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halshs-00442818, version 1 - 22 Dec 2009

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2009.73

Maison des Sciences Économiques, 106-112 boulevard de L'Hôpital, 75647 Paris Cedex 13
http://ces.univ-paris1.fr/cesdp/CES-docs.htm
ISSN : 1955-611X

halshs-00442818, version 1 - 22 Dec 2009

Heterogeneous Firms, 'Profit Shifting' FDI and International Tax Competition*

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October 2009

* We are grateful to Giancarlo Corsetti, Russel Cooper, Omar Licandro and Morten Ravn for constant advice. We would also like to thank Andrew Bernard, Jonathan Eaton, Carsten Eckel, Karolina Ekholm, Eckhard Janeba, Tim Kehoe, Horst Raff, Vincent Rebeyrol, Frank Stähler, Tanguy van Ypersele, seminar participants at the University of Mannheim and the University of Tuebingen, the 24th Congress of the EEA, Barcelona 2009, the XIV Workshop on Dynamic Macroeconomics, Vigo 2009, the Annual Meeting of the Scottish Economic Society, Perth 2009, the IXth RIEF Doctoral Meeting in International Trade and International Finance, Aix-en Provence 2009, the 11th Workshop in International Economic Relations, Göttingen 2009, the INFER workshop on Firm and Product Heterogeneity, Brussels 2009 as well as participants of the EUI Trade Group and the PSE International Trade lunchtime seminar for fruitful discussions and comments. All remaining errors are ours. This is a revised version of EUI Working Paper 2009/15 (February 2009). Krautheim acknowledges financial support by the Région Ile-de-France.

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Résumé

Les entreprises les plus grandes sont les plus susceptibles d'opérer dans les paradis fiscaux pour exploiter les différences de taxes. Nous étudions un jeu en taxes entre un grand pays et un paradis fiscal en modélisant des firmes hétérogènes en concurrence monopolistique qui ont la possibilité de transférer leurs profits à l'étranger. Nous montrons qu'un plus grand degré d'hétérogénéité des firmes (étalement à moyenne constante de la distribution des coûts) accroît le degré de concurrence fiscale. En d'autres termes, cela réduit le taux de taxe d'équilibre du grand pays, augmente les transferts vers l'étranger de la base d'imposition et réduit ainsi le revenu fiscal d'équilibre. Une plus grande substituabilité entre variétés conduit à des effets similaires. Enfin, nous montrons que les modèles avec entreprises homogènes sous-estiment l'importance de la concurrence fiscale.

JEL: *F23, H25, H87*

Mots-Clef: *heterogeneous firms, tax competition, profit shifting, tax havens*

Abstract

Larger firms are more likely to use tax haven operations to exploit international tax differences. We study a tax game between a large country and a tax haven modeling heterogeneous monopolistic firms, which can shift profits abroad. We show that a higher degree of firm heterogeneity (a mean-preserving spread of the cost distribution) increases the degree of tax competition, i.e. it decreases the equilibrium tax rate of the large country, leads to higher outflows of its tax base and thus decreases its equilibrium tax revenue. Similar effects hold for a higher substitutability across varieties. We find that models with homogeneous firms understate the strength of tax competition.

JEL: *F23, H25, H87*

Keywords: *heterogeneous firms, tax competition, profit shifting, tax havens*

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1 Introduction

With globalization tax havens have become more important. The increased opportunities for multinational firms to shift profits towards these low-tax jurisdictions have changed the strategic tax game for international profits. Recent empirical evidence by Desai, Foley, and Hines (2006) shows that larger firms use tax haven operations more intensively.[1] This suggests that firm heterogeneity is relevant for international tax competition. Theory, however, has mainly focused on models with homogeneous firms.[2]

We introduce a tractable model of tax competition with heterogeneous firms between a large country and a tax haven. Firm heterogeneity is introduced in exactly the way that has been found to be relevant empirically: heterogeneity in productivity and size. The analysis reveals that economies with a higher degree of firm heterogeneity (relatively many productive firms) and higher substitutability across goods (low monopolistic market power) face stronger international tax competition.[3] The crucial tradeoff for the governments is between the *intensive margin* of taxation (revenues per unit of the tax base) and the *extensive margin* of taxation (size of the tax base).

In a large country, firms in a monopolistically competitive industry make positive profits, which are taxed by the government. Given the tax rate firms can decide to avoid paying taxes at home by opening an affiliate in a tax haven and shift profits abroad. The governments of the large country and the tax haven set their tax rates non-cooperatively. Our setup allows us to derive the pure strategy Nash equilibrium of the tax game between a large country and a tax haven.

In equilibrium the tax haven undercuts the large country which gives firms an incentive to do 'profit shifting' FDI. While the fixed cost of opening an affiliate in the tax haven is the same for all firms, the gains from profit shifting depend on the level of profits a firm is making. In line with the findings of Desai, Foley, and Hines (2006), in equilibrium the most productive (and thus largest and most profitable) firms shift profits while less productive firms continue to pay taxes at home.[4]

[1] In line with these findings Graham and Tucker (2006) show that larger firms are more likely to avoid taxes through corporate tax shelters.

[2] Some notable exceptions will be discussed below.

[3] We measure the degree of tax competition by the fraction of the tax base shifted to the tax haven in equilibrium. Stronger competition corresponds to higher outflows. Using equilibrium government income and the equilibrium tax rates as alternative measures of tax competition, the results are similar.

[4] Desai, Foley, and Hines (2006) analyze data on American multinational firms from the Bureau of Economic Analysis annual survey of U.S. Direct Investment Abroad for the years 1982 to 1999. Grouping countries with US affiliates into tax havens and non-havens allows them to find correlations between tax haven activities and firm level characteristics.

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Tax competition is strongest when the distribution of profits across firms is such that the most productive firms account for a large share of aggregate profits. This is the case when firms are very heterogeneous and when monopolistic market power is low. In this case, the large country suffers a substantial outflow of its tax base. The tax haven gains as it can set a relatively high tax rate and still attracts a considerable fraction of the tax base.

When instead there is low firm heterogeneity and high monopolistic market power, the tax base does not react strongly to tax differences and the large country is 'protected' from international tax competition. It can set a relatively high tax rate without loosing much of its tax base. The tax haven is forced to undercut the large country 'aggressively' in order to attract some of the tax base.

In our model tax competition creates a distortion. Welfare is thus higher when the large country is more 'protected' from tax competition which is the case when firms are more homogeneous. If taxes themselves were distortionary, welfare effects could be different.

To complement our findings, we compare our model to a model with homogeneous firms. We confirm that the model with homogeneous firms is the limit case of our model with heterogeneous firms and find that tax competition is lowest when firms are perfectly homogeneous. This implies that models with homogeneous firms understate the strength of tax competition. Our model shows that taking into account firm heterogeneity is important as it increases the degree of tax competition by increasing the mobility of the tax base.[5] We also analyze the role of the fixed costs of profit shifting. When these fixed costs are high it is more costly for firms to shift profits. This allows the large country to set a higher tax rate, which in turn makes it more profitable for firms to shift profits. In equilibrium these two effects exactly offset each other and the fraction of firms shifting profits and the fraction of profits shifted abroad remains constant. With a higher tax rate and a constant tax base, the equilibrium tax revenue in the large country increases.

Starting with Zodrow and Mieszkowski (1986) and Wilson (1986) a large and growing theoretical literature has analyzed the increasing competitive pressures of governments to reduce corporate tax rates.[6] While this literature tends to focus on outflows of capital, several the-

[5]Heterogeneity affects tax competition through the distribution of the tax base (profits) across firms. Thus any policies or other factors that increases the heterogeneity of firm profits increase tax competition in a similar way. For example the presence of multi-product firms as in Bernard, Redding, and Schott (forthcoming), Mayer, Melitz, and Ottaviano (2009) and Eckel and Neary (2006) would imply larger variance of the profit distribution for a given productivity distribution and thus increase tax competition.

[6]See Wilson (1999), Wilson and Wildasin (2004) or Fuest, Huber, and Mintz (2005) for surveys.

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oretical contributions have considered the possibility of multinational firms to shift profits to jurisdictions with lower tax rates.[7]

Recent empirical studies have shown that the mobility of profits has a considerable impact on the ability of governments to increase tax income by increasing tax rates. Using OECD industry level data Bartelsman and Beetsma (2003) show that a considerable fraction of additional revenue that could result from a unilateral tax increase is lost due to profit-shifting.[8] Clausing (2003) provides direct evidence on profit-shifting showing that differences in corporate tax rates have an economically significant impact on intra-firm prices. Mintz and Smart (2004) model and test income shifting behavior of firms using Canadian data. They find that the elasticity of taxable income of 'income shifting' firms is larger than that of other firms. Huizinga and Laeven (2008) use data from 32 European countries to estimate the elasticity of the tax base and shifting costs. They report that many countries seem to profit from income shifting activities by multinational firms.[9]

The quantitative importance of tax havens has been documented by Hines and Rice (1994), Hines (2004), Sullivan (2004) and Desai, Foley, and Hines (2006). There is also a theoretical discussion on the role of tax havens.[10]

Our model is related to the literature on tax competition in a 'New Economic Geography' (NEG) context.[11] These models typically consider the location decision of (homogeneous) monopolistically competitive firms between two asymmetric countries. While we also consider monopolistically competitive firms we abstract from the location decision. This allows us to analyze the role of industry structure (determined by firm heterogeneity in productivity) on the degree of tax competition.

Starting with Bernard and Jensen (1999) a large empirical literature in international trade has analyzed the link between productivity of firms and export decisions. There it has been shown that exporting firms are on average more productive, have higher sales in the home market and pay higher wages. The causality is generally found to run from productivity to export status, i.e. more productive firms self-select into exporting. Thus firms do not differ in their 'ability

[7] See e.g. Elitzur and Mintz (1996), Haufler and Schjelderup (2000), Janeba (2000), Mintz and Smart (2004), Peralta, Wauthy, and van Ypersele (2006) and Bucovetsky and Haufler (2008).

[8] These profit shifting activities typically involve tax deferral, transfer pricing, fictitious leveraging and other forms of financial policy. For evidence and a more detailed discussion see Sullivan (2004) and Devereux, Lockwood, and Redoano (2008).

