providing tax evasion services to firms and by tax administrations seeking to limit this tax evasion. Conversely, in the framework of Hong and Smart (2010), the presence of tax havens improves efficiency by facilitating profit shifting of multinational firms.

In the second part of the paper, we introduce tax havens into the model. Following Slemrod and Wilson (2009), we let 'tax havens' refer to jurisdictions that do not levy capital taxes and use 'countries' to refer to other jurisdictions. Our main result is that the presence of tax havens may increase the revenue of countries. Starting from an asymmetric equilibrium, introducing tax havens reduces the revenue of low-tax countries more than the revenue of high-tax countries and therefore induces low-tax countries to become high-tax countries. When the number of tax havens is sufficiently large, the asymmetric equilibrium is replaced by a separating equilibrium where all countries apply the same high tax rate. Although tax havens reduce the tax bases of countries ('leakage effect'), they also induce low-tax countries to raise their tax rates, which increases revenue in countries ('crowding effect'). In some cases, the crowding effect dominates the leakage effect and the presence of tax havens increases tax revenues of countries. The immediate policy implication is that cooperation between OECD countries should not necessarily aim at eliminating tax havens as a means of raising corporate tax revenues since this could induce countries to engage in tax competition for profits and thus result in lower equilibrium tax revenues.

The outline of the paper is as follows: in Section 2, we analyze a world economy without tax havens and characterize the symmetric and asymmetric equilibria. In Section 3, we introduce tax havens and characterize the separating equilibrium in order to compare tax revenues in equilibria with and without tax havens. In Section 4, we conclude. In order to keep a flow in the text, all proofs are relegated to the Appendix.

2. A world economy without tax havens

We consider a world economy with N *ex ante* identical countries and one multinational corporation (the 'MNC'). The MNC has production plants in all N countries and each plant is represented by a production function $f(k_n)$ where k_n is the input of capital in country n. We assume that mobility of real capital is costless and that N is very large. The only source of government revenue is a tax on capital.[3] The gross tax base of the MNC in country n equals the capital investment k_n. We allow, however, for the possibility that the MNC shifts profits between jurisdictions and let q_{nm} denote the tax base that is shifted from country n to country m in this fashion. In the spirit of Haufler and Schjelderup (2000), we assume that profit shifting is associated with shifting costs in the country from which profits are shifted, hence in the most general specification shifting costs in country n are given by $C_n = C_n(q_{n1},...,q_{nN})$.

In the following, we analyze a two-stage game in which governments set tax rates simultaneously and non-cooperatively in the first stage while correctly anticipating the behavioral responses of the MNC in the second stage. In Sections 2.1–2.4, we solve the problem of the MNC and derive the optimal allocation of real capital and profits conditional on tax rates. In Section 2.5, we derive first-order conditions to the government problem. In Sections 2.6 and 2.7, we identify the symmetric and asymmetric Nash equilibria of the tax game.

2.1. The problem of the MNC

The MNC sets real investment levels k_n and profit shifting levels q_{nm} in order to maximize global profits net of taxes and shifting costs while facing the constraint that global real investment cannot exceed the global capital endowment. Hence, the maximization problem of the MNC looks the following:

$$\max_{k_n, q_{nm}} \sum_{n=1}^{N} \left\{ f(k_n) - \left(k_n - \sum_m q_{nm} + \sum_m q_{mn} \right) t_n - C_n(q_{n1}, q_{n2} \ldots q_{nN}) \right\} \quad (1)$$

subject to:

$$\sum_n k_n = Ns \quad (1a)$$

$$q_{nm} \geq 0 \ \forall n, m \quad (1b)$$

$$k_n \geq 0 \ \forall n \quad (1c)$$

$$\left(k_n - \sum_m q_{nm} + \sum_m q_{mn} \right) \geq 0 \ \forall n \quad (1d)$$

where t_n is the statutory tax rate in country n and s is an exogenous capital endowment in each of the N countries. The constraints (1b)–(1d) require that profit shifting levels, real investment levels and tax bases are non-negative. To avoid unnecessary complications, we assume that the exogenous capital endowment s is sufficiently large to ensure that the constraints (1c)–(1d) are not binding in the equilibria considered.

We note that the MNC maximization problem is separable in real investment levels k_n and profit shifting levels q_{nm} which enables us to solve the MNC problem with respect to the optimal allocation of profits and the optimal allocation of real capital separately.[4] Since $C_n(\cdot)$ plays a very important role in shaping tax competition for shifted profits, we devote the following section to a discussion of shifting costs.

2.2. Shifting costs

Shifting costs are usually thought to capture either costly efforts by the MNC to conceal tax evasion from the tax authorities or a risk of detection. In either case, it seems reasonable to assume increasing marginal costs of shifting profits reflecting, for instance, that tax audits tend to focus on large scale irregularities. Such considerations have led related papers to assume that shifting costs are a convex function of total shifted profits. While this assumption is appealing in two-country models, such as Haufler and Schjelderup (2000) and Stöwhase (2005), there is reason to reconsider it in our multi-country model. When the MNC faces an international tax environment with several low-tax countries, it seems natural to introduce a cost advantage of diversification reflecting that shifting large amounts of profits to one country is more conspicuous and therefore requires more concealment efforts or entails a larger risk of detection than shifting the same amount of profits to several countries. This reasoning is probably most convincing if we think of the MNC as shifting profits to low-tax countries by means of manipulated transfer prices. Were the MNC to shift a given amount of profits to only one

[3] We assume throughout the paper that countries apply a uniform tax rate to capital. Hence, we do not pursue the analysis of optimal tax policy under the alternative assumption that countries can apply preferential regimes to certain types of capital (Keen, 2001).

[4] It would probably be more realistic to let costs of shifting profits from country n to country m depend negatively on the real investment level in country m since, arguably, detection is more likely when profits are shifted to countries where the MNC has little real activity. This point has previously been made by Mintz and Smart (2004). Such an extension, however, falls outside the scope of this paper.

low-tax country, transfer prices would have to deviate substantially from prices set according to the arm's length principle, which we would expect to be easily detectable. Conversely, if the MNC shifts the same amount of profits while spreading it out on more low-tax countries, transfer prices would be closer to arm's length prices, which we would expect to be harder to detect.

Drawing on these considerations, we make the following assumption about shifting costs:[5]

$$C_n(q_{n1}, q_{n2}...q_{nN}) = \frac{\left(\sum_m q_{nm}\right)^2}{2\alpha} + \frac{N\sum_m (q_{nm})^2}{2\beta} + \Phi \tag{2}$$

where the last term Φ is a fixed cost incurred when there is profit shifting from country n to at least one other country. The first two terms of the shifting cost function reflect concealment efforts or the risk of detection whereas the third term captures the fact that profit shifting typically requires some (fixed) investment in expert knowledge in the fields of tax law, accounting and transfer pricing rules.[6]

With this specification, marginal costs of shifting profits from country n to country m has one term which is proportional to the total amount of profits shifted out of country n and another term which is proportional to the amount of profits shifted from country n to country m. The cost advantage of diversification implied by this specification is best illustrated with a simple example: consider profit shifting out of a high-tax country n to two low-tax countries m and l where $t_n > t_m > t_l$. The marginal tax saving of shifting profits to country l and country m is $(t_n - t_l)$ and $(t_n - t_m)$ respectively, hence the tax saving of shifting profits to country l exceeds that of shifting profits to country m. Above some threshold level of q_{nl} however it becomes profitable to shift some profits to country m because differences in marginal costs more than offset the differences in tax rates $t_m - t_l$.

It is useful to note already at this point that the relative size of parameters α and β shapes the competitive environment in which low-tax countries operate. When β is infinitely large, the second term of the cost function disappears, and the marginal cost of profit shifting from country n to country m depends entirely on total shifted profits. In this case, there is no cost advantage of diversification, hence profits are shifted exclusively to the country with the lowest tax rate. This corresponds to perfect competition for profits in the sense that low-tax countries face an infinitely elastic demand for inward profit shifting. When α is infinitely large, the first term of the cost function disappears and the amount of profits shifted from country n to country m depends exclusively on the tax rate differential $(t_n - t_m)$. Hence, each low-tax country can be seen as monopolist in the sense that low-tax countries do not compete among themselves over shifted profits. When α and β take finite values, low-tax countries effectively compete for shifted profits while retaining some degree of market power that depends on the relative sizes of α and β.[7]

2.3. Optimal allocation of profits

In this section, we derive the optimal allocation of profits by solving the MNC profit maximization problem with respect to the $N(N-1)$ decision variables q_{nm}. The first-order condition for any q_{nm} is:

$$(t_n - t_m) \leq \frac{\sum_l q_{nl}}{\alpha} + \frac{N q_{nm}}{\beta}$$

where the left-hand side is the tax saving of shifting profits from country n to country m and the right-hand side is the marginal cost. Deriving a closed form solution for q_{nm} is not trivial due to the interdependence of the first-order conditions and the prevalence of corner solutions. In Lemma 1, we solve the problem taking an iterative approach.

Lemma 1. *Without loss of generality, we number the N countries according to their tax rate in ascending order so that $t_1 \leq ... \leq t_n \leq ... \leq t_N$. If there is profit shifting from a country n, there is profit shifting to the L countries 1, 2....L and the amount of profits shifted from country n to country $m \leq L$ is given by*:

$$q_{nm} = \frac{\beta}{(N\alpha + L\beta)} \left\{ \frac{\beta}{N} \sum_{l=1}^{L} (t_l - t_m) + \alpha(t_n - t_m) \right\} \tag{3}$$

where Eq. (3) *implicitly defines L as the largest number for which $q_{nL} > 0$.*

Proof. See Appendix. □

The expression for q_{nm} is in line with the intuition outlined above. When all low-tax countries apply the same tax rate (i.e. when $t_l = t_m$ $\forall l \leq L$), the first term in the curly brackets disappears and q_{nm} only depends on the tax rate differential $(t_n - t_m)$ and the number of low-tax countries L. When tax rates differ across low-tax countries (i.e. when $t_l \neq t_m$ for some country $l \leq L$), the first term in the curly brackets reduces q_{nm} for each low-tax country l with a tax rate lower than t_m and increases q_{nm} for each low-tax country l with a tax rate exceeding t_m.

In order to simplify notation in expressions related to profit shifting, we introduce the function $\psi(\cdot)$ which we define in the following way:

$$\psi(x) \equiv \frac{\beta}{\alpha + x\beta}$$

Finally, we present a result that will be useful several times in the remainder of the paper relating the discrete choice of the MNC whether to engage in profit shifting or not to shifting cost parameters and tax rates.

Lemma 2. *Assuming that zN countries apply a low tax rate t^L and the remaining $(1-z)N$ countries apply a high tax rate t^H, there is profit shifting from high-tax countries to low-tax countries if and only if*:

$$\Phi \leq \frac{z\alpha\psi(z)}{2} \left(t^H - t^L\right)^2 \tag{4}$$

Proof. See Appendix. □

2.4. Optimal allocation of real capital

We now turn to the optimal allocation of real capital, which we determine by solving the MNC profit maximization problem with respect to the N decision variables k_n. The first-order condition for any k_n reads:

$$f'(k_n) - t_n = \chi \tag{5}$$

[5] The real significance of the assumption of a diversification motive in profit shifting is that it makes low-tax jurisdictions imperfect substitutes from the point of view of multinational firms engaged in international tax planning. We thus conjecture that the basic features of our model would be retained in the presence of any other element that introduces this feature, e.g. differences in legal framework or reputational differences.

[6] Essentially, the N in the second term of the cost function ensures that the relative strength of the two first terms is independent of N, since, loosely speaking, in the first term, the summation over N countries is squared and in the second term the summation over N countries is multiplied by N.

[7] It should be noted that the values of α and β are really endogenous to policy in the sense that both specific provisions of the tax code and the amount of resources allocated to tax enforcement have a bearing on the costs of profit shifting. To keep the model tractable, we ignore these policy dimensions and assume strict exogeneity of α and β throughout the paper.

where χ is the Lagrange multiplier associated with the real investment constraint. The condition states that the net-of-tax marginal product of real capital should be equalized across countries. Since the main focus of the present paper is profit shifting, we allow ourselves to impose a little more structure on the production side of the economy by specifying the following production function:

$$f(k_n) = \zeta k_n - \frac{1}{2\gamma} k_n^2$$

where $\zeta > 0$, $\gamma > 0$ and parameters are assumed to be such that the $f'(k_n) > 0$ for all relevant levels of k_n. This production function has the convenient property that the second derivative is constant, which allows us to write the optimal allocation of real capital in a particularly simple way:

Lemma 3. *The optimal capital stock in country n is*:

$$k_n = s - \gamma(t_n - t_w) \tag{6}$$

where t_w is the average tax rate in the rest of the world.

Proof. See Appendix. □

It follows directly from Lemma 3 that the amount of real capital dislocated from country n following a unit increase in t_n equals γ and thus does not depend on the initial distribution of real capital.

2.5. The government problem

We assume throughout the paper that governments set tax rates in order to maximize tax revenues.[8] The optimization problem of the government in country n thus looks the following:

$$\max_{t_n} t_n \{k_n - q_n\}$$

where we have introduced the short-hand notation q_n for net erosion of the tax base in country n due to profit shifting:

$$q_n \equiv \sum_m q_{nm} - \sum_m q_{mn}$$

The first-order condition to the problem is:

$$\{k_n - q_n\} + t_n \left\{ \frac{\partial k_n}{\partial t_n} - \frac{\partial q_n}{\partial t_n} \right\} = 0 \tag{7}$$

The first term in curly brackets is the 'rate effect' of a marginal tax change, i.e. the change in revenue absent any behavioral responses. The second term is the 'base effect', i.e. the change in revenue due to changes in the tax base caused by behavioral responses of the MNC. In the remainder of the paper, we shall refer to the rate effect and the base effect as R and B respectively. The first-order condition simply states that in a local revenue maximum, the rate effect and base effect must sum up to zero, $R = -B$.

An important feature of a multi-country model with tax competition for profits is that q_{nm} is a discontinuous function of tax rates. This implies that q_{nm} is not differentiable at all tax rates, hence there may be local revenue maxima where Eq. (7) is not satisfied. Throughout our analysis, we must therefore carefully consider whether the non-differentiable tax rates are potential revenue maxima.

2.6. Symmetric equilibrium

While much of our analysis will focus on asymmetric equilibria, we initially identify a symmetric equilibrium to serve as a benchmark in the remainder of the paper. We start the analysis with a formal definition:

Definition 1. A symmetric equilibrium is a tax rate t^S that satisfies the following: when all N countries set the tax rate t^S, no country can strictly increase its revenue by changing its tax rate while taking the tax rates of the other countries as given.

In Proposition 1, we present our first result which is related to the existence of a unique symmetric equilibrium.[9]

Proposition 1. (*Symmetric equilibrium*) *For all finite, positive values of parameters* $(\alpha, \beta, \gamma, s, \Phi)$, *there exists a unique symmetric equilibrium*:

$$t^S = \frac{s}{\gamma}$$

Proof. See Appendix. □

The unique symmetric equilibrium is identical to the unique equilibrium prevailing in a standard tax competition model without profit shifting. Since profit shifting does not take place in equilibrium and marginal tax changes do not induce the MNC to shift profits due to the fixed cost Φ, the potential of the MNC to engage in profit shifting has no bearing on the properties of the equilibrium.

2.7. Asymmetric equilibrium

In the present section, we analyze asymmetric equilibria where countries group themselves into high-tax countries and low-tax countries. Firstly, we derive conditions for existence and show that the number of asymmetric equilibria varies from zero to two as a function of the parameters. We also present results describing some general properties of asymmetric equilibria. Secondly, we fully characterize the unique asymmetric equilibrium prevailing in the important special case where tax competition for profits is close to perfect ($\beta/\alpha \to \infty$). Finally, we use numerical methods to further explore the properties of asymmetric equilibria. Before turning to the analysis, we present the following formal definition of an asymmetric equilibrium:

Definition 2. An asymmetric equilibrium is a vector (t^H, t^L, z) that satisfies the following: when a fraction z of the N countries apply the tax rate t^L and the remaining countries apply the higher tax rate t^H no country can strictly increase its revenue by changing its tax rate while taking the tax rates of the remaining countries as given.

As a first step of the analysis, we derive three equilibrium conditions. Essentially, the three conditions are necessary (but not sufficient) for t^H and t^L to constitute global revenue maxima from the perspective of a single country given that a fraction z of the other countries set the tax rate t^L and the remaining countries set the tax rate t^H.

[8] Under the assumption of a very large N and furthermore assuming that ownership of the MNC is uniformly distributed across agents in the world economy, revenue maximization is equivalent to maximizing a general utility function over private and public consumption of a representative agent. This is due to the fact that the burden of capital taxes is borne jointly by the owners of the MNC, of which domestic owners amount to a negligible fraction. Hence, any individual country perceives a negligible private cost associated with an increase in capital taxes and therefore optimally maximizes tax revenue.

[9] The proof uses the assumption of a very large N to rule out the possibility that a single country n can reduce its tax rate enough to induce the MNC to shift profits into country n. In a previous version of the paper, we showed that without the assumption of a very large N, there is a lower bound on the fixed costs that support t^S as a symmetric equilibrium.

Firstly, both t^H and t^L must satisfy Eq. (7) evaluated in the asymmetric equilibrium. It is relatively straightforward to restate Eq. (7) in the following way for high-tax and low-tax countries respectively:

$$s-z\gamma\left(t^H-t^L\right)-z\alpha\psi(z)\left(t^H-t^L\right)=t^H\{\gamma+z\alpha\psi(z)\} \tag{8}$$

$$s+(1-z)\gamma\left(t^H-t^L\right)+(1-z)\alpha\psi(z)\left(t^H-t^L\right) \\ =t^L\{\gamma+(1-z)\alpha\psi(z)+z(1-z)\beta\psi(z)\} \tag{9}$$

The two equations have the same structure. On the left-hand side, the first two terms reflect the capital k invested by the MNC whereas the third term reflects net erosion of the tax base due to profit shifting q. To derive these expressions, we have evaluated Eqs. (6) and (3) in the asymmetric equilibrium. On the right-hand side, the first term in the curly brackets is the tax sensitivity of the capital stock $\partial k/\partial t$ whereas the remaining terms reflect the tax sensitivity of shifted profits $\partial q/\partial t$. To derive the latter terms, we have differentiated Eq. (3) with respect to t_n in the case of Eq. (8) and t_m in the case of Eq. (9). It is instructive to note that $\partial q/\partial t$ in low-tax countries comprises two distinct effects $(1-z)\alpha\psi(z)$ and $z(1-z)\beta\psi(z)$. Considering a tax reduction in a low-tax country, the former effect reflects increased profit shifting from high-tax countries (a 'creation effect'), whereas the latter effect reflects redirection of profits which would otherwise have been shifted to other low-tax countries (a 'diversion effect'). Importantly, in an equilibrium where all low-tax countries set the same tax rate, diversion effects cancel out, hence q in low-tax countries only comprises the creation effect.

Secondly, it is clear that t^H and t^L must generate the same revenue in the asymmetric equilibrium. Using the same expressions as before, this condition may be stated in the following way:

$$t^H\left\{s-z\gamma\left(t^H-t^L\right)-z\alpha\psi(z)\left(t^H-t^L\right)\right\} \\ =t^L\left\{s+(1-z)\gamma\left(t^H-t^L\right)+(1-z)\alpha\psi(z)\left(t^H-t^L\right)\right\} \tag{10}$$

The terms in curly brackets express the tax base $k-q$ in high-tax countries (left-hand side) and low-tax countries (right-hand side) in the asymmetric equilibrium.