[9] Additional empirical evidence of profit shifting can be found in Grubert and Mutti (1991), Hines and Rice (1994), Hines (1999) and Egger, Eggert, Winner, and Keuschnigg (2008).

[10] See Hong and Smart (forthcoming) and Slemrod and Wilson (2006)

[11] See e.g. Kind, Knarvik, and Schjelderup (2000), Ludema and Wooton (2000), Baldwin and Krugman (2004), Borck and Pflueger (2006) and Ottaviano and van Ypersele (2005)

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to go abroad' but along a 'structural' dimension (productivity) which affects all their optimal decisions both in the home and the foreign market. This empirical finding has also motivated a large theoretical literature in international trade and FDI.[12]

Several recent contributions have addressed firm heterogeneity in international tax competition. In these papers different approaches to modeling firm heterogeneity have been chosen. One way to generate some degree of heterogeneity is e.g. to assume like Ogura (2006) (following Mansoorian and Myers (1993)) that otherwise identical firms have different costs of investing outside their home region. This type of heterogeneity is unrelated to the productivity of a firm. Burbidge, Cuff, and Leach (2006) introduce a related type of firm heterogeneity into a model with perfect competition, immobile labor and mobile capital. They model firm heterogeneity as an idiosyncratic, exogenous comparative advantage in one of the locations. So firms are heterogeneous in the sense that they are more productive in one country or the other. Equivalently, countries are heterogeneous in their ability to fruitfully accommodate particular firms.

These types of heterogeneity differ fundamentally from the heterogeneity identified in the empirical literature described above, where the productivity level is a 'structural' attribute of the firm: all firms are facing the same environment, but differ in a 'deep' characteristic which then determines their optimal decisions.

Some papers have addressed this type of heterogeneity in productivity. Baldwin and Okubo (2008) outline a New Economic Geography (NEG) model with tax competition and heterogeneous firms. They do not derive the equilibrium of the tax game. Instead they assume a tax difference and focus their analysis on the trade-off between base-widening and rate-lowering tax reforms.

Davies and Eckel (forthcoming) also propose an NEG-type model of tax competition with heterogeneous firms. They achieve tractability by making a particular assumption on the ownership structure. When firms change location their ownership is transferred to the representative consumer of the host country. Thus, besides attracting tax income there is an additional welfare gain from attracting firms via increased profit income. This allows them to analyze location decisions of firms and firm entry.

In recent work, Haufler and Stähler (2009) consider a model of tax competition with heterogeneous firms and endogenous firm location. In their model each firm produces one unit of a homogeneous good independently of its productivity. This is equivalent to firms having hetero-

[12] For surveys of the empirical and theoretical literature see Bernard, Jensen, Redding, and Schott (2007) and Helpman (2006)

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geneous fixed costs, zero marginal costs and a capacity constraint of one. They assume that governments maximize income instead of welfare. These assumptions allow them to prove equilibrium existence and analyze the effects of exogenous changes in demand.

The remainder of the paper is structured as follows. Section two presents the case of a large country in financial autarky. Section three introduces profit shifting. The equilibrium is derived in section four. Section five discusses the main results. Section six provides further intuition. Section seven analyzes conditions for equilibrium existence and section eight concludes.

2 Financial Autarky

We first outline the structure of the large country in financial autarky. Labor is the only input in production. There is a unit mass of workers each of which inelastically supplies one unit of labor. There are two sectors, one producing varieties of a differentiated good and one producing a homogeneous good with constant returns to scale. The homogeneous good is used as the numeraire with its price normalized to one. We only consider equilibria in which the homogeneous good is produced. This implies that wages are unity. There is a fixed and exogenous measure of firms that are owned by consumers in the large country.

Preferences: The workers are all identical and share the same quasi-linear preferences over consumption of the two goods and a good provided by the government:

$$U = \alpha \; lnQ + \beta \; G + q_0 \qquad with \qquad Q = \left(\int_{\Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

Where $q(\omega)$ is the quantity consumed of variety ω. The elasticity of substitution between varieties is given by $\sigma > 1$ and Q thus represents consumption of a preference weighted basket of differentiated goods. G is the quantity of a public good provided by the government. The consumption of the numeraire good is given by q_0. α and β are parameters with $0 < \alpha < 1 < \beta$.[13] Demand for one particular variety is:

$$q(\omega) = \frac{p(\omega)^{-\sigma}}{P^{-\sigma}} \; Q. \tag{2}$$

[13] These preferences are similar to those used in Baldwin and Okubo (2006) and Baldwin and Okubo (2008). To obtain closed form solutions, we assume linear utility from the public good. In order to generate positive demand for it we set $\beta > 1$.

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Where $p(\omega)$ is the price of variety ω, the aggregate price index of the differentiated goods sector is given by $P = \left(\int_0^{a_m} p(a)^{1-\sigma} dF(a)\right)^{\frac{1}{1-\sigma}}$ and $Q = \alpha/P$.[14]

The government: The only tax instrument of the government is a proportional tax on the profits of firms in the home country.[15] Tax income is used to provide government services G to the consumers. The government can transform one unit of the numeraire good into one unit of the government services. It is assumed to maximize welfare of its own citizens.

Firms: In the homogeneous good sector firms produce with a constant returns to scale technology and earn zero profits. There is a fixed and exogenous measure of firms in the differentiated good sector that is without loss of generality normalized to one. Each firm produces a different variety. Firms differ in their levels of marginal cost, which is constant for each firm. We assume that these marginal cost levels are distributed Pareto on $[0, a_m]$ with the distribution function given by:

$$F(a) = \left(\frac{a}{a_m}\right)^{\gamma}$$

where a_m is the highest marginal cost level. The degree of firm heterogeneity (i.e. the variance of the cost distribution) is determined by a_m and the shape parameter γ of the Pareto distribution. We assume $\gamma > \sigma - 1$ in order for aggregate profits to be finite. There is no fixed cost of production for firms, so in equilibrium all firms produce.

Firms in the differentiated good sector charge a constant mark-up over marginal cost:

$$p(a) = \frac{\sigma}{\sigma - 1}\, a. \tag{3}$$

The level of the mark-up depends on the elasticity of substitution between varieties. When σ is high, firms have a low degree of monopolistic market power and can only afford to charge a low mark-up.

A firm's gross profits are given by $\pi(a) = r(a)/\sigma$ which implies:

$$\pi(a) = a^{1-\sigma}\, T_1 \quad with \quad T_1 = \frac{\alpha}{\sigma}\left(\frac{\gamma - (\sigma - 1)}{\gamma}\right) a_m^{\sigma-1}. \tag{4}$$

[14] $F(a)$ is the distribution function of cost levels of firms and a_m is the maximum cost level.

[15] Ottaviano and van Ypersele (2005) add a lump sum tax on labor, which leads to negative tax rates on capital. This would not be the case in our model. As firms cannot shift production, in our setting a lump sum tax on labor would make the capital tax redundant.

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T_1 is a constant that only depends on parameters of the model.[16]

Net profits are given by $\pi(a)^{net} = (1-t)\,\pi(a)$, where $t \in [0,1]$ is a tax rate set by the government and taken to be exogenous by the firm. Firm choices that maximize gross profits also maximize net profits. The tax is thus not distorting the optimal production decision of the firm.

In financial autarky all firms pay taxes at home. The tax base is thus given by aggregate profits of firms:

$$\Pi_H^A = \int_0^{a_m} \pi(a)\; dF(a) = \frac{\alpha}{\sigma} \tag{5}$$

which is constant.

Optimal tax rate in autarky: Households have income from labor and receive the net profits of firms in their country. In autarky the aggregate income I^A of consumers is thus:

$$I^A = L + (1 - t_H^A)\Pi_H^A.$$

Welfare in financial autarky is:

$$U^A = \bar{U} + (1 - t_H^A)\;\Pi_H^A + \beta\; t_H^A\;\Pi_H^A. \tag{6}$$

Where $\bar{U} \equiv \alpha\; ln\left(\frac{\alpha}{P}\right) - \alpha + 1$ collects terms that are unaffected by the taxation decision. The first term in $\bar{U}$ reflects utility of consuming the basket of differentiated products, α is the cost of this basket and 1 is labor income. The second term in (6) are profits retained by consumers. The last term represents utility from the consumption of the public good.

In financial autarky the welfare maximizing tax rate of the large country is then given by $t_H^A = 1$. Since no outflows of tax base are possible in financial autarky, $\beta > 1$ implies that it is optimal for the government to collect the highest possible amount of tax revenue.[17]

[16] $T_1 = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1} \frac{\alpha P^{\sigma-1}}{\sigma}$. The price index is defined as $P = \left(\int_0^{a_m} p(a)^{1-\sigma} dF(a)\right)^{\frac{1}{1-\sigma}}$. Evaluating the integral using (3) leads to $P = \frac{\sigma}{\sigma-1}\; a_m \left(\frac{\gamma}{\gamma-(\sigma-1)}\right)^{\frac{1}{1-\sigma}}$ which is a constant. This implies $T_1 = \frac{\alpha}{\sigma}\left(\frac{\gamma-(\sigma-1)}{\gamma}\right) a_m^{\sigma-1}$.

[17] This is a very stylized result. We have chosen the simplest possible way to create an incentive to collect taxes without adding any trade-off in autarky. This preserves tractability when the trade-off we are interested in is introduced with profit shifting: the trade-off between the intensive margin (level of the tax rate) and the extensive margin (outflows of tax base). With profit shifting an interior solution exists, on which we focus our analysis. For this only the tax difference is important.

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3 Profit Shifting

Next we consider the case where firms in the large country have the possibility to open an affiliate in the tax haven, which allows them to shift profits abroad. These profits are then taxed according to the tax rate in the tax haven, but not at home, where the firm declares zero profits.[18] Opening an affiliate in the tax haven requires paying a fixed cost f_t.

Individual firm behavior and the tax base: Whether an individual firm chooses to pay the fixed cost of shifting profits abroad depends on the tax differential and on the level of profits the firm generates. The lower the marginal cost of a firm, the higher are the firm's profits and thus the more likely it is that the firm chooses to pay the fixed cost of 'profit-shifting' FDI.
We define the 'profit shifting cutoff cost level' as the cost level a^* for which a firm is indifferent between paying taxes at home and paying taxes in the tax haven. Note that profit shifting only takes place for a positive tax difference $\rho = t_H - t_X > 0$. In this case the cutoff cost level is determined by the following condition:

$$(1 - t_H)\ \pi(a^*) = (1 - t_X)\ \pi(a^*) - f_t.$$

Where $\pi(a^*)$ are gross profits of a firm with marginal cost of a^*, t_H is the domestic tax rate and t_X is the rate set by the tax haven. When the tax difference is zero or negative, no profit shifting takes place. Rewriting the cutoff condition gives:

$$\pi(a^*) = f_t/\rho \tag{7}$$

with the corresponding cost cutoff level:

$$a^* = \left(\frac{\rho\ T_1}{f_t}\right)^{\frac{1}{\sigma-1}}. \tag{8}$$

Under financial integration the most productive firms (with a cost level below a^*) self-select into profit-shifting FDI. The mass of firms is thus endogenously split into multinationals and domestic firms. The measure of profit shifting firms is:

$$N_x = G(a^*) = (a^*)^{\gamma}\, a_m^{-\gamma} \tag{9}$$

[18] In order to keep the analysis focused, we only consider the case where firms can shift their total profits abroad. Introducing partial profit shifting would neither affect the main mechanism of the model nor the qualitative results.

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This productivity sorting is in line with the empirical evidence on the determinants of the use of tax haven operations.

Tax base: The tax base in the home country is given by aggregate profits of firms that have not become multinationals and thus pay taxes at home: $\Pi_H = \int_{a^*}^{a_m} \pi(a)\ dF(a)$. The tax base taxed in the tax haven is given by $\Pi_X = \int_0^{a^*} \pi(a)\ dF(a)$. Evaluating the integrals leads to:

$$\Pi_X = \rho^{\epsilon} f_t^{-\epsilon} T_2 a_m^{-\gamma} \tag{10}$$

$$\Pi_H = \Pi_H^A - \Pi_X \tag{11}$$

with $\epsilon \equiv \frac{\gamma}{\sigma-1} - 1$ and $T_2 = \frac{\epsilon+1}{\epsilon}\ T_1^{\epsilon+1}$. Thus the tax base flowing to the tax haven only depends on constant terms and the tax difference.

ϵ combines two of the crucial parameters of the model: the shape parameter of the cost distribution and the elasticity of substitution between varieties. Recall that above we have assumed that $\gamma > (\sigma - 1)$ which implies $\epsilon > 0$.

Household Income: In addition to their income from labor, households receive the net profits of firms paying taxes at home and of firms paying taxes in the tax haven. Under financial integration, the aggregate income I of consumers is thus given by:

$$I = L + (1 - t_H)\Pi_H + (1 - t_X)\Pi_X - N_x f_t. \tag{12}$$

Where the last term accounts for the fact that net profits of firms paying taxes in the tax haven are also net of the fixed cost payed to do profit shifting FDI.[19]

Governments: Under financial integration governments have to take into account the tax rate set in the other legislation. Taxes are set in a simultaneous one-shot game.[20] To analyze the tax game, we first derive the best response functions of the two governments.

4 Equilibrium under Financial Integration

As in financial autarky, the only variable governments can set are the profit tax rates in their legislations. In this section we derive the best response functions of the two governments in the

[19] We assume that the fixed cost of tax avoidance is not tax-deductible, i.e. profits are not taxed net of these fixed costs.

[20] The case where one country has a first mover advantage is discussed in a complementary appendix available upon request.

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international tax game.

4.1 Optimization of the Tax Haven

The structure of the tax haven is kept as simple as possible. It does not have a tax base of its own. Its only source of revenue stems from taxing multinational companies that have an affiliate in the tax haven. Taking the tax rate in the large country as given, the tax haven maximizes total revenue $V = t_X \Pi_X$.

One can think of the tax haven as the limit case of a very small country. The measure of differentiated goods firms is proportional to the mass of consumers, which are close to zero. In this case the tax haven's own tax base is 'almost zero'. The same holds for demand for the differentiated good (imported from the large country with zero trade cost). Then welfare maximization of the government in the tax haven is equivalent to maximization of tax revenues. The attracted tax base Π_X is only positive if the tax haven sets a lower tax rate than the large country. Thus for any given (positive) tax rate of the large country t_H, it will always be optimal for the tax haven to undercut, so that $\rho > 0$. Revenue maximization leads to:

$$t_X = \frac{t_H}{\epsilon + 1} = \frac{\sigma - 1}{\gamma}\, t_H = min\left\{\frac{\rho}{\epsilon}; \frac{1}{\epsilon + 1}\right\}. \tag{13}$$

where the *min* reflects the fact that t_H is bounded from above by unity. Note that $\epsilon + 1 = \gamma/(\sigma - 1) > 1$. The tax haven sets a tax rate that is a constant fraction of the rate of the large country. The extent to which the tax haven undercuts the large country is determined by the shape parameter of the cost distribution and the elasticity of substitution. We can now state the following proposition:

Proposition 1 *Under financial integration when firms have the possibility to do profit shifting FDI,*

(i) the tax haven always undercuts the large country.

(ii) the undercutting is the stronger the higher the shape parameter γ and the stronger the market power of individual firms (lower σ).

Proof: *(i)* follows from the fact that for $t_H > 0$, a tax rate of $t_X \geq t_H$ implies $\Pi_X = 0$ and thus $V = 0$, while any $0 < t_X < t_H$ implies $\Pi_X > 0$ and thus $V > 0$. *(ii)* follows directly from (13). **q.e.d.**

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4.2 Optimization of the Large Country

For any given tax rate of the tax haven t_X, the government of the large country sets its tax rate t_H to maximize welfare of its citizens $U(t_H, t_X)$.

For certain parameter values the best response function of the large country is discontinuous. In these cases we find that the there is a threshold level of t_X depending on parameters. Below this threshold level the large country chooses a tax rate implying a strictly positive tax difference. Above, the large country chooses a tax difference of zero, i.e. $t_H = t_X$ which, given (10) can never be an equilibrium. The discontinuity in the response function as well as the conditions for equilibrium existence are discussed in detail in section 7. There we show that for empirically relevant parameter values the equilibrium exists.

Under financial integration the implicit best response of the large country for a given t_X is:

$$t_H^{\rho>0} = min\left\{\frac{(\beta-1)\,(T_3-\rho^{\epsilon})}{\epsilon\ \beta\ \rho^{\epsilon-1}};1\right\} \tag{14}$$

as long as the implied value of t_H is large enough to satisfy:

$$\rho^{\epsilon} \geq \frac{(1-\epsilon)(\beta-1)}{\frac{\epsilon}{\epsilon+1}+(\beta-1)}\ T_3. \tag{15}$$

With $T_3 \equiv f_t^{\epsilon}\ T_1^{-\epsilon} a_m^{\gamma-(\sigma-1)}$. Otherwise the best response is given by:

$$t_H^{\rho\leq 0} = t_X. \tag{16}$$

These results are derived in Appendix A. Appendix B states and derives a condition on t_X which is analog to (15). If t_X satisfies this condition, the large country optimally sets its tax rate according to (14).

4.3 Equilibrium of the Tax Game

We now turn to the equilibrium of the tax game.

Proposition 2 *(i) An equilibrium of the tax game exists iff*

$$\beta\left(\epsilon^3+2\epsilon^2-1\right)-\epsilon^2 \geq 0 \quad or \quad \left(\frac{\epsilon+1}{\epsilon}\right)^2\left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)^{\frac{1}{\epsilon}}\frac{\sigma}{\alpha}\ f_t \geq 1. \tag{17}$$

(ii) The equilibrium tax rates are then given by:

$$t_H^* = min\left\{\left(\frac{\epsilon+1}{\epsilon}\right)^2\left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)^{\frac{1}{\epsilon}}\frac{\sigma}{\alpha}\ f_t\ ,1\right\}. \tag{18}$$

$$t_X^* = min\left\{\frac{\epsilon+1}{\epsilon^2}\left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)^{\frac{1}{\epsilon}}\frac{\sigma}{\alpha}\ f_t\ ,\ \frac{1}{\epsilon+1}\right\} \tag{19}$$

Proof: The equilibrium tax difference ρ^* can be derived taking the difference of (14) and (13) and solving for the tax difference:

$$\rho^* = min\left\{\frac{\epsilon+1}{\epsilon}\left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)^{\frac{1}{\epsilon}}\frac{\sigma}{\alpha}\ f_t\ ,\frac{\epsilon}{\epsilon+1}\right\}. \tag{20}$$

the first condition in *(i)* follows directly from plugging (20) into condition (15) and simplifying which is the relevant condition for interior solutions.[21] Before turning to the second condition, note that the equilibrium tax rates in *(ii)* follow directly from combining (20) and (13). Now it is obvious from (18) that the the second condition in *(i)* is necessary and sufficient for the economy to be in a corner solution of $t_H^* = 1$. Thus when at least one of the two conditions in *(i)* holds, equilibrium existence is assured. **q.e.d.**

Based on this we can derive all relevant equilibrium objects for interior solutions. The equilibrium cost cutoff is given by:

$$a^{**} = \left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)^{\frac{1}{\epsilon(\sigma-1)}} a_m. \tag{21}$$

The equilibrium number of firms choosing 'profit shifting' FDI is:

$$N_X^* = \left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)^{\frac{\epsilon+1}{\epsilon}}. \tag{22}$$

[21] This result allows to narrow down the possible range for ϵ in our model. Given $\beta > 1$ we find a lower bound for existence of an interior equilibrium at about 0.618. This can be obtained by solving the equation $-1+2\epsilon^2+\epsilon^3 = 0$, which represents the limit case for $\beta \to \infty$.