We are now prepared to present our first results concerning asymmetric equilibria. In Lemma 4, we present conditions for the existence of one or more vectors (t^H, t^L, z) satisfying equilibrium conditions (8)–(10). In Proposition 2, we show that the equilibrium conditions (8)–(10) are indeed sufficient provided that Φ is not too high.

Lemma 4. *Existence of solutions* (t^H, t^L, z) *to the equilibrium conditions* (8)–(10) *depends on parameters* (α, β, γ) *in the following way*:

(i) *For* $\beta/\alpha\in[5.22;\infty[$, *there exist two distinct solutions.*[10]
(ii) *For* $\beta/\alpha\in[4; 5.22]$, *there exist two distinct solutions when* γ/β *is larger than some threshold value* $\overline{\Omega}$; *one solution when* $\gamma/\beta=\overline{\Omega}$; *and no solution when* $\gamma/\beta=\overline{\Omega}$ *where* $\overline{\Omega}\to\infty$ *as* $\beta/\alpha\to 4$ *and* $\overline{\Omega}\to 0$ *as* $\beta/\alpha\to 5.22$.
(iii) *For* $\beta/\alpha\in[0; 4]$, *there exists no solution.*

Proof. See Appendix. □

Proposition 2. (*Existence of asymmetric equilibrium*): *any vector* (t^H, t^L, z) *satisfying equilibrium conditions* (8)–(10) *is associated with a positive threshold value* $\overline{\Phi}$ *and constitutes an asymmetric equilibrium if and only if* $\Phi\leq\overline{\Phi}$.

Proof. See Appendix. □

Essentially, Proposition 2 implies that when tax competition for profits is sufficiently strong (β/α is above a threshold value), there are two candidates for asymmetric equilibrium. When the fixed cost of profit shifting Φ is low, both of these equilibrium candidates constitute asymmetric equilibria. When the fixed cost of profit shifting falls in an intermediate range, only one of the equilibrium candidates constitutes an asymmetric equilibrium. When the fixed cost of profit shifting is high, no asymmetric equilibrium exists.

To explain the possibility of asymmetric equilibrium in a world economy of perfectly identical countries, we consider the optimal tax policy of a country n in an asymmetric equilibrium. If t_n is sufficiently close to t^H, there is no profit shifting between country n and other high-tax countries, hence a marginal reduction in t_n increases the tax base by reducing profit shifting out of country n. We label this type of policy strategy 'defensive tax competition'. If t_n is sufficiently close to t^L, country n effectively competes with other low-tax countries for shifted profits from high-tax countries, hence a marginal reduction in t_n increases the tax base of country n not only by inducing the MNC to shift more profits out of each of the high-tax countries but also by diverting profits, which would otherwise have been shifted to other low-tax countries. We label this type of policy strategy 'aggressive tax competition'. It follows that high-tax countries have a relatively small tax base with a relatively low tax sensitivity whereas low-tax countries have a relatively large tax base with a relatively high tax sensitivity, hence the possibility that t^H and t^L both satisfy the first-order condition for revenue maximization. When the endogenous fraction of low-tax countries z is such that those two local revenue maxima t^H and t^L generate the same revenue, we have identified a candidate for asymmetric equilibrium.

As implied by Proposition 2, however, such an equilibrium candidate is not necessarily an equilibrium. Obviously, a vector (t^H, t^L, z) can only be an asymmetric equilibrium if the fixed cost of profit shifting Φ is small enough to allow the MNC to at least break even on profit shifting from high-tax countries to low-tax countries. This introduces an upper bound on the values of Φ that support a given equilibrium candidate (t^H, t^L, z) as equilibrium. As it turns out, however, we need to impose a stronger restriction on Φ. To see this, consider the case of a vector (t^H, t^L, z) satisfying (8)–(10) where Φ is such that the MNC exactly breaks even on profit shifting. By lowering its tax rate marginally below t^H, a high-tax country is able to prevent profit shifting out of its jurisdiction, which triggers a discrete increase in the tax base and thus in the tax revenue. Such a value of Φ obviously does not support (t^H, t^L, z) as an equilibrium. It follows that from the perspective of an individual country n there is another candidate for a revenue maximum than t^H and t^L, namely the tax rate $t^U\in[t^L; t^H]$ which is just low enough to deter the MNC from shifting profits out of country n. Essentially, in order for (t^H, t^L, z) to constitute an equilibrium, Φ needs to be so low that t^U is sufficiently below t^H to generate a smaller revenue than the latter.[11]

While we have so far been concerned with the existence of asymmetric equilibria, we shall now proceed to characterize the equilibrium properties. Put differently, we shall address the question how the vector of parameters ($\alpha, \beta, \gamma, s, N$) shapes equilibrium vectors (t^H, t^L, z). As a first step, we present the following Lemma:

Lemma 5. *The candidates for asymmetric equilibrium are identical for any large value of N. The candidates for asymmetric equilibrium are not affected by a proportional change in* α, β, γ *and* s.

Proof. See Appendix. □

[10] The limit 5.22 is the approximate solution to $\min\left\{\frac{1-z+z^2}{z^2(1-z)}\right\} s.t. z\in(0,1)$.

[11] The proof uses the assumption of a large N to rule out the possibility that a country n can reduce its tax rate enough to induce the MNC to shift profits from low-tax countries into country n. In a previous version of the paper, we showed that without the assumption of a large N, there is also a lower bound $\underline{\Phi}$ on the fixed costs supporting a vector (t^H, t^L, z) as an asymmetric equilibrium.

Essentially, Lemma 5 allows us to reduce the dimensions of a parameter space. While the first part of the Lemma allows us to disregard N altogether, the second part implies that the remaining parameters may, without loss of generality, be normalized by a constant. We normalize on α, hence the relevant set of parameters is limited to $(\beta/\alpha, \gamma/\alpha, s/\alpha)$. Holding other things constant, each of these parameters characterizes specific features of the economic environment. The parameter s/α reflects the size of the tax base relative to its tax sensitivity. The parameter γ/α captures the importance of real capital mobility relative to the mobility of profits. Finally, as discussed above, the parameter β/α is related to the strength of the diversification motive in profit shifting and thus to the competitive environment in which low-tax countries operate. Since the key contribution of our paper is the introduction of a diversification motive in profit shifting, we shall mostly be concerned with the way in which β/α affects the equilibrium properties. We do, however, in Propositions 3 and 4, briefly present results related to the role of parameters s/α and γ/α.

Proposition 3. (*Tax base vs. tax base sensitivity*): *increasing s/α while holding β/α and γ/α constant leaves z unchanged but gives rise to an increase in t^H and t^L proportional to the increase in s/α.*

Proof. See Appendix. □

Proposition 3 states that increasing the tax base relative to the tax sensitivity of the tax base results in higher equilibrium tax rates but does not affect the equilibrium distribution of high-tax and low-tax countries. Intuitively, a larger tax base adds to the positive revenue effect of increasing taxes (R) relative to the negative revenue effect ($-B$), which results in higher equilibrium tax rates. Since a change in s/α leads to a proportionate change in the tax base of all countries, there is no change in the revenue earned by high-tax countries relative to that earned by low-tax countries, hence the equilibrium values of z are unaltered.

Proposition 4. (*Real investment vs. profit shifting*): *letting γ/α and s/α approach infinity while holding β/α constant, both t^H and t^L approach s/γ while Φ approaches zero.*

Proof. See Appendix. □

Proposition 4 states that when the mobility of profits becomes very small relative to the mobility of real capital and the size of the tax base, the equilibrium tax rates of both high-tax and low-tax countries approach the tax rate prevailing in a standard tax competition model without profit shifting. Moreover, the largest fixed cost $\overline{\Phi}$ supporting these equilibria approaches zero so that in the limit no asymmetric equilibrium exists regardless of the size of Φ. It is reassuring that as tax competition for profits becomes less significant, our model converges to the standard model of tax competition for real investment in the dual sense that equilibrium tax rates converge to s/γ and that an ever smaller range of Φ support these asymmetric equilibria.

In the following Proposition, we consider the special case where β/α is very large. There are several reasons to focus on this special case. Firstly, it is an important theoretical benchmark relevant for cases where the diversification motive in profit shifting is relatively weak. Secondly, under the assumption of a very large β/α, there is only one equilibrium candidate, hence if an asymmetric equilibrium exists it is unique. Finally, the assumption of a very large β/α enhances the tractability of the model considerably and thus allows us to fully describe the asymmetric equilibrium. For these reasons, we shall also devote special attention to the case of a very large β/α in the next section when we compare policy outcomes in a world with and without tax havens.

Proposition 5. (*Perfect competition for profits*): *letting β/α approach infinity while holding γ/α and s/α constant, the unique asymmetric equilibrium converges in the following way*:

$$\left(t^H; t^L; z\right) \rightarrow \left(\frac{s}{\gamma + 2\alpha}; 0; 0\right)$$

$$\overline{\Phi} \rightarrow \frac{\alpha}{2}\left[\frac{s}{(\gamma + 2\alpha)}\right]^2 \left[\frac{(\gamma + \alpha)}{\gamma}\left\{1 - \sqrt{\frac{\alpha}{\gamma + \alpha}}\right\}\right]^2$$

Proof. See Appendix. □

Proposition 5 states that for values of Φ smaller than a threshold value $\overline{\Phi}$, very large values of β/α are associated with a unique asymmetric equilibrium where a small fraction of countries z engages in aggressive tax competition setting a tax rate t^L close to zero. Intuitively, a large value of β/α implies that the allocation of shifted profits is very sensitive to tax differences between low-tax countries, hence tax competition for shifted profits is fierce and t^L is driven down to zero. Such an environment is obviously unfavorable to low-tax countries and, in equilibrium, z needs to take a value that favors low-tax countries in order to satisfy the equilibrium condition that all countries earn the same revenue. In the unique asymmetric equilibrium, z thus approaches zero, which implies that the tax base of low-tax countries is very large since shifted profits deriving from a large number of high-tax countries are shared by a small number of low-tax countries.