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The tax base that flows to the tax haven in equilibrium is:

$$\Pi_X^* = \frac{\beta - 1}{\epsilon\beta + 2\beta - 1} \frac{\alpha}{\sigma}. \tag{23}$$

Overall government income from taxation is then given by:

$$G_H^* = \frac{\beta - 1}{\beta} \frac{(\epsilon + 1)^3}{\epsilon^2} \left(\frac{\beta - 1}{\epsilon\beta + 2\beta - 1} \right)^{\frac{\epsilon+1}{\epsilon}} f_t. \tag{24}$$

For some parameter values (e.g. very high fixed costs of profit shifting) the government would like to set a tax rate larger one. In this case there is a corner solution with $t_H = 1$ and $t_X = \frac{1}{\epsilon+1}$. We focus our analysis on interior solutions. For completeness we report all relevant variables for the corner solution in appendix C.[22]

5 The Role of Industry Structure and Market Power

5.1 Industry Structure and Tax Competition

In this subsection we analyze the impact of firm heterogeneity on the degree of tax competition and the 'aggressiveness' of the tax haven. In section 5.4 we compare these results to the results obtained from a model with homogeneous firms.

We measure the strength of tax competition by the fraction of the tax base leaving the country in equilibrium, Π_X^*/Π_H^A.[23] Furthermore we measure the 'aggressiveness' of the tax haven by the equilibrium tax difference. We find that the degree of firm heterogeneity does indeed affect the degree of tax competition the large country is facing and the 'aggressiveness' of the tax haven:

Proposition 3 *Under financial integration when firms have the possibility to do profit shifting FDI,*

(i) the degree of tax competition measured as Π_X^*/Π_H^A is higher when firms are more heterogeneous (low γ)[24] *and when monopolistic market power of firms is low (high σ).*

(ii) When firms are more homogeneous (higher γ) the 'aggressiveness' of the tax haven measured as the equilibrium tax difference increases.

[22] In the corner solution, the trade-off between the intensive- and extensive margin is distorted as the government cannot set $t_H > 1$.

[23] Alternative measures for the degree of tax competition are the impact on equilibrium tax revenues and the equilibrium tax rates. We show in section 5.3 that the results are similar.

[24] To analyze the effect of firm heterogeneity we look at a mean preserving spread of the cost distribution. As the equilibrium tax base Π_X^* (as well as G^* and t_H^*) are independent of a_m it is sufficient to look at a change in γ.

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Proof: see appendix D

The first part of this Proposition implies that when firms are more homogeneous, the large country is more 'protected' from tax competition. The intuition is best explained considering the intensive- and extensive margin of taxation. On the one hand setting a higher tax rate implies higher revenues from firms that stay in the large country (intensive margin) but on the other hand a higher rate leads to an outflow of tax base (extensive margin). The most productive firms are the first ones to shift profits abroad. When firms are more homogeneous the number of very productive firms is low. Then the very productive firms account for a smaller fraction of the tax base. In that case, the extensive margin effect is weak, and the intensive margin effect dominates. The large country can afford to set a high tax rate as it only looses a small fraction of its firms. It is thus 'protected' from tax competition by its industry structure.
The intuition behind part *(ii)* is similar: the smaller the fraction of the tax base accounted for by the very productive firms, the harder it is for the tax haven to attract tax base. The tax haven will thus set a tax rate that implies a larger absolute tax difference. This increases the cutoff cost level and leads more firms to shift profits abroad. A large tax difference could be interpreted as 'aggressiveness' of the tax haven. The model, however, shows that this 'aggressiveness' is stronger when it is difficult for the tax haven to attract tax base i.e. the extensive margin effect is weak.

5.2 Fixed Cost of Profit Shifting and Tax Competition

The fixed costs of profit shifting play a central role in our model as they affect the cutoff between firms paying taxes at home and abroad. In this subsection we discuss in more detail which equilibrium values get affected by f_t and which are independent of this parameter.
First note that both tax rates are linearly increasing in the fixed costs. Suppose fixed costs increase. Then it is more costly for firms to avoid taxes and for given tax rates less firms are shifting their profits abroad. In this situation the large country raises its tax rate in order to optimally trade off the intensive and extensive margins of taxation. As the tax haven undercuts by a constant fraction its tax rate goes up as well while the absolute tax difference ρ increases. This increase in the absolute tax difference exactly offsets the effect of the initial increase in the fixed costs such that the cutoff cost level a^{**} does not change. Thus for interior solutions the cutoff cost level a^{**}, the share of firms shifting profits N_X^* and the tax bases Π_H^* and Π_X^* are independent of the fixed costs f_t. With an increasing tax rate and an unchanged tax base,

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equilibrium tax income G_H^* increases.

5.3 Alternative measures of tax competition

In Proposition 3 we use equilibrium outflows of the tax base to measure the strength of tax competition. While we chose tax base outflows as our preferred measure there are two possible alternatives. These are total tax income G^* and the tax rate t_H. In Appendix E we show that under relatively weak parameter restrictions these two alternative measures deliver results in line with Proposition 3. As long as $\beta < 4$, total tax income of the large country G_H^* is increasing in γ. I.e when firms are more homogeneous the impact of tax competition is weaker. For $\beta < 2$ the same holds true for the equilibrium tax rate t_H^*, which is increasing in γ.

5.4 Heterogeneous vs. Homogeneous Firms

In this subsection we analyze the equilibrium of our model under homogenous firms and compare it to the results with heterogenous firms. We show that in line with Proposition 3 models with homogeneous firms understate the strength of tax competition.

With homogenous firms either all firms shift profits or all firms pay taxes at home. Assume that indifferent firms do not do profit shifting. For any given t_X, the large country optimally sets a tax rate such that firms are indifferent i.e. the zero cutoff profit condition holds with equality i.e. $\rho\pi = f_t \Leftrightarrow \rho = \frac{\sigma}{\alpha} f_t$. The tax haven always tries to undercut sufficiently in order to attract tax base, but its tax rate is bounded from below by zero. Thus the large country sets a tax rate that ensures that all firms pay taxes at home even for $t_X = 0$. This implies an optimal limit tax of $t_H^{*h} = \frac{\sigma}{\alpha} f_t$.

In equilibrium the whole tax base stays in the large country. Thus: $\Pi_H^{*h} = \frac{\alpha}{\sigma}$ and total tax income is $G^{*h} = f_t$. As should be expected these results coincide with the limiting result of our heterogenous firms model for $\gamma \to \infty$, i.e.: $t_H^{*lim} = \lim_{\gamma\to\infty} t_H^* = \frac{\sigma}{\alpha} f_t$; $\Pi_H^{*lim} = \lim_{\gamma\to\infty} \Pi_H^* = \frac{\alpha}{\sigma}$ and $(t_H^* \Pi_H^*)^{*lim} = \lim_{\gamma\to\infty} t_H^* \Pi_H^* = f_t$.

Finally note that the tax base and total tax income are always larger with homogenous firms than with heterogenous firms.[25] This complements the results in Proposition 3: the more homogeneous firms are, the lower is the degree of tax competition. In the limit case of homogeneous firms, tax competition - measured by the equilibrium impact it has on the large country - is lowest. This

[25] To see this note that differences between the limit values and interior values for government income are $t_H^* \Pi_H^* - (t_H^* \Pi_H^*)^{*lim} = f_t \left(1 - \frac{\beta(1+\epsilon)^3 \left(\frac{\beta-1}{\epsilon\beta+2\beta-1} \right)^{1+\frac{1}{\epsilon}}}{(\beta-1)\epsilon^2} \right)$. This expression is always positive. Thus government income with homogenous firms is always larger than with heterogenous firms. The same holds for the tax base.

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implies that introducing heterogeneous firms into models of international tax competition adds a new channel to the analysis: the extensive margin of taxation. Models with homogeneous firms do not take this channel into account and thus understate the strength of tax competition.

6 Firm Heterogeneity, Tax Base and Tax Competition

We have shown above that the shape parameter of the productivity distribution γ and the elasticity of substitution σ affect the degree of tax competition. For the intuition of the model it is useful to see how these parameters determine the distribution of profits across firms, i.e. the tax base.

here: Figure 1

Figure 1 provides a graphical illustration of the distribution of the tax base across firms with different cost levels. The thick dashed line plots the density of firms with cost level a and the solid line represents the share of profits of these firms in aggregate profits.[26] The thin vertical dashed line marks the equilibrium cutoff cost level given by (21). The area under the solid curve that is to the left of the a^{**} line thus represents the fraction of aggregate profits shifted to the tax haven. While the area under the dashed line represents the measure of firms that account for these profits: the firms shifting profits.

The four graphs in Figure 1 illustrate how an increase in ϵ affects the distribution of the tax base. In the first three graphs we set $\sigma = 6$ and increase the Pareto parameter γ such that we obtain values of $\epsilon = 0.75$, $\epsilon = 1$ and $\epsilon = 1.5$. The latter value corresponds to the estimate of Eaton, Kortum, and Kramarz (2008). The lowest value corresponds to the value of ϵ implied in their analysis based on the sales of French firms in France conditioned on entry into a particular foreign market.[27] In the last graph we keep the value of $\gamma = 13.75$ and lower σ to 4 which increases ϵ to 3.58.[28]

[26] While an increase in the Pareto parameter γ does not affect aggregate profits, changes in the elasticity of substitution σ do. Normalizing with aggregate profits, the area under the solid line remains equal to unity in all graphs.

[27] Eaton, Kortum, and Kramarz (2008) estimate ϵ using the method of simulated moments. As mentioned above their estimate is 1.46. They provide some additional information of plausible values of ϵ exploiting the relation between ϵ and some observations in the data. In their Figure 3a they plot average sales of firms in France (conditional on entry into market n) against the number of French firms selling in market n. They find that firms that serve markets which are served by a low number of firms tend to have higher sales in France. From the slope of this relationship they deduce a value of ϵ of 0.75. A different way to obtain a value for ϵ is to use the plot of the export intensity on the number of firms selling an a particular market. The slope implies an ϵ of 1.63 which is much closer to their estimate of 1.46.

[28] In all graphs we have set the maximum cost level a_m to unity.

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The four graphs illustrate how the shape parameter of the cost distribution γ and the elasticity of substitution σ affect the distribution of the tax base and the equilibrium cutoff. In the first graph firms are more heterogeneous in the sense that there is a relatively large number of firms with low cost levels. The solid line shows that these firms account for a relatively large fraction of aggregate profits. This implies that in this case the extensive margin effect of taxation is large: a small increase in the cutoff level leads to a large outflow of the tax base.

As in the next two graphs with a higher γ firms are more homogeneous, the measure of firms with high cost levels increases. Since these firms are more numerous they also account for a larger fraction of aggregate profits. Which implies weaker effects on the extensive margin.

The last graph shows that a decrease in σ has a similar effect. Keeping γ constant and reducing σ to 4, the high cost firms account for an even higher share of aggregate profits. Since consumers are less able to substitute the goods of the high cost producers, the share of profits of this group rises.

So in line with Proposition 3 *(i)*, the graphs show that a low degree of firm heterogeneity (high γ) 'protects' the large country from tax competition as it makes its tax base less reactive to differences in tax rates. A low value of the elasticity of substitution σ works in the same direction. Proposition 3 *(ii)* states that the more homogeneous firms are, the stronger is the undercutting of the tax haven. By equation (8) this larger tax difference implies a higher cutoff cost level. This increasing 'aggressiveness' can be seen in the graphs: as γ increases, the cutoff level decreases. When the low productivity firms account for a larger fraction of the profits, the tax haven has to push up the cutoff cost level in order to attract some of the higher cost firms.

here: Figure 2

Figure 2 illustrates the impact of firm heterogeneity on the equilibrium tax base and the equilibrium tax rates from Proposition 3. We have seen above that an increase in heterogeneity (a mean-preserving spread of the cost distribution) affects these equilibrium variables only via the Pareto parameter γ but not via the maximum cost level a_m. The effect of an increase in γ is thus equivalent to the effect of a decrease in firm heterogeneity.

The first graph in Figure 2 plots the fraction of the tax base flowing to the tax haven (solid line) and the measure of firms shifting profits (dashed line) as a function of the shape parameter. A decrease in firm heterogeneity (increase in γ) implies that the tax base reacts less to tax differences and thus the fraction of the tax base attracted by the tax haven decreases.

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The second graph plots the equilibrium tax rates of the large country (solid line) and the rate set by the tax haven (dashed line). As γ increases, the equilibrium tax rate of home as well as the tax difference increase. With lower heterogeneity, the tax base is less reactive to tax differences so the large country can afford to set a high tax rate (low losses on the extensive margin). At the same time the tax haven undercuts the large country by more in order to attract some of the tax base.[29]

7 Equilibrium Existence

In this section we graphically illustrate the existence condition as stated in Proposition 2 and discuss some intuition for the potential discontinuity of the best response function of the large country. Note that an equilibrium exists iff the best response function of the large country and the best response function of the tax haven intersect.

In the following we consider the three possible cases: a continuous best response function of the large country which always implies equilibrium existence (Figure 4), a discontinuous best response function of the large country with equilibrium existence (Figure 5) and a discontinuous best response function of the large country without equilibrium existence (Figure 6).

here: Figure 4

Figure 4 illustrates the case of $\epsilon > 1$. For this parameter value condition (15) always holds. The best response function of the large country is continuous and is given by (14) for all values of t_X. It is represented by the solid line. The dashed line plots the best response of the tax haven, equation (13). As stated in Proposition 1 for a given positive $\bar{t}_H > 0$ the tax haven always undercuts the large country.

here: Figure 5 and Figure 6

Figures 5 and 6 illustrate the case of $\epsilon < 1$. Now the best response of the large country is discontinuous and the equilibrium does not always exist. For low values of $\bar{t}_X$ the best response of the large country is given by (14). For high values, the optimal response of the large country is to set the same tax rate as the tax haven.

In Figure 5 the equilibrium exists. The discontinuity of the best response function of the large

[29] The vertical line represents $\epsilon = 1$. Under this parametrization for a range of low values of gamma no equilibrium exists. Conditions for equilibrium existence are discussed in the following section.

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country is far enough to the right, so that the two best response functions intersect and an equilibrium exists. Figure 6 uses the same parameter values except for the fact that γ is lower, which implies a very low ϵ. In this case the best response function of the tax haven never intersects with the response function of the large country and thus no equilibrium exists. Condition (15) is violated: the discontinuity lies too far to the left.

The large country faces a trade off between the intensive- and the extensive margin effects of taxation. A higher tax rate implies both higher revenues from firms that stay in the large country (intensive margin effect) and an outflow of tax base (extensive margin effect). When, like in Figure 6, ϵ is very low, the extensive margin effect is so strong that it can be optimal for the large country to prevent all firms from paying taxes abroad by setting a tax rate low enough to keep even the most productive firm at home ($t_H = t_X$).

The more profits are concentrated among the high productivity firms (i.e. the lower ϵ) the larger is the range of values of t_X for which the large country sets outflows to zero. Additionally, equation (13) implies that when ϵ is low the tax haven undercuts the large country by less. Graphically, this translates into a reaction function that is closer to the diagonal. Through both effects a low ϵ makes the existence of an equilibrium less likely.

We have shown in footnote 21 above that a value of $\epsilon = 0.618$ is sufficient to assure the existence of the equilibrium. This value is far below the empirical estimates discussed above. We have thus focused our analysis on the empirically relevant cases.[30]

8 Conclusions

In this paper we provide a benchmark model of tax competition with heterogeneous firms. It captures two features of the data. First, larger firms tend to use tax havens operations more intensively. Second, tax havens play a central role for international tax planing strategies of multinational firms. In line with empirical evidence we consider firms with heterogeneous marginal productivities and thus heterogeneous profits. We achieve analytical tractability by focusing on the case of 'very' asymmetric countries: a large country and a tax haven.

We provide the expressions for equilibrium tax rates, equilibrium tax base and equilibrium government revenues in closed form. This allows us to analyze the effects of different variables on the equilibrium allocations. We show that stronger firm heterogeneity (a mean-preserving spread of the cost distribution) increases the degree of tax competition: it decreases the equilibrium

[30] A possible way to address situations of $\epsilon < 0.618$ could be to consider mixed strategy equilibria.

tax rate of the large country, leads to higher outflows of its tax base and thus decreases its equilibrium tax revenue. Similar effects hold for a higher substitutability across varieties. The rational behind these results is that firm heterogeneity and monopolistic market power shape the distribution of aggregate profits, the tax base. Since more profitable firms are more prone to shift profits abroad, the two governments face a tradeoff between the *intensive* and the *extensive margin* of taxation. We show that by ignoring the latter, models with homogeneous firms systematically understate the strength of tax competition.

Our benchmark model could be extended in several ways. Two large but asymmetric countries could be considered. Allowing for firm entry and endogenous reallocation would give rise to an interesting tradeoff. While a country could loose part of its tax base due to profit shifting, this could be the only way for it to keep production of very productive firms at home.[31]

Another extension would be to enlarge the set of tax instruments. Firm heterogeneity creates a problem for a government as it cannot discriminate between firms with different productivity levels. Thus any instrument that allows the government to treat firms asymmetrically reduces the problem arising from firm heterogeneity.

Finally our benchmark model provides a starting point to test empirically the effect of firm heterogeneity on tax rates chosen by governments. According to our model countries with more heterogeneous firms should, ceteris paribus, set lower tax rates. In addition, the model implies that the government would like to impose different tax rates in different sectors. If this is not feasible in practice, the government could still impose rules e.g. on deductability of capital investment or depreciation rules that would affect sectors with different capital structure differently.

[31] Due to the complexity of a setup with two asymmetric countries, we conjecture that this case could only be analyzed numerically. For this the closed form solutions derived in this paper could provide a valuable benchmark.

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Appendix

A Proofs for the Discontinuous Response Function

This appendix derives the discontinuous best response function of the large country as well as parameter condition (15) which determines whether the best response function is given by (14) or (16).

We first derive equations (16) and (14). They represent two different cases which we discuss separately. In case 1 the large country sets a tax rate below or equal the rate of the tax haven. In case 2 it sets a higher rate. We will show that condition (15) determines which of the two cases represents the best response.

Case 1: First consider the case in which the government sets a tax rate below or equal to the tax haven's rate. All firms then pay taxes at home. Total welfare in this case is:

$$U^{\rho \leq 0}(t_H, t_X) = \bar{U} + (1 - t_H)\ \Pi_H^A + \beta\ t_H\ \Pi_H^A. \tag{25}$$

Since the government values public expenditure more than expenditure on the homogenous good by its citizens ($\beta > 1$) it sets the highest possible tax rate that satisfies $t_H \leq t_X$.[32] This tax rate is given by (16).

[32]Note that in the autarky equilibrium, the large country also sets the highest possible tax rate under the condition that $t_H^A \leq 1$.

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Case 2: Now consider the case where the government sets a tax rate that satisfies $t_H > t_X$. Welfare in the large country is then given by

$$U^{\rho>0}(t_H, t_X) = \bar{U} + (1 - t_H)\ \Pi_H + (1 - t_X)\Pi_X - N_X f_t + \beta\ t_H\ \Pi_H \tag{26}$$

Where $\Pi_H = \Pi_H^A - \Pi_X$ reflects the fact that some of the tax base in the home country flows to the tax haven when the tax differential is positive.

From the first order condition of the maximization problem, we derive (14). Where t_X and $t_H^{\rho>0}$ enter in the tax differential ρ. Equation (14) provides a relatively simple implicit solution for the best response function of the government which only depends on the tax differential and parameters of the model. To complete the proof, we proceed in two steps. We first derive condition (15) under the *assumption* that the second order condition for a welfare maximum holds for (14). In a second step we show that this is the case whenever (14) is the countries' best response function derived in step 1.

Step 1: We first determine when according to the FOC (assuming the SOC to be satisfied) the large country will set its tax rate according to (14). This is the case as long as $U(t_H^{\rho>0}, t_X) \geq U(t_H^{\rho\leq 0}, t_X)$. Plugging (26) and (25) into this condition, rearranging and using (16) and $(1 - t_X) - (1 - t_H^{\rho>0}) = \rho$ we get:

$$\rho\ (\beta - 1)\ \Pi_H^A \geq \left(\beta\ t_H^{\rho>0} - \rho\right)\ \Pi_X + N_X\ f_t. \tag{27}$$

Now first using $f_t N_x = \Pi_X\ \rho\ \frac{\epsilon}{\epsilon+1}$, then $\Pi_H^A = T_2\ T_1^{-\epsilon}\ a_m^{1-\sigma}$ and $\Pi_X = \rho^{\epsilon}\ T_2\ f_t^{-\epsilon}\ a_m^{-\gamma}$, simplifying and solving for $t_H^{\rho>0}$ gives:

$$t_H^{\rho>0} \leq \frac{(\beta - 1)T_3 + \rho^{\varepsilon}\frac{1}{\varepsilon+1}}{\beta\ \rho^{\varepsilon-1}}. \tag{28}$$

To see for which values of ρ the tax rate in (14) satisfies condition (28), we plug (14) into (28), which gives:

$$\rho^{\epsilon} \geq \frac{(1 - \epsilon)(\beta - 1)}{\frac{\epsilon}{\epsilon+1} + (\beta - 1)}\ T_3.$$

As long as for a given t_X the t_H implied by (14) is high enough to satisfy this condition, we will have $U(t_H^{\rho>0}, t_X) \geq U(t_H^{\rho\leq 0}, t_X)$ and thus the best response function of the large country given

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by (14). When the above condition is violated, we have $U(t_H^{\rho>0}, t_X) < U(t_H^{\rho\leq 0}, t_X)$. In this case the best response of the large country is given by (16) because it maximizes $U(t_H^{\rho\leq 0}, t_X)$.