As implied by Lemma 4, there is a second equilibrium candidate. Intuitively, a value of z close to one mitigates the downward pressure on t^L by reducing the number of high-tax countries and thus the amount of shifted profits for which low-tax countries compete. As z approaches one, the tax base of low-tax countries approaches that of high-tax countries, hence t^L must approach t^H to satisfy the equilibrium condition that all countries earn the same revenue. This, in turn, implies that the highest fixed cost $\overline{\Phi}$ supporting this equilibrium approaches zero. In the limit, when no values of Φ support the equilibrium candidate where z approaches one, the equilibrium where z approaches zero is the unique asymmetric equilibrium.

Although the result presented in Proposition 5 is derived under the assumption of a very large β/α, it is important to note that we have not restricted other dimensions of parameter space. Hence, the result holds for any (finite) values of γ/α and s/α, that is under any assumptions about the mobility of profits relative to real investment and about the size of the tax base relative to the tax sensitivity of the tax base.

Due to the inherent complexity of the model, we use numerical analysis to further illustrate the relation between the parameters of the shifting cost function and the asymmetric equilibria. Specifically, we vary β/α over the entire range $[0;\infty[$ while holding γ/α and s/α constant.[12] Fig. 1 shows our results. The dashed bold curve indicates the correspondence between β/α and z which is defined for values $\beta/\alpha \geq 4.62$.[13] In particular, to each value of $\beta/\alpha > 4.62$ correspond two values of z which we denote z' and z'' where $z' < z''$. The bold curves indicate tax rates t^H and t^L as functions of z. Hence, to each value of $\beta/\alpha > 4.62$ correspond two vectors $(t^{H'}, t^{L'}, z')$ and $(t^{H''}, t^{L''}, z'')$, which are the equilibrium candidates. In Fig. 1, we have chosen an arbitrary value of β/α for which we have illustrated the two equilibrium candidates $(t^{H'}, t^{L'}, z')$ and $(t^{H''}, t^{L''}, z'')$. Finally, the gray area bounded by

[12] The numerical analysis is conducted in the following way: we compute the value of β/α that establishes equilibrium for a given value of z using Eq. (20). Moreover, we compute t^H and t^L using Eq. (18)–(19) and $\overline{\Phi}$ using (21). The remaining parameters are fixed at the following values: $s = 20$, $\gamma = 20$, $\alpha = 20$.

[13] In Fig. 1, the lowest value taken by $\log(\beta/\alpha)$ is approximately 1.53, which is equivalent to $\beta/\alpha = 4.62$.

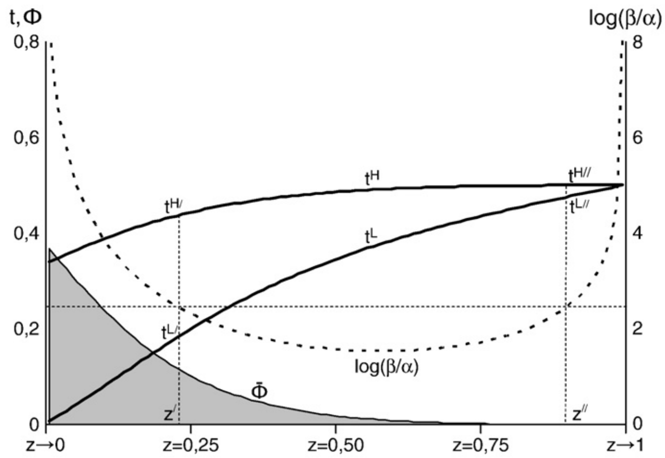

Fig. 1. Asymmetric equilibrium — a numerical illustration.

$\overline{\Phi}$ gives the correspondence between an equilibrium candidate (t^H,t^L,z) and the set of fixed costs Φ that supports it as an asymmetric equilibrium.

The figure illustrates several points that we have previously made. As shown in Proposition 2, when β/α is larger than a threshold value, in this case 4.62, there are two equilibrium candidates $(t^{H'},t^{L'},z')$ and $(t^{H''},t^{L''},z'')$, each of which is supported as an asymmetric equilibrium by a range of fixed costs $[0;\overline{\Phi}]$. Values of $\beta/\alpha<4.62$, however, do not give rise to an asymmetric equilibrium. Moreover, as shown in Proposition 5, as β/α approaches infinity, the $\overline{\Phi}$ associated with $(t^{H''},t^{L''},z'')$ approaches zero, hence $(t^{H'},t^{L'},z')$ is the only possible asymmetric equilibrium.

In our numerical example, tax rates t^H and t^L increase monotonically with z whereas the opposite is true for $\overline{\Phi}$. This suggests that the equilibrium candidate with the higher z generally exhibits the highest tax rates whereas the equilibrium candidate with the lower z is supported by the largest range of fixed costs Φ. This conjecture is supported by a series of numerical examples conducted with other fixed values of γ/α and s/α (not reported here).

3. A world economy with tax havens

In this section, we use the model developed above to analyze how the presence of tax havens affects the revenue of countries. When analyzing the world economy with tax havens, we focus on the separating equilibrium where all countries set the same tax rate. Firstly, we derive conditions for existence of separating equilibrium in the general case. Secondly, we compare the tax revenue earned by countries in this separating equilibrium with tax havens to the tax revenue they would have earned in the corresponding symmetric and asymmetric equilibria without tax havens. In the special case where tax competition for profits is close to perfect ($\beta/\alpha\rightarrow\infty$), we are able to fully characterize the separating equilibrium and compare tax revenues to the unique asymmetric equilibrium analytically. In other cases, we rely on numerical analysis to show that the presence of tax havens potentially increases the tax revenue of countries.

In order to keep the model tractable, we make the following simplifying assumptions: (i) tax havens do not tax capital, (ii) tax havens have a negligible exogenous capital endowment and (iii) tax havens have a negligible potential for hosting real investment. While assumptions (ii) and (iii) may be justified on grounds of relative geographical smallness (Dharmapala and Hines, 2006), assumption (i) is the standard way to characterize tax haven policies in the literature (Fuest and Hemmelgarn, 2005; Hong and Smart, 2010; Slemrod and Wilson, 2009). An alternative to the exogenous zero tax rate that seems particularly appealing would be to assume that tax havens maximize tax revenue under the constraint that shifted profits constitute their only tax base.[14] Such an approach would be consistent with the point made by Schön (2005) that although tax havens usually apply zero tax rates on corporate income, other fiscal levies on corporations typically account for a significant share of government revenue, which suggests that tax policies in tax havens are, at least partly, driven by a revenue motive. It should be noted, however, that although revenue from capital taxes may be large in relative terms due to the smallness of tax haven economies, the effective tax rate on capital is negligible. Since the aim of the present paper is to analyze the impact of tax havens on policy outcomes in countries through the opportunities they offer firms in terms of international tax planning rather than an analysis of optimal tax haven policies *per se*, we find it reasonable to adopt the usual assumption of a zero capital tax rate in tax havens.[15]

As it turns out, the number of tax havens is an important determinant of the properties of the separating equilibrium since it shapes the incentives to engage in aggressive tax competition. We therefore introduce a new parameter a into the model which indicates the number of tax havens relative to the number of countries. By definition, the total number of tax havens thus equals aN. We start the analysis of the separating equilibrium with the following formal definition.

Definition 3. A separating equilibrium is a tax rate t^N satisfying the following: when the N countries set the tax rate t^N and the aN tax havens set a zero tax rate, no country can strictly increase its revenue by changing its tax rate while taking as given the tax rates of all other jurisdictions.

From an analytical point of view, the separating equilibrium has the major advantage that countries set a uniform tax rate. Consequently, the three conditions (8)–(10) characterizing the asymmetric equilibria is replaced by a single condition, namely the first-order condition for revenue maximization (7) evaluated in the separating equilibrium:

$$s-a\alpha\psi(a)t^N = t^N\{\gamma + a\alpha\psi(a)\}$$

It follows immediately that when a separating equilibrium exists, the tax rate t^N must be given by:

$$t^N \equiv \frac{s}{\gamma + 2a\alpha\psi(a)}$$

In Proposition 6, we present conditions for existence of separating equilibrium.

Proposition 6. (*Existence of separating equilibrium*) *Assume that* $\beta/\alpha>1$. *There exists a threshold value* $\underline{a}$ *so that it is unattractive for countries to compete for shifted profits if and only if* $a\geq\underline{a}$. *Values of* $a<\underline{a}$ *do not support* t^N *as a separating equilibrium. Values of* $a\geq\underline{a}$ *are associated with a threshold value* $\overline{\Phi}$ *so that* t^N *constitutes a separating equilibrium if and only if* $\Phi<\overline{\Phi}$. *The threshold value* $\underline{a}$ *is decreasing monotonically in* β/α *and* γ/α *and does not depend on* s/α.

Proof. See Appendix. □

Proposition 6 states that two conditions need to hold in order for t^N to constitute an equilibrium. Firstly, the number of tax havens must be large enough to deter countries from engaging in tax competition for profits, hence the requirement that a is larger than a threshold $\underline{a}$.

[14] This seems to be the assumption underlying the empirical model of Hines and Rice (1994).

[15] In a previous version of this paper, we pursued the idea of revenue maximizing tax havens, which mostly added complexity to the model without changing the qualitative results.