Step 2: It remains to be shown that for any given t_X equation (14) is a welfare maximum (and not a minimum) for all relevant values of t_H. Relevant values are all values of t_H that satisfy (15) for a given t_X.[33]

First note that the second derivative of the welfare function with respect to the tax rate of the large country is given by:

$$\frac{\partial^2 U}{\partial t_H^2} = -2(\beta-1)\frac{\partial \Pi_X}{\partial t_H} - \frac{\partial^2 \Pi_X}{\partial^2 t_H}[(\beta-1)t_H + t_X] - \frac{\partial^2 N_x}{\partial^2 t_H} f_t.$$

For notational convenience, we define $T_5 \equiv T_2 \epsilon \rho^{\epsilon-1} f_t^{-\epsilon} a_m^{-\gamma} > 0$. We then use $\frac{\partial \Pi_X}{\partial t_H} = T_5$ together with $\frac{\partial^2 \Pi_X}{\partial t_H^2} = \frac{\epsilon-1}{\rho} T_5$ and $\frac{\partial^2 N_x}{\partial t_H^2} f_t = \epsilon T_5$ to get:

$$\begin{aligned} \frac{\partial^2 U}{\partial t_H^2} &= -T_5 \left(2(\beta-1) + \epsilon + \frac{\epsilon-1}{\rho}\left[(\beta-1)t_H + t_X\right] \right) \\ &= -T_5 \left(2(\beta-1) + \epsilon - (\epsilon-1) + (\epsilon-1)\ \beta\ \frac{t_H}{\rho} \right) \end{aligned}$$

From (14) it follows that $\frac{t_H}{\rho} = \frac{(\beta-1)}{\epsilon}\frac{T_3}{\beta}\frac{}{\rho^\epsilon} - \frac{(\beta-1)}{\epsilon}\frac{}{\beta}$ so that:

$$\frac{\partial^2 U}{\partial t_H^2} = -T_5 \left(2(\beta-1) + \epsilon + \frac{(\beta-1)(\epsilon-1)}{\epsilon}\left(\frac{T_3}{\rho^\epsilon} - 1\right) - \epsilon + 1 \right). \tag{29}$$

We need to show that equation (15) is a sufficient condition for (29) to be negative. To do so, we proceed in two steps. We first show that it is negative when the above condition holds with equality. We then show that this is also true for larger values of ρ.

Define ρ^e as the value of ρ, where (15) holds with equality. We will first determine the sign of (29) for ρ^e i.e. $\frac{\partial^2 U}{\partial t_H^2}\ |_{\rho^e}$.

$$\frac{\partial^2 U}{\partial t_H^2}\ |_{\rho^e} = -T_5 \left(2(\beta-1) + 1 - T_j - \frac{(\beta-1)(\epsilon-1)}{\epsilon} \right) \tag{30}$$

With $T_j \equiv \frac{(\beta-1)(1-\epsilon)}{\epsilon}\ \frac{\frac{\epsilon}{\epsilon+1}+(\beta-1)}{(\beta-1)(1-\epsilon)} = \frac{1}{\epsilon+1} + \frac{\beta-1}{\epsilon} > 0$

[33] All values that do not satisfy (15) are irrelevant as in these cases the best response of the large country is given by the 'case 1' best response (16) anyway.

Simplifying and recalling that $T_5 > 0$ then gives:

$$\frac{\partial^2 U}{\partial t_H^2} \mid_{\rho^e} \quad = \quad -T_5 \left((\beta - 1) + \frac{\epsilon}{\epsilon + 1} \right) < 0. \tag{31}$$

This implies that for $\rho = \rho^e$ the second order condition holds and (14) is indeed the optimal response.

To see that this is true for all $\rho \geq \rho^e$, note that any value of $\rho \geq \rho^e$ can be written as $\rho = x\ \rho^e$ with $x \geq 1$. In order to obtain $\frac{\partial^2 U}{\partial t_H^2} \mid_{\rho^e}$, we have plugged in ρ^e into (29). Now considering any value of $\rho \geq \rho^e$, we can plug $\rho = x\ \rho^e$ into (29).

It can be seen in (29) that ρ enters twice in the expression for $\frac{\partial^2 U}{\partial t_H^2}$. Entering via T_5 it does not affect the sign. To see the effect of a higher ρ on the second term, note that when we use $\rho = x\ \rho^e$, T_j in equation (30), is replaced by $T_j\ \frac{1}{x^\epsilon} < T_j$. The positive effect of T_j on the sign of $\frac{\partial^2 U}{\partial t_H^2}$ is thus dampened for a any $\rho > \rho^e$. This shows that (15) is indeed a sufficient condition for (14) to be a utility maximum. **q.e.d.**

B Maximum t_X for Equilibrium Existence

The values of t_X for which the best response is given by (14) is

$$t_X \leq \left((\beta - 1) \left(\frac{(1-\epsilon)(\beta-1)}{\frac{\epsilon}{\epsilon+1} + (\beta - 1)} \right)^{\frac{1-\epsilon}{\epsilon}} - (\beta - 1 + \epsilon\beta) \left(\frac{(1-\epsilon)(\beta-1)}{\frac{\epsilon}{\epsilon+1} + (\beta - 1)} \right)^{1/\epsilon} \right) \frac{T_3^{1/\epsilon}}{\epsilon\beta}. \tag{32}$$

Proof: Define ρ^{jump} as the tax differential just before the regime switch to $\rho = 0$. For ρ^{jump}, (15) holds with equality. Note that $t_X^{jump} = t_H^{\rho>0}[\rho^{jump}] - \rho^{jump}$ combining this with (14) and (15), the value of t_X for which the best response for the large country switches from $\rho > 0$ to $\rho = 0$ is given by

$$t_X^{jump} = \frac{(\beta - 1)\ T_3}{\epsilon\beta\ \left(\frac{(1-\epsilon)(\beta-1)}{\frac{\epsilon}{\epsilon+1} + (\beta-1)}\ T_3 \right)^{\frac{\epsilon-1}{\epsilon}}} - \frac{(\beta - 1) + \epsilon\beta}{\epsilon\beta} \left(\frac{(1-\epsilon)(\beta-1)}{\frac{\epsilon}{\epsilon+1} + (\beta - 1)}\ T_3 \right)^{1/\epsilon}.$$

This can be simplified to

$$t_X^{jump} = \left((\beta - 1) \left(\frac{(1-\epsilon)(\beta-1)}{\frac{\epsilon}{\epsilon+1} + (\beta - 1)} \right)^{\frac{1-\epsilon}{\epsilon}} - (\beta - 1 + \epsilon\beta) \left(\frac{(1-\epsilon)(\beta-1)}{\frac{\epsilon}{\epsilon+1} + (\beta - 1)} \right)^{1/\epsilon} \right) \frac{T_3^{1/\epsilon}}{\epsilon\beta}.$$

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To prove the inequality in (32), it remains to be shown that all values of t_X below t_X^{jump} imply that the large country sets its tax rate such that $\rho > 0$.

We know that the utility of the best response with $\rho > 0$ dominates for $t_X = t_X^{jump}$. A sufficient condition for this to hold for $t_X \leq t_X^{jump}$ as well, is that ρ decreases in $t_X \; \forall \; t_X \leq t_X^{jump}$. From before we have:

$$t_H = \frac{(\beta - 1)(T_3 - \rho^{\epsilon})}{\epsilon \beta \rho^{\epsilon - 1}}$$

subtracting t_X on both sides and multiplying by $\epsilon\beta\rho^{\epsilon-1}$ we get:

$$\epsilon\beta\rho^{\epsilon} = (\beta - 1)T_3 - (\beta - 1)\rho^{\epsilon} - t_X \epsilon\beta\rho^{\epsilon-1}$$

This can be rewritten as:

$$t_X = Q(\rho) = \frac{1}{\epsilon\beta}[(\beta - 1)T_3\rho^{1-\epsilon} - (\epsilon\beta + \beta - 1)\rho]$$

It remains to show that $Q'(\rho) < 0 \; \forall \; t_X \leq t_X^{jump}$

$$Q'(\rho) = (1 - \epsilon)(\beta - 1)T_3\rho^{-\epsilon} - (\epsilon\beta + \beta - 1) < 0$$

This condition can be rewritten to:

$$\rho^{\epsilon} > \frac{(1 - \epsilon)(\beta - 1)}{(\epsilon\beta + \beta - 1)} \; T_3$$

Condition (15) gives a lower bound for ρ. Plugging in this bound into the previous condition delivers:

$$\frac{(1 - \epsilon)(\beta - 1)}{\frac{\epsilon}{\epsilon+1} + \beta - 1} \; T_3 > \frac{(1 - \epsilon)(\beta - 1)}{(\epsilon\beta + \beta - 1)} \; T_3$$

which can be simplified to:

$$\beta > \frac{1}{\epsilon + 1}$$

which is always true. **q.e.d.**

C Corner Solution of Maximum Tax Rates

This appendix reports the expression for the main equilibrium objects when parameters are such that the governments choose the maximum tax levels. This case arises when the large country would optimally set a tax rate larger one. In this corner solution the large country

cannot optimally trade off the intensive and extensive margins of taxation anymore as there is an upper bound for adjustment of the intensive margin. Since the focus of this paper is to analyze the effect of these two margins of the tax game, the case of $t_H^* = 1$ is only briefly outlined for completeness.

The main equilibrium objects are given by $a^{**c} = \left(\frac{\epsilon^2}{(\epsilon+1)^2}\frac{\alpha}{\sigma f_t}\right)^{\frac{1}{\sigma-1}} a_m$, $N_X^{*c} = \left(\frac{\epsilon^2}{(\epsilon+1)^2}\frac{\alpha}{\sigma f_t}\right)^{\epsilon+1}$ and $\Pi_X^{*c} = \left(\frac{\epsilon^2}{(\epsilon+1)^2}\frac{\alpha}{\sigma f_t}\right)^{\epsilon}\frac{\alpha}{\sigma}$, where the superscript c stands for corner solution.

One one reason why the large country might want to set a tax rate above one is when the fixed cost of profit shifting are very high. As the large country cannot optimally trade of its intensive and extensive margin, changes in fixed costs also move a^*, N_X and the tax bases Π_H and Π_X. As ρ increases less than would be optimal for the large country, the cutoff cost level decreases in fixed costs. The share of firms shifting profits abroad decreases and the home tax base increases.

D Proof of Proposition 3

To determine the impact of firm heterogeneity on an equilibrium object, it is standard to adjust the maximum cost value a_m such that the mean of the cost distribution remains constant, while the variance (heterogeneity) changes. Since the equilibrium values of Π_X and ρ are independent of a_m, a change in firm heterogeneity affects Π_X^* and ρ^* only via γ. Considering the partial derivatives with respect to γ is thus sufficient to establish the effect of firm heterogeneity on the degree of tax competition and the 'aggressiveness' of the tax haven.

We can prove *(i)* and *(ii)* algebraically. The fraction of equilibrium outflows from the large country are $\frac{\Pi_X^*}{\Pi_H^A} = \frac{\beta-1}{\epsilon\beta+2\beta-1}$. We thus have

$$\frac{\partial \Pi_X^*/\Pi_H^A}{\partial \gamma} = -\frac{\beta(\beta-1)}{(\epsilon\beta+2\beta-1)^2(\sigma-1)} > 0$$

this proves the statement on γ in *(i)*. And

$$\frac{\partial(\Pi_X^*/\Pi_H^A)}{\partial \sigma} = \frac{(\beta-1)}{(\epsilon\beta+2\beta-1)^2}\ \frac{\beta\gamma}{(\sigma-1)^2} > 0$$

proves the statement on σ.

Next we look at the change of ρ with γ. The equilibrium tax difference is:

$$\frac{\partial \rho^*}{\partial \gamma} = \frac{\sigma}{\alpha}\frac{\epsilon+1}{\epsilon}\left(\frac{\beta-1}{\epsilon\beta+2\beta-1)}\right)^{\frac{1}{\epsilon}} f_t.$$

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We take the first derivative and simplify to get:

$$\frac{\partial \rho^*}{\partial \gamma} = -\frac{\sigma}{\alpha}\left(\frac{\beta-1}{\epsilon\beta+2\beta-1)}\right)^{\frac{\epsilon+1}{\epsilon}} \frac{\epsilon(2\epsilon\beta+3\beta-1)+(1+\epsilon)(\epsilon\beta+2\beta-1)\log\left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)}{(\beta-1)(\sigma-1)\epsilon^3} f_t.$$

This expression has the same sign as:

$$S(\beta,\epsilon) = -\epsilon(2\epsilon\beta+3\beta-1)+(1+\epsilon)(\epsilon\beta+2\beta-1)\log\left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)$$

We use numerical minimization to determine the global minimum of this expression which for $\epsilon \to 0$ and $\beta \approx 1.3$ is $S(\beta,\epsilon) \approx 2.68$. This implies that given the parameter constraints from the model ($\epsilon > 0$ and $\beta > 1$) this expression is always positive. **q.e.d.**

E Proofs for Alternative Measures of Tax Competition

In this section we show that for reasonable parameter values ($\beta > 4$ and $\beta > 2$, respectively) it is assured that $\frac{\partial G_H^*}{\partial \gamma} > 0$ and $\frac{\partial t_H^*}{\partial \gamma} > 0$. To see this note that total tax income is given as:

$$t_H^* \Pi_H^* = \frac{\beta-1}{\beta}\frac{(\epsilon+1)^3}{\epsilon^2}\left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)^{\frac{\epsilon+1}{\epsilon}} f_t$$

Its derivative with respect to γ is:

$$\frac{\partial t_H^* \Pi_H^*}{\partial \gamma} = -\frac{\beta(\epsilon+1)^2\left(\frac{\beta-1}{\epsilon\beta+2\beta-1)}\right)^{\frac{1}{\epsilon}}\left(\epsilon(\epsilon+2\epsilon\beta+5\beta-2)+(\epsilon+1)(\epsilon\beta+2\beta-1))\text{Log}\left[\frac{\beta-1}{\epsilon\beta+2\beta-1)}\right]\right)}{\epsilon^4(\epsilon\beta+2\beta-1)^2(\sigma-1)} f_t$$

The sign of which is equal to the sign of:

$$S_{G\gamma}(\beta,\epsilon) = -\epsilon(\epsilon+2\epsilon\beta+5\beta-2)+(\epsilon+1)(\epsilon\beta+2\beta-1))\text{Log}\left[\frac{\beta-1}{\epsilon\beta+2\beta-1)}\right]$$

here Figure 3

The first graph in Figure 3 plots all ϵ, β combinations for which this function (and thus the derivative above) is zero. In the west of this line it is positive, and negative to the east. Using numerical minimization, we can determine its infimum under the restriction of $\beta < 4$. The function attains its infimum at $\beta \to 4$ and $\epsilon \approx 1.75$ with a value of ≈ 0.24 which is positive.

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The tax rate is:

$$t_H^* = \left(\frac{\epsilon+1}{\epsilon}\right)^2 \frac{\sigma}{\alpha}\left(\frac{\beta-1}{\epsilon\beta+2\beta-1}\right)^{\frac{1}{\epsilon}} f_t$$

Its derivative with respect to γ is:

$$\frac{\partial t_H^*}{\partial \gamma} = -\frac{(\epsilon+1)\left(\frac{\beta-1}{\epsilon\beta+2\beta-1)}\right)^{1+\frac{1}{\epsilon}}\left(\epsilon(3\epsilon\beta+5\beta-2)+(\epsilon+1)(\epsilon\beta+2\beta-1)\text{Log}\left[\frac{\beta-1}{\epsilon\beta+2\beta-1)}\right]\right)}{\epsilon^4(\beta-1)(\sigma-1)}\frac{\sigma}{\alpha}f_t$$

The sign of which is equal to the sign of:

$$S_{t_H\gamma}(\beta,\epsilon) = -\epsilon(3\epsilon\beta+5\beta-2)+(\epsilon+1)(\epsilon\beta+2\beta-1))\text{Log}\left[\frac{\beta-1}{\epsilon\beta+2\beta-1)}\right]$$

The second graph in Figure 3 plots all ϵ, β combinations for which this function (and thus the derivative above) is zero. In the west of this line it is positive, and negative in the east. Using numerical minimization, we can determine its infimum under the restriction of $\beta < 2$. The function attains its infimum at $\beta \to 2$ and $\epsilon \approx 2.40$ with a value of ≈ 0.72 which is positive.