Secondly, the fixed cost of profit shifting must be small enough to ensure that the MNC breaks even on profit shifting from countries to tax havens and that a country cannot increase its revenue by lowering its tax rate to the point where the MNC stops shifting profits out of its jurisdiction, hence the requirement that Φ is smaller than a threshold $\overline{\Phi}$. Intuitively, as β/α increases, tax competition for profits becomes fiercer and it becomes less attractive to engage in aggressive tax competition with tax havens. Similarly, as γ/α increases, profits become less mobile relative to real investment and the tax base gain associated with tax competition for profits shrinks. In both cases, it requires a smaller number of tax havens to deter countries from undercutting the equilibrium tax rate t^N.[16]

The main purpose of the present section is to analyze how the presence of tax havens affects outcomes in countries. In the following proposition, we compare revenues earned by countries in the symmetric equilibrium and the separating equilibrium.

Proposition 7. *(Symmetric vs. separating equilibrium) The revenue earned by countries in the separating equilibrium in the presence of tax havens is smaller than the revenue earned by countries in the symmetric equilibrium in the absence of tax havens.*

Proof. See Appendix. □

Proposition 7 states that if a world economy of N countries is initially in a symmetric equilibrium, introducing a number of tax havens large enough to sustain a separating equilibrium unambiguously reduces the revenue of countries. This result is in line with the intuition from standard models of tax competition. The presence of tax havens allows the MNC to reduce global tax liabilities by shifting profits from countries. This represents a negative 'leakage effect' in the sense that the tax base of countries is eroded. Moreover, the extent to which the MNC shifts profits out of countries is tax sensitive, hence the presence of tax havens increases the tax sensitivity of tax bases and reduces equilibrium tax rates. This represents a negative 'competition effect'.

We proceed to compare revenues earned by countries in asymmetric and separating equilibria. In the general case, the difficulties associated with a complete characterization of asymmetric equilibrium impede an analytical treatment of this issue. In the special case where competition for profits is close to perfect (large β/α), however, we are able to compare revenues analytically. In the following two propositions, we first show how the separating equilibrium converges as β/α approaches infinity and then compare revenues in this separating equilibrium to the unique asymmetric equilibrium presented in Proposition 5.

Proposition 8. (*Perfect competition for profits*) *Letting β/α approach infinity, the unique separating equilibrium converges in the following way*:

$$t^N \rightarrow \frac{s}{\gamma + 2\alpha}$$
$$\underline{a} \rightarrow 0.5z$$
$$\overline{\Phi} \rightarrow \frac{\alpha}{2}\left[\frac{s}{(\gamma + 2\alpha)}\right]^2 \left[\frac{(\gamma + \alpha)}{\gamma}\left\{1 - \sqrt{\frac{\alpha}{\gamma + \alpha}}\right\}\right]^2$$

where z is the fraction of low-tax countries in the unique asymmetric equilibrium in a world economy without tax havens.

Proof. See Appendix. □

Proposition 9. (*Asymmetric vs. separating equilibrium*) *Assume that β/α approaches infinity and that Φ is smaller than $\overline{\Phi}$ as defined in Proposition 8. By Proposition 5, there exists a unique asymmetric equilibrium (t^H, t^L, z) in a world economy with N countries. By Proposition 8, there exists a unique separating equilibrium t^N in a world economy with N countries and aN tax havens if $a > \underline{a}$ where $\underline{a} \rightarrow 0.5z$. There exists a threshold value $\overline{a} \in [\underline{a}; z]$ so that for any $a \in [\underline{a}; \overline{a}]$ the revenue earned by countries is larger in the separating equilibrium than in the asymmetric equilibrium where $\overline{a} \rightarrow \underline{a}$ for $\gamma/\alpha \rightarrow 0$ and $\overline{a} \rightarrow z$ for $\gamma/\alpha \rightarrow \infty$.*

Proof. See Appendix. □

Proposition 9 states that if tax competition for profits is close to perfect and the world economy of N countries is initially in the unique asymmetric equilibrium, there is scope for increasing the tax revenue of countries by introducing tax havens into the world economy. In particular there exists a range of a for which the introduction of aN tax countries gives rise to a separating equilibrium where countries earn a higher revenue than in the initial asymmetric equilibrium and this range of a is larger when real investment is mobile relative to profits (large γ/α).[17]

Generally, a shift from an asymmetric equilibrium with zN low-tax countries to separating equilibrium with aN tax havens affects the revenue of high-tax countries through three channels. Firstly, countries benefit from a tax base increase equal to the net capital export from high-tax countries to low-tax countries in the asymmetric equilibrium $z\gamma(t^H - t^L)$. Since tax havens, by assumption, are too small to host real investment, there is no real capital export from countries in the separating equilibrium. Secondly, the amount of profits shifted out of high-tax countries at a given tax rate t changes from $z\alpha\psi(z)(t - t^L)$ to $a\alpha\psi(a)t$. Assuming that $aN < zN$, this change in tax base may be either positive or negative: The fact that tax havens set a lower tax rate than low-tax countries tends to raise the amount of shifted profits whereas the lower number of jurisdictions attracting shifted profits has the opposite effect. Finally, the tax sensitivity of the amount of profits shifted out of the high-tax countries (i.e. $\partial q/\partial t$) is reduced from $z\alpha\psi(z)$ to $a\alpha\psi(a)$, which increases revenue as it allows for a higher equilibrium tax rate. In general, the net effect of a shift from the asymmetric equilibrium to the separating equilibrium depends on the relative strength of these effects and is *a priori* undetermined. It follows from Proposition 9 that in the special case where β/α and γ/α become very large, the effects working through the number of jurisdictions competing for profits dominate other effects, hence, in the limit, any separating equilibrium where $aN < zN$ is associated with a higher revenue than the corresponding asymmetric equilibrium.[18]

In the remainder of the section, we apply numerical methods to show that the potential for beneficial tax havens is not limited to the special case analyzed in Proposition 9. Fig. 2 illustrates our results. As in Fig. 1, the dashed bold curve indicates the correspondence between β/α and z for fixed values of s/α and γ/α. Each asymmetric equilibrium (each z) is associated with threshold values $\underline{a}$ indicating the lowest value of a consistent with a separating equilibrium and $\overline{a}$ indicating the highest value of a where countries earn a higher revenue in the separating equilibrium with aN tax havens than in the asymmetric

[16] The assumption $\beta/\alpha > 1$ ensures that introducing tax havens into a world economy initially in an asymmetric equilibrium has the direct effect of reducing tax revenue of low-tax countries more than the tax revenue of high-tax countries and thus induces low-tax countries to become high-tax countries.

[17] It should be noted, however, that as β/α approaches infinity, the revenue earned by countries in asymmetric and separating equilibria converge, hence revenue differences between the two types of equilibria are only second-order. This may be verified comparing the equilibria described by Proposition 5 and Proposition 8.

[18] We emphasize that $\underline{a}$ should be not interpreted as the lowest value of a for which the presence of aN tax havens have a positive impact on tax revenues but rather as the lowest value of a supporting a separating equilibrium and thus the lowest value of a allowing for analytical comparison of tax revenues in equilibria with and without tax havens. It may very well be that the presence of aN tax havens, where $a < \underline{a}$, gives rise to a 'mixed equilibrium' with high-tax countries, low-tax countries and tax havens where countries earn a higher tax revenue than in the corresponding asymmetric equilibrium.

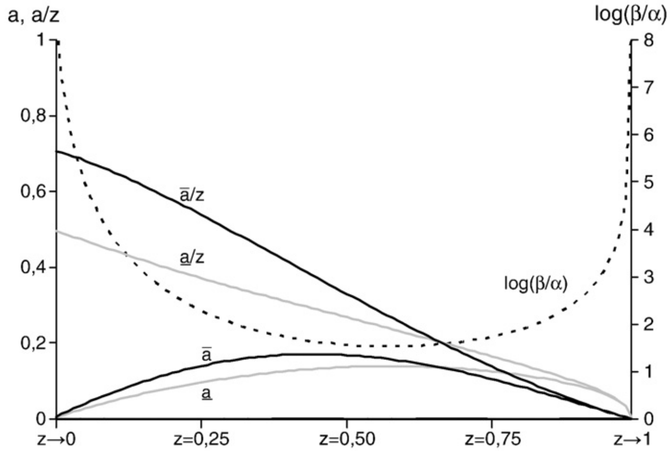

Fig. 2. Separating equilibrium — a numerical illustration.

equilibrium without tax havens. We illustrate the values of $\underline{a}$ and $\bar{a}$ in absolute terms as well as relative to z (absolute and relative threshold values obviously converge as $z\rightarrow 1$). There are several important things to note. Firstly, in any asymmetric equilibrium with z smaller than approximately 0.67, it holds that $\underline{a}<\bar{a}$, hence in these asymmetric equilibria, the presence of tax havens potentially increases the revenue of countries. Secondly, $\bar{a}/z$ decreases monotonically with z, hence asymmetric equilibria where tax competition for profits is close to perfect and equilibrium values of z are small allow for the largest relative number of tax havens while preserving the property that the presence of tax havens increases tax revenues. Finally, $\bar{a}$ has an interior maximum when z equals approximately 0.45, hence asymmetric equilibria where tax competition for profits is far from perfect and equilibrium values of z are intermediate allow for the largest absolute number of tax havens while preserving the property that the presence of tax havens increases tax revenues. Similar patterns are found in numerous other numerical examples (not reported here).

4. Concluding remarks

In the first part of the paper, we set up a model of tax competition between a large number of identical countries competing for real investment and profits. At the heart of the model were assumptions about the costs associated with profit shifting, specifically we departed from related papers by introducing a diversification motive in profit shifting strategies. Our main finding was that there may exist asymmetric equilibria with high-tax and low-tax countries. This result is clearly of empirical relevance since it provides an explanation for observed asymmetries in capital taxation. From a methodological point of view, we believe that the assumption of 'imperfect' tax competition could prove useful in other contexts, in particular as an alternative to computing mixed strategy equilibria in other settings where no pure strategy equilibrium exists under the usual assumption of 'perfect' tax competition (Wilson, 2005). The model also provides guidance to the emerging empirical literature on the tax elasticity of the corporate income tax base (Gruber and Rauh, 2007). By highlighting that low-tax countries engaged in aggressive tax competition for profits potentially face much larger tax elasticities of the corporate tax base than high-tax countries, the model stresses the importance of allowing for heterogeneous tax elasticities of tax bases across jurisdictions in empirical applications.

In the second part of the paper, we used this framework to analyze the role of tax havens. We found that tax havens affect the revenue of countries in various ways, which generally leaves the net revenue effect undetermined. Tax havens attract profits from countries but also render competition for profits less attractive, which induces low-tax countries to become high-tax countries. While the former leakage effect reduces revenue, the latter crowding effect increases it. On balance, the presence of tax havens may increase the equilibrium tax revenue of countries provided that the number of tax havens is not too large.

The latter result has significant policy implications, most importantly it raises doubt of whether eliminating tax havens would be desirable for OECD countries even if it were feasible. Put simply, if tax havens were eliminated, the incentive to engage in aggressive tax competition would persist. In the new equilibrium, it is therefore likely that some countries would take over the role as low-tax jurisdictions from tax havens, which could leave all countries worse off than they are when the presence of tax havens deters countries from engaging in aggressive tax competition.

Finally, we emphasize that our analysis does not amount to a proper welfare analysis since it only includes effects on government revenue. Indeed, a welfare analysis would also need to account for changes in net corporate profits (i.e. net of shifting costs and taxes). While such an analysis falls outside the scope of this paper, we point to one aspect that strengthens the case for beneficial tax havens: In any asymmetric equilibrium, the tax differential between high-tax countries and low-tax countries introduces a production inefficiency, which is eliminated in the separating equilibrium where all countries apply the same tax rate. Hence, gross corporate profits are unambiguously higher in the separating equilibrium with tax havens than in the asymmetric equilibrium without tax havens.

Acknowledgements

I am grateful to Peter B. Sørensen, John D. Wilson, Claus T. Kreiner, Jes W. Hansen, Niels K. Frederiksen, participants at lunch seminars at the University of Copenhagen and UC Berkeley as well as participants at the Summer School on Fiscal Federalism for helpful comments and suggestions. Moreover, I am thankful for suggestions made by Jonathan Eaton (editor) and an anonymous referee from which the paper has benefitted enormously. Part of the manuscript was drafted while visiting UC Berkeley and I am grateful for the kind reception I received there.

Appendix A

Proof of Lemma 1. We restate the first-order condition for optimal profit shifting from country n to country m:

$$\frac{\partial\pi}{\partial q_{nm}}\leq 0\Leftrightarrow(t_n-t_m)\leq\frac{\sum_m q_{nm}}{\alpha}+\frac{Nq_{nm}}{\beta}\forall m\neq n \tag{11}$$

In the remainder of the proof we let q^*_{nm} denote optimal profit shifting levels from country n to country m, however, we suppress the asterisk in the main text to simplify notation. When $t_n>t_1$, we obtain the following solution to Eq. (11) under the assumption that $q^*_{n2}=...=q^*_{nN}=0$:

$$\widetilde{q_{n1}}=\frac{\alpha\beta}{(\alpha N+\beta)}(t_n-t_1) \tag{12}$$

Eq. (12) gives the level of profit shifting from country n to country 1 assuming that there is no profit shifting from country n to other countries. This is optimal if the cost advantage of shifting some profits to country 2 is smaller than the tax saving of shifting profits only to the country 1. Hence, $q^*_{n1}=\widetilde{q_{n1}}$ and $q^*_{n2}=...=q^*_{nN}=0$ if and only if:

$$\left\{\frac{\partial\pi}{\partial q_{n2}}\bigg|q_{n2}=...=q_{nN}=0,q_{n1}=\widetilde{q_{n1}}\right\}\leq 0\Leftrightarrow(t_n-t_2)\leq\frac{\beta}{\alpha N+\beta}(t_n-t_1) \tag{13}$$

If on the other hand Eq. (13) is not satisfied, there is profit shifting from country n to country 2. Assuming that $q_{n3}^*=...=q_{nN}^*=0$, we obtain the following solutions to the system of first-order conditions (11):

$$\widetilde{q_{n1}} = \frac{\beta}{N(\alpha N+2\beta)}\{\beta(t_2-t_1)+\alpha N(t_n-t_1)\} \tag{14}$$

$$\widetilde{q_{n2}} = \frac{\beta}{N(\alpha N+2\beta)}\{\beta(t_1-t_2)+\alpha N(t_n-t_2)\} \tag{15}$$

Eqs. (14) and (15) give the level of profit shifting from country n to country 1 and 2 assuming that there is no profit shifting from country n to other countries and this is optimal if and only if $q_{n3}^*=0$. Hence, $q_{n1}^*=\widetilde{q_{n1}}$ and $q_{n2}^*=\widetilde{q_{n2}}$ and $q_{n3}^*=...=q_{nN}^*=0$ if and only if:

$$\left\{\frac{\partial\pi}{\partial q_{n3}}\middle| q_{n3}=...=q_{nN}=0;q_{n1}=\widetilde{q_{n1}},q_{n2}=\widetilde{q_{n2}}\right\}\le 0 \tag{16}$$

$$\Leftrightarrow (t_n-t_3)\le\frac{\beta}{\alpha N+2\beta}\{(t_n-t_1)+(t_n-t_2)\}$$

If Eq. (16) is not satisfied there is profit shifting from country n to country 3. Solving Eq. (11) conditional on $q_{n4}^*=...=q_{nN}^*=0$ gives rise to $\widetilde{q_{n1}}$, $\widetilde{q_{n2}}$ and $\widetilde{q_{n3}}$ on a form similar to (14)–(15). As before, $q_{n1}^*=\widetilde{q_{n1}}$, $q_{n2}^*=\widetilde{q_{n2}}$, $q_{n3}^*=\widetilde{q_{n3}}$ and $q_{n4}^*=...=q_{nN}^*=0$ if and only if $q_{n4}^*=0$ which can be determined with a condition similar to Eq. (16). Generalizing this approach, the number of countries L to which there is profit shifting from country n is given implicitly by the following equations:

$$\left\{\frac{\partial\pi}{\partial q_{nL}}\middle| q_{nL}=...=q_{nN}=0;q_{nl}=q_{nl}^*\ (L-1)\forall l<L\right\}>0$$

$$\left\{\frac{\partial\pi}{\partial q_{nL+1}}\middle| q_{nL+1}=...=q_{nN}=0;q_{nl}=q_{nl}^*\,(L)\forall l\le L\right\}\le 0$$

where:

$$q_{nm}^*(L)=\frac{\beta}{N(\alpha+L\beta)}\left\{\sum_{l=1}^{L}\beta(t_l-t_m)+\alpha N(t_n-t_m)\right\} \tag{17}$$

Eq. (17) also determines optimal total profit shifting from country n to each of the L countries. □

Proof of Lemma 2. If the MNC chooses to shift profits from a high-tax country, the optimal amount of profits q_{nm} shifted to each low-tax country is given by Eq. (3) and the total tax saving of doing so equals the total amount of profits shifted zNq_{nm} multiplied by the tax differential (t^H-t^L). The cost of shifting profits out of a high-tax country is given by Eq. (2). The MNC chooses to shift profits if tax savings net of shifting costs are non-negative, i.e. if Eq. (4) is satisfied. □

Proof of Lemma 3. We differentiate Eq. (5) with respect to t_n using the specific functional form of $f(\cdot)$ and rearrange to show that $dk_n/dt_n=\gamma$. In order to prove Eq. (6), we note that when all other countries apply the same tax rate t_y, the capital stock of country n is given by $k_n=s-\gamma(t_n-t_y)$. We consider a change of tax rates by two countries $m\neq n$ and $l\neq n$ which satisfies that $dt_m=-dt_l>0$ and therefore leaves the average tax rate among the $N-1$ countries unchanged at t_y. The MNC optimally responds by moving real capital from country m to country l so as to equate net-of-tax real capital returns in the two countries, which leaves the capital stock in all other countries as well as χ unaltered. It follows that the expression for k_n holds when t_y is simply the average of the rates applied by all countries in the rest of the world.