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F Figures

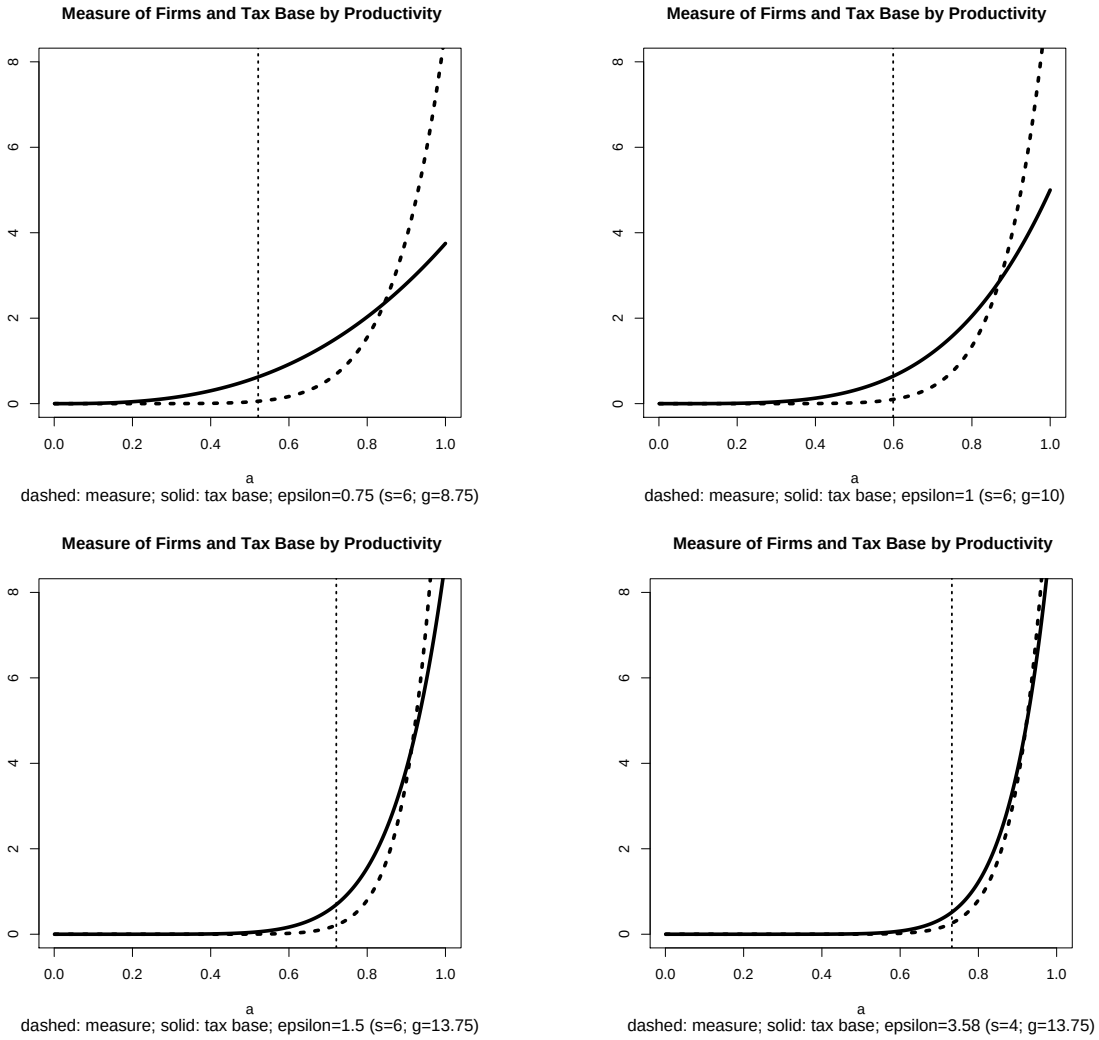

Figure 1: These three graphs illustrate the effect of the Pareto parameter γ and the elasticity of substitution σ on the distribution of the tax base (solid line). Profits are normalized by overall aggregate profits (Π_H^A) thus the area under the curve is unity in all cases. A point on the curve represents the share of overall profits firms with cost level a account for. The dashed line plots the density of firms $f(a)$. The dashed vertical line plots the equilibrium cutoff level. We use $a_m = 1$. In the first three graphs we set $\sigma = 6$ and vary γ such that ϵ rises from 0.75 ($\gamma = 8.75$) to 1 ($\gamma = 10$) and then to 1.5 ($\gamma = 13.75$). In the last graph we keep $\gamma = 13.75$ and decrease σ to 4 which implies $\epsilon = 3.58$.

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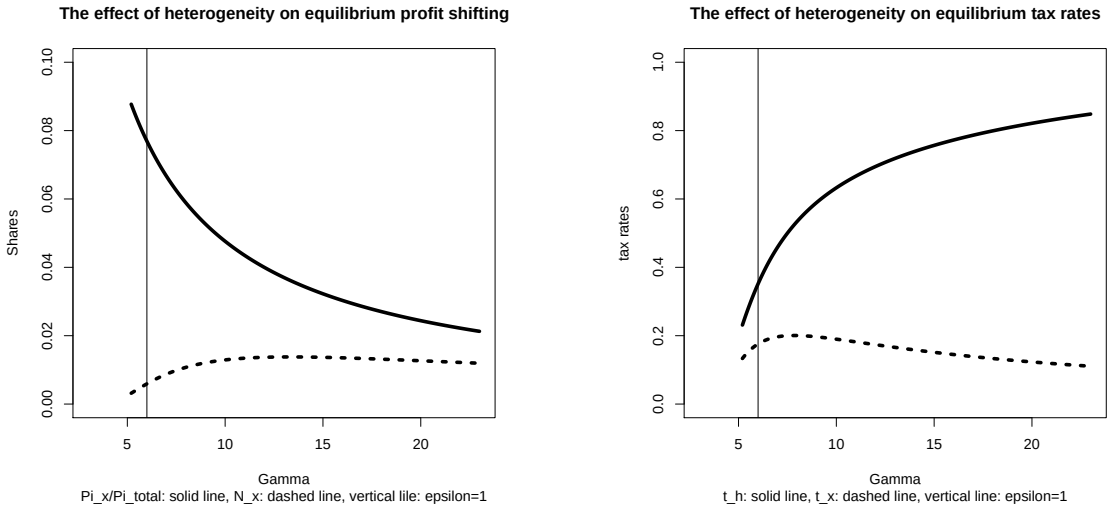

Figure 2: In the first graph the solid line represents the fraction of the tax base flowing to the tax haven as a function of γ. The fraction of firms that choose 'profit shifting' FDI is given by the dashed line. The second graph plots the equilibrium tax rates of the large country (solid line) and the rate set by the tax haven (dashed line). In both graphs the vertical line represents $\epsilon = 1$. For too low values of gamma no equilibrium exists.

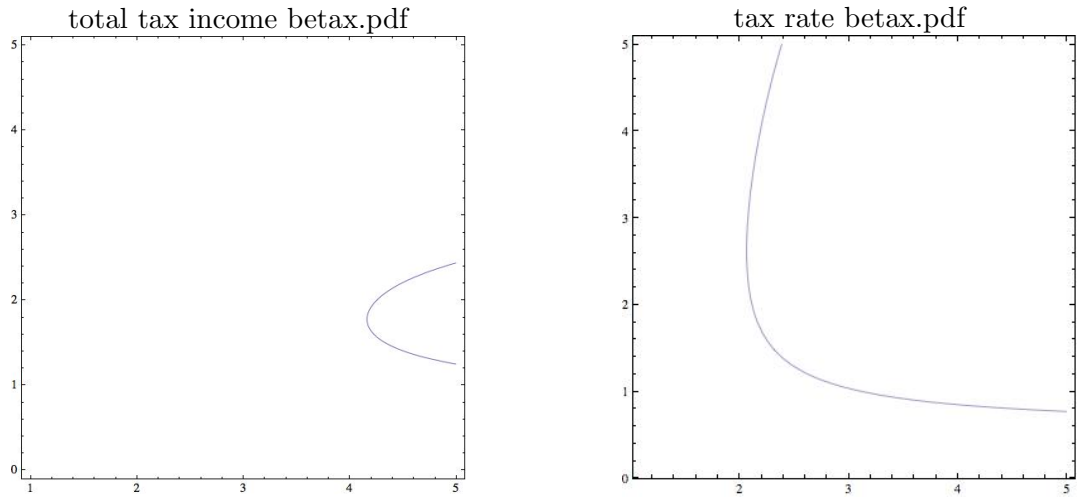

Figure 3: X-axis: β, y-axis: ϵ. All points to the west of the black line are parameter combinations, which assure that a change in γ affects the two measures of tax competition in the predicted way. A hight γ (low heterogeneity) implies weaker tax competition.

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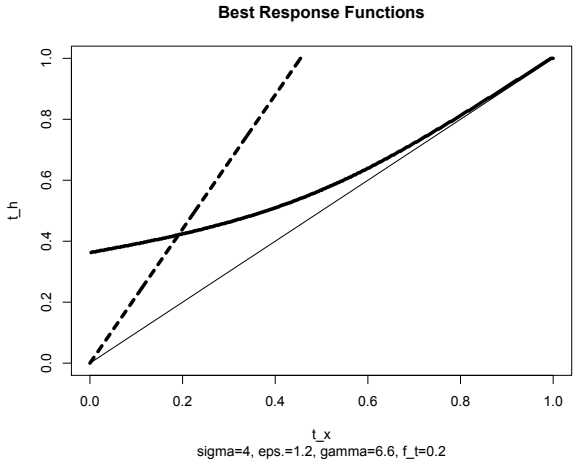

Figure 4: This Figure provides a numerical example for the equilibrium of the tax game for $\epsilon > 1$. For $\epsilon > 1$ the best response function of the large country is continuous (bold solid line) and there exists a unique intersection with the best response function of the tax haven (dashed line). The best response of the large country implies $\rho > 0$ for all tax rates of the tax haven. The parameter values chosen are $\sigma = 4$, $\gamma = 6.6$ (implying $\epsilon = 1.2$), $a_m = 1$ and $f_t = 0.2$.

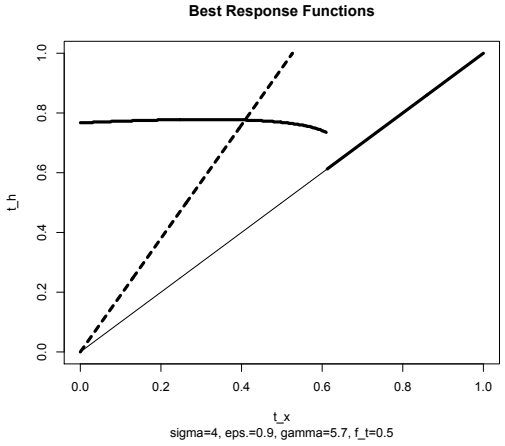

Figure 5: This numerical example illustrates that for $\epsilon < 1$ the reaction function of the large country (bold solid line) is discontinuous. For low values of t_X the large country sets a higher tax rate to finance public expenditure accepting an outflow of tax base. A low ϵ implies, however, that the most productive firms account for a large fraction of the tax base. Setting the tax differences to zero (keeping the most productive firms paying taxes at home) is optimal for high values of t_X. In this example with $\epsilon = 0.9$ the equilibrium exists. The parameter values chosen are $\sigma = 4$, $\gamma = 5.7$, $a_m = 1$ and $f_t = 0.5$.

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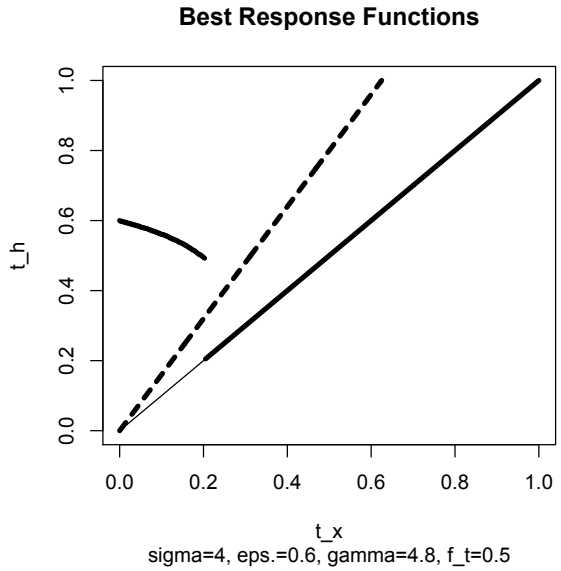

Figure 6: This numerical example uses the same parameter values as Figure 5 except that γ (and thus ϵ) is lower. This implies that the most productive firms account for a large fraction of the tax base and that the tax base thus reacts strongly to tax differences. Trying to avoid these firms from paying taxes abroad, the large country sets the tax difference to zero already for low levels of t_X. Since the tax haven always undercuts, this cannot be an equilibrium. In this example no equilibrium exists. The parameter values chosen are $\sigma = 4$, $\gamma = 4.8$ (implying $\epsilon = 0.6$), $a_m = 1$ and $f_t = 0.5$.