Proof of Proposition 1. We derive t^S as the unique tax rate that satisfies Eq. (7) under symmetry using that no profit shifting takes place in equilibrium ($q_n=0$) and that marginal deviations from symmetry do not cause the MNC to shift profits due to the fixed cost of profit shifting ($dq_n/dt_n=0$). In order to conclude that t^S is an equilibrium, we need to rule out the possibility that a single country can increase its revenue by means of (non-marginal) deviations from equilibrium. It is easy to see from Lemma 2 that under the assumption of a large number of countries ($z=(1/N)\rightarrow 0$), a single country reducing its tax rate below t^S cannot induce the MNC to shift profits due to the positive fixed cost of profit shifting. Hence, t^S is the global revenue maximum from the perspective of a single country. □

Proof of Lemma 4. By rearranging (8) and (10), we obtain the following expressions for equilibrium tax rates conditional on a value of z:

$$t^H=\frac{s}{[\gamma+(2-z)z\alpha\psi(z)]} \tag{18}$$

$$t^L=\frac{[\gamma+z\alpha\psi(z)]}{[\gamma+\alpha\psi(z)]}\frac{s}{[\gamma+(2-z)z\alpha\psi(z)]} \tag{19}$$

Substituting Eqs. (18) and (19) into Eq. (9) yields the following constraint which implicitly determines z as a function of parameters α,β and γ:

$$\frac{\gamma}{\beta}=\frac{\left(1-z+z^2\right)-z^2(1-z)\frac{\beta}{\alpha}}{\left[1+z\frac{\beta}{\alpha}\right]\left[z(1-z)\frac{\beta}{\alpha}-1\right]}\equiv\Omega(z) \tag{20}$$

We first note that the LHS of Eq. (20) is constant and positive whereas the RHS is a function of z which we denote $\Omega(z)$. We let $p(z)$ refer to the numerator of $\Omega(z)$ and $q(z)$ to the denominator. We note that $q(0)<0$ and $q(1)<0$ and that $q(z)>0$ for some $z\in[0;1]$ if and only if $\beta/\alpha>4$. Let z_1 and z_4 denote the two roots of $q(z)$ if they exist where $z_1<z_4$. Moreover, we note that $p(0)>0$ and $p(1)>0$ and that $p(z)<0$ for some $z\in[0;1]$ if and only if $\beta/\alpha>5.22$. Let z_2 and z_3 denote the two roots of $p(z)$ if they exist where $z_2<z_3$. It is easily verified that $q(\tilde{z})<0\Rightarrow p(\tilde{z})>0$ for any $\tilde{z}\in[0;1]$ hence z_2 and z_3 belong to the interval $[z_1;z_4]$. We first consider the case where $\beta/\alpha<4$. It is easy to see that $q(z)$ is negative and $p(z)$ is positive for all values of z, hence no values of z satisfy Eq. (20). We proceed to consider the case where $\beta/\alpha>5.22$. It follows from the properties of $q(z)$ and $p(z)$ that $\Omega(z)>0$ if and only if $z\in[z_1;z_2]$ or $z\in[z_3;z_4]$. Moreover, $\Omega(z)\rightarrow\infty$ as z approaches z_1 from above and as z approaches z_4 from below and $\Omega(z)\rightarrow 0$ as z approaches z_2 from below and as z approaches z_3 from above . Since $\Omega(z)$ takes all values $]\infty;0]$ in the interval $[z_1;z_2]$ and in the interval $[z_3;z_4]$,there exist two distinct values z' and z'' satisfying Eq. (20) where $z'\in[z_1;z_2]$ and $z''\in[z_3;z_4]$. Finally, we consider the case $\beta/\alpha\in[4;5.22]$. Here $\Omega(z)$ has the same properties as in the previous case except that $\Omega(z)>0$ in the entire interval $[z_1;z_4]$. Let z_5 denote the value of z that minimizes $\Omega(z)$ in the interval $[z_1;z_4]$ and define $\overline{\Omega}\equiv\Omega(z_5)$. It follows that $\Omega(z)$ takes all values $]\overline{\Omega};\infty]$ in both intervals $[z_1;z_5]$ and $[z_5;z_4]$. Hence, if $\gamma/\beta>\overline{\Omega}$ there are two values z' and z'' satisfying Eq. (20), if $\gamma/\beta=\overline{\Omega}$ there is one value of z satisfying Eq. (20) whereas there are no values of z satisfying Eq. (20) if $\gamma/\beta<\overline{\Omega}$. It follows directly from the properties of $p(z)$ and $q(z)$ that $\overline{\Omega}$ approaches infinity as $\beta/\alpha\rightarrow 4$ and zero as $\beta/\alpha\rightarrow 5.22$. Evaluating Eqs. (18) and (19) at equilibrium values of z yields equilibrium values of tax rates t^H and t^L. □

Proof of Proposition 2. Consider a vector (t^H, t^L, z) that solves equilibrium conditions (8)–(10) and consider the optimal choice of tax rate in a country n given that a fraction z of the other countries set the tax rate t^L and the remaining countries set the tax rate t^H. The tax rate t^L maximizes revenue in country n over the range $[0;t^D]$ where t^D is the highest tax rate that induces the MNC to shift profits from high-tax countries to country n. By an argument identical to the one used in the proof of Proposition 1, the assumption of a large N rules out the possibility that a single country n can induce the MNC to shift profits from low-tax countries to country n by setting a tax rate below t^L. Similarly, t^H maximizes revenue in country n over the range $]t^U; \infty]$ where t^U is the lowest tax rate at which the MNC shifts profits from country n to low-tax countries. In order for (t^H, t^L, z) to constitute an equilibrium, it must hold that there is no tax rate in the range $]t^D; t^U]$ that generates a higher revenue than t^H and t^L.

We first argue that t^U maximizes revenue over the range $]t^D; t^U]$. We note that the rate effect R_n is decreasing monotonically and the base effect $-B_n$ is increasing monotonically over each of the intervals $]t^D; t^U[$ and $]t^U; t^H]$. By construction, $R_n = -B_n$ at $t_n = t^H$ and it follows that $R_n > -B_n$ at $t_n = t^U + \varepsilon$ for $\varepsilon \to 0$. At $t_n = t^U$, by definition, R_n shifts discretely, hence R_n is larger when t_n is marginally below t^U than when t_n is marginally above t^U. The discrete shift in the tax base at $t_n = t^U$ implies that $-B_n$ is infinitely large at this point. However, $-B_n$ is smaller when t_n is marginally below t^U than when t_n is marginally above t^U. It follows that $R_n > -B_n$ over the entire interval $]t^D; t^U[$, hence t^U generates a larger revenue than any $t \in]t^D; t^U[$.

Having shown that t^U is the revenue maximum over the interval $]t^D; t^U]$, it suffices to ensure that t^H generates a higher revenue than t^U. We let Γ denote the net revenue gain of a country n deviating from the asymmetric equilibrium by setting the tax rate t while assuming that t is close enough to t^L to deter the MNC from shifting profits from country n to low-tax countries.

$$\Gamma(t) = -\gamma\left(t^H - t\right)^2 - z\alpha\psi(z)\left(2t^H - t^L\right)\left(t^H - t\right) + t^H z\alpha\psi(z)\left(t^H - t^L\right)$$

where we have used Eq. (8). It is easy to see that $\Gamma' > 0$ over the interval $[0; t^H]$ and that there exists a unique $t^* \in [t^L; t^H]$ so that $\Gamma(t^*) = 0$. Hence, t^* is the lowest tax rate that allows a deviating country n to earn at least the same revenue as other countries under the assumption that t^* is low enough to prevent profit shifting out of country n. It follows directly that if Φ is so small that the MNC at least breaks even on profit shifting out of country n when country n sets tax rate t^*, this type of deviations strictly decreases revenue and (t^H, t^L, z) constitutes an asymmetric equilibrium. Using Lemma 2, we can thus compute the highest value of Φ supporting (t^H, t^L, z) as an asymmetric equilibrium as the value of Φ that just allows the MNC to break even on profit shifting out of country n when country n sets the tax rate t^*:

$$\overline{\Phi} = \frac{z\alpha\psi(z)}{2}\left(t^* - t^L\right)^2 \quad (21)$$

which is strictly positive for finite parameter values. □

Proof of Lemma 5. To prove the first half of the Lemma, we simply note that N appears nowhere in the three equilibrium conditions (8)–(10). To prove the second half of the Lemma, we note that a proportional increase in α, β, γ and s leaves β/α and γ/β unchanged, hence the values of z that solve Eq. (20) are unchanged. Moreover, the equilibrium tax rates conditional on a value of z given by Eqs. (18) and (19) are unchanged. □

Proof of Proposition 3. We recall that equilibrium values of z must satisfy Eq. (20). Changing s/α while holding β/α and γ/α constant does not affect Eq. (20), hence equilibrium values of z are unchanged. We divide both numerators and denominators of Eqs. (18) and (19) by α. Clearly, for a given value of z, changing s/α while holding β/α and γ/α constant leads to proportional increases in t^H and t^L. □

Proof of Proposition 4. As γ/α approaches infinity for a constant (finite) value of β/α, the left-hand side of Eq. (20) approaches infinity in which case the two solutions to Eq. (20) converge as follows:

$$z \to \frac{1}{2} \pm \sqrt{\frac{\frac{\beta}{\alpha} - 4}{4\frac{\beta}{\alpha}}}$$

Dividing both numerators and denominators of Eqs. (18) and (19) by α and letting s/α and γ/α go to infinity, it is easy to see that t^H and t^L approach s/γ. Applying Eq. (21) and recalling that $t^* \in [t^L; t^H]$, it follows directly that $\overline{\Phi} \to 0$. □

Proof of Proposition 5. We recall from the proof of Lemma 4 that $z' \in [z_1; z_2]$ and $z'' \in [z_3; z_4]$. It may easily be verified that as β/α approaches infinity, z_2 approaches zero whereas z_3 approaches one. Hence, as β/α approaches infinity, z' approaches zero whereas z'' approaches one. Rewriting Eq. (20) for the asymptotic case where $\beta/\alpha \to \infty$ and recalling that we do not *a priori* know how $z\beta/\alpha$ converges, we find the following expression for z':

$$z' \to \frac{1}{\sqrt{\frac{\beta}{\alpha}\left(1 + \frac{\gamma}{\alpha}\right)}} \quad (22)$$

Dividing both numerators and denominators of Eqs. (18) and (19) by α and evaluating the resulting expressions for the special case where $\beta/\alpha \to \infty$ while using Eq. (22) yields (t^H, t^L, z). To find the value of $\overline{\Phi}$ associated with z', we use that $t^L \to 0$ and the fact that Eq. (22) implies that $z'\psi(z') \to 1$ to rewrite $\Gamma(t) = 0$ as:

$$\Gamma(t) = \frac{-\gamma}{\gamma + \alpha}t^2 + 2t^H t - \left(t^H\right)^2 = 0$$

Computing the root t^* of this second-order polynomium and inserting in Eq. (21) yields $\overline{\Phi}$. It follows directly from Eqs. (18) and (19) that in the case of z'', t^L converges to t^H which, in turn, implies that the associated value of $\overline{\Phi}$ approaches zero. In the limit, the equilibrium candidate with $z \to 0$ is thus the unique asymmetric equilibrium. □

Proof of Proposition 6. We consider the optimal deviations from equilibrium by a country n in different ranges of tax rates and derive conditions that these deviations generate a smaller revenue than the revenue associated with the equilibrium tax rate t^N. Let t^D denote the highest tax rate that induces the MNC to shift profits from other countries to country n. Moreover, let t^U denote the lowest tax rate at which the MNC shifts profits from country n to tax havens. By definition, t^N maximizes revenue of country n over the range $]t^U; \infty]$. By an argument identical to the one applied in the proof of Proposition 2, the tax rate t^U maximizes revenue of country n over the range $]t^D; t^U]$. The tax rate t^{LL} which maximizes the revenue of country n over the range $[0; t^D]$ is determined by Eq. (7) evaluated for a country n engaging in aggressive tax competition.

$$s + (\gamma + \alpha\psi(a))\left(t^N - t^{LL}\right) - a\beta\psi(a)t^{LL} = t^{LL}\{\gamma + (\alpha + a\beta)\psi(a)\} \quad (23)$$

Using the expression for t^N we find an explicit solution for t^{LL}.

We first characterize the condition ensuring that t^{LL} generates a smaller revenue than t^N. Inserting expressions for t^{LL} and t^N into the left-hand side of Eq. (23) gives the tax base of a country setting t^{LL}. Hence, multiplying this expression by t^{LL} gives us the highest possible revenue of a country competing for shifted profits Π^{LL}.

$$\Pi^{LL} = s^2\left[\frac{\{2\gamma + (1 + 2a)\alpha\psi(a)\}^2}{\{\gamma + 2a\alpha\psi(a)\}^2\{2\gamma + 2\alpha\psi(a) + 2a\beta\psi(a)\}}\right]$$

Similarly, one may determine the revenue of a country in the separating equilibrium Π^N:

$$\Pi^N = s^2\left[\frac{\{\gamma + a\alpha\psi(a)\}}{\{\gamma + 2a\alpha\psi(a)\}^2}\right]$$

It is straightforward to show that $\Pi^N \geq \Pi^{LL}$ if and only if:

$$4\psi(a)\left(\frac{\beta}{\alpha}-1\right)a^2 + 4\frac{\gamma}{\alpha}\left(\frac{\beta}{\alpha}-1\right)a-\psi(a)\geq 0 \tag{24}$$

Under the assumption that $\beta/\alpha>1$, the first two terms are positive. It is straightforward to show that Eq. (24) is monotonically increasing in a, negative for $a \to 0$ and positive for $a \to \infty$. It follows that there exists a unique threshold $\underline{a}$ so that $\Pi^N \geq \Pi^{LL}$ if and only if $a \geq \underline{a}$. Moreover, it is easy to see that Eq. (24) is unambiguously increasing in both β/α and γ/α.

We proceed to characterize the condition ensuring that t^U generates a smaller revenue than t^N. We let Γ denote the net revenue gain of a country n deviating from the separating equilibrium by setting the tax rate t while assuming that t is small enough to deter the MNC from shifting profits from country n to tax havens.

$$\Gamma(t) = -\gamma\left(t^N-t\right)^2-2a\alpha\psi(a)\left(t^N\right)\left(t^N-t\right) + a\alpha\psi(a)\left(t^N\right)^2 \tag{25}$$

where we have used the expression for t^N. It is easy to see that $\Gamma' > 0$ over the interval $[0; t^N]$ and that there exists a unique $t^* \in [0; t^N]$ so that $\Gamma(t^*) = 0$. Hence, t^* is the lowest tax rate that allows a deviating country n to earn at least the same revenue as other countries under the assumption that t^* is low enough to prevent profit shifting out of country n. Using Lemma 2 and applying the same argument as in the proof of Proposition 2, it follows that any value of Φ higher than $\overline{\Phi}(a)$ ensures that t^N generates a larger revenue than t^U where:

$$\overline{\Phi}(a) = \frac{a\alpha\psi(a)}{2}(t^*)^2.$$

□

Proof of Proposition 7. As argued in Section 2.6, the tax base of a country in the symmetric equilibrium equals s and multiplying by t^S, it is easy to see that the revenue of a country in the symmetric equilibrium Π^S equals:

$$\Pi^S = \frac{s^2}{\gamma}$$

which is unambiguously larger than Π^N derived in the proof of Proposition 6. □

Proof of Proposition 8. To derive the limit of t^N, we use Eq. (22) to show that $a\psi(a) \to 1$ as $\beta/\alpha \to \infty$. We also use the latter result to rewrite $\Gamma(t) = 0$ as

$$\Gamma(t) = \frac{-\gamma}{\gamma+\alpha}t^2 + 2t^N t-\left(t^N\right)^2 = 0$$

Computing the solution t^* to this second-order equation and inserting in Eq. (21) gives the limit of $\overline{\Phi}$. Finally, it is easy to see that as $\beta/\alpha \to \infty$, Eq. (25) converges in the following way:

$$4\psi(a)\frac{\beta}{\alpha}a^2 + 4\frac{\gamma}{\alpha}\frac{\beta}{\alpha}a-\psi(a)\geq 0$$

Using Eq. (22), it is straightforward to show that this inequality holds if and only if $a/z > 1/2$. □

Proof of Proposition 9. Inserting Eqs. (18)–(19) into the expression on the left-hand side of Eq. (8) gives us the tax base of a high-tax country in the asymmetric equilibrium without tax havens, which may be used to determine the asymmetric equilibrium revenue Π^H:

$$\Pi^H = s^2\frac{\gamma + z\alpha\psi(z)}{\{\gamma + (2-z)z\alpha\psi(z)\}^2}$$

In the proof of Proposition 6, we have computed the revenue of countries in the separating equilibrium Π^N. Using Eq. (22), it is relatively straightforward to show that $\Pi^N - \Pi^H \geq 0$ if and only if $a \leq \overline{a}$ where:

$$\overline{a} = z\frac{3\left(\frac{\gamma}{\alpha}\right)^3 + 11\left(\frac{\gamma}{\alpha}\right)^2 + 12\left(\frac{\gamma}{\alpha}\right) + 4}{3\left(\frac{\gamma}{\alpha}\right)^3 + 13\left(\frac{\gamma}{\alpha}\right)^2 + 18\left(\frac{\gamma}{\alpha}\right) + 8}$$

It follows directly that $\overline{a} \to 0.5z$ as $\gamma/\alpha \to 0$ and $\overline{a} \to z$ as $\gamma/\alpha \to \infty$. □

References

Bartelsman, E.J., Beetsma, R.M.W.J., 2003. Why pay more? Corporate tax avoidance through transfer pricing in OECD countries. J. Public Econ. 87, 2225–2252.

Clausing, K.A., 2003. Tax-motivated transfer pricing and US intrafirm trade prices. J. Public Econ. 87, 2207–2223.

Desai, M., Foley, F., Hines, J.R., 2004. A multinational perspective on capital structure choice and internal capital markets. J. Finance 59, 2451–2487.

Huizinga, H., Laeven, L., Nicodème, G., 2008. Capital structure and international debt shifting. J. Financ. Econ. 88, 80–118.

Hines, J.R., 1999. Lessons from behavioral responses to international taxation. National Tax J. 52, 305–322.

Haufler, A., Schjelderup, G., 2000. Corporate tax systems and cross country profit shifting, Oxford economic papers, 52, pp. 306–325.

Fuest, C., Hemmelgarn, T., 2005. Corporate tax policy, foreign firm ownership and thin capitalization. Reg. Sci. Urban Econ. 35, 508–526.

Mintz, J., Smart, M., 2004. Income shifting, investment and tax competition: theory and empirical evidence from provincial taxation in Canada. J. Public Econ. 88, 1149–1168.

Hong, Q., Smart, M., 2010. In praise of tax havens: international tax planning and foreign direct investment. Eur. Econ. Rev. 54, 82–95.

Peralta, S., Wauthy, X., Ypersele, T., 2006. Should countries control international profit shifting? J. Int. Econ. 68, 24–37.

Slemrod, J., 2004. Are corporate tax rates, or countries, converging? J. Public Econ. 88, 1169–1186.

Bucovetsky, S., 1991. Asymmetric tax competition. J. Urban Econ. 30, 167–181.

Baldwin, R., Krugman, P., 2004. Agglomeration, integration and tax harmonization. Eur. Econ. Rev. 48, 1–23.

Wilson, J.D., 1987. Trade in a tiebout economy. Am. Econ. Rev. 77, 431–441.

Slemrod, J., Wilson, J.D., 2009. Tax competition with parasitic tax havens. J. Public Econ. 93, 1261–1270.

Keen, M., 2001. Preferential regimes can make tax competition less harmful. National Tax Journal 54, 757–762.

Stöwhase, S., 2005. Asymmetric capital tax competition with profit shifting. J. Econ. 2, 175–196.

Dharmapala, D., Hines, J.R., 2006. Which countries become tax havens? Natl Bur. Econ. Res. 12802.

Hines, J.R., Rice, E.M., 1994. Foreign tax havens and American business. Q. J. Econ. 109, 149–182.

Schön, W., 2005. Playing different games? Regulatory competition in tax and company law compared. Common Mark. Law Rev. 42, 331–365.

Wilson, J.D., 2005. In: Alm, J., Martinez-Vasquez, J., Rider, M. (Eds.), Tax competition with and without preferential treatment of a highly mobile tax base. The Challenges of Tax Reform in a Global Economy, Springer.

Gruber, J., Rauh, J., 2007. How elastic is the corporate income tax base? In: Auerbach, A., Hines, J.R., Slemrod, J. (Eds.), Taxing Corporate Income in the 21st Century, Cambridge University Press.