

Competition for Firms in an Oligopolistic Industry: Do Firms or Countries Have to Pay?*

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Preliminary version
February 2007

Abstract

We set up a model of generalised oligopoly where two countries of different size compete for an exogenous, but variable, number of identical firms. The model combines a desire by national governments to attract internationally mobile firms with the existence of location rents that arise even in a symmetric equilibrium where firms are dispersed. Whether taxes are positive or negative in the location equilibrium depends on the interplay of these two counteracting forces. As economic integration proceeds, equilibrium taxes and national welfare in both countries are initially reduced, but rise again as trade costs fall even further. A range of trade costs is identified where economic integration raises the welfare of the small country, but lowers welfare in the large country.

Keywords: tax and subsidy competition, oligopolistic markets

JEL Classification: H 25, H 73, F 15, F 23

*We thank Rainald Borck, Ben Ferrett and participants at the Asia Pacific Trade Seminar, Kobe and in seminars at Munich and Nuremberg for helpful discussions. This paper was started when the second author visited the Center for Economic Studies at the University of Munich and continued when the first author was visiting Strathclyde University. We thank both institutions for their hospitality.

1 Introduction

The rise in foreign direct investment and the increasing role played by large, multinational firms has been one of the most important developments in the world economy over the last three decades. This change has had profound effects on the overall stance that governments take towards the location of mobile firms in their jurisdiction. A first policy area where this development can be seen is corporate taxation. Table A.1 in the appendix shows that nominal and effective average rates of corporation tax have fallen significantly over the last two decades. Moreover, there is evidence that multinational firms are able to further reduce their tax payment. Hines (2005, Table 1), for example, shows that the effective tax rates paid by U.S.-based multinationals have fallen more strongly during the period 1982-1999 than their host countries' statutory tax rates. This indicates either that multinationals are able to shift part of their profits to low-cost countries, or that they receive specific tax breaks in the host countries (or a combination of the two).¹

A second policy area where an increased 'bargaining power' of firms vis-a-vis host governments is visible is state aid for the location of new plants or the expansion of existing ones. Such investment subsidies have become commonplace, in particular in sectors that combine the use of modern technologies with the creation of new jobs. This is well documented in the European Union (EU), where state aid given by member states to individual enterprises in their jurisdiction must be approved by the European Commission. Table A.2 in the appendix lists 15 cases where substantial investment subsidies, typically accounting for 10-30% of the present value of the investment, have been approved by the EU Commission in the years 2001-2004 alone.²

If these trends are viewed together, and investment subsidies and corporate tax pay-

¹There is growing empirical evidence for profit shifting by multinationals; see Hines (1999) for a survey. Discriminatory tax breaks granted to multinational firms are a major current policy issue at both the OECD and the EU level. The EU's Primarolo Report (1999), for example, lists a total of 66 examples of discriminatory tax preferences in favour of multinational enterprises.

²Note that the subsidy payments collected in Table A.2 cover only direct monetary transfers and thus represent merely a lower bound for the the overall value of the incentive package. The latter often includes additional measures, such as the free provision of public infrastructure. See also Davies (2005, Table 1) for a similar collection of investment subsidies granted by the U.S. states.

ments are compared in present-value terms, it is not even clear in many cases whether firms make net tax payments to their host countries or whether governments instead pay mobile firms for locating in their jurisdiction. This ambiguity is the starting point for the present paper. One of our main goals is to identify the conditions under which countries, or firms, make payments to the other party in equilibrium. We do so in a model that incorporates both a desire of national governments to attract internationally mobile firms, but also the ability of governments to tax the location rents earned by firms.

More specifically, we set up a model of generalised oligopoly where two countries compete for an exogenous, but variable number of identical firms. Governments have an incentive to attract firms to their jurisdiction in order to save on trade costs and reduce consumer prices. At the same time, location rents arise in our model because a firm that moves to the other country will face more competitors and therefore a lower mark-up in this market. Whether taxes are positive or negative in the location equilibrium depends on the interplay of these two counteracting forces. Our model is simple enough to derive reduced-form expressions for the equilibrium tax rates on mobile firms, even in the case where countries are of asymmetric size. A core question raised in our analysis is how economic integration (a fall in trade costs) affects tax rates and welfare in the large and in the small country. We find that equilibrium tax rates in both countries are positive at high levels of trade costs, then fall to negative values (i.e. location subsidies) as economic integration proceeds, and finally rise again when trade costs fall even further. Similarly welfare levels are first falling and then rising again when trade costs are continuously reduced. Importantly, the minimum of taxes and welfare is reached at different levels of trade costs for the large and for the small region. This implies that there is a range of trade costs where economic integration raises the welfare of the small country, but lowers welfare in the large country.

Our model draws on two strands in the literature that have so far developed independently, and have led to rather different conclusions. A first set of papers focuses on the competition of potential host countries for a single multinational firm. In these models the equilibrium policy generally involves a location subsidy to the firm. Reasons why countries (or states) will want to attract firms are scale economies in the provision of public goods and services, in conjunction with a mobile workforce (Black and Hoyt,

1989), positive spillovers from employment in the host jurisdiction (Haaparanta, 1996; Davies, 2005), savings in trade costs (Hauffer and Wooton, 1999), or technological backwardness (Fumagalli, 2003). Recent work has shown, however, that these results change when an indigenous firm is already operating in one of the countries (Bjorvatn and Eckel, 2006) or when countries compete for two mobile firms, rather than one (Ferrett and Wooton, 2005). In the latter case countries may even be able to tax away all profits in the non-cooperative tax equilibrium. A general feature of these models is that they involve the comparison of discrete equilibrium allocations and analyze specific scenarios that are difficult to compare or generalise.

A second literature strand has analysed tax competition for internationally mobile firms in models of the new economic geography (Kind *et al.*, 2000; Baldwin and Krugman, 2004; Ottaviano and van Ypersele, 2005; Borck and Pflüger, 2006). These models employ a framework of monopolistic competition where otherwise identical firms produce different varieties of a composite good.³ This literature typically focuses on the regime where all firms agglomerate in a ‘core country’ and the resulting agglomeration rents can be taxed, at positive levels, by this country’s government. Within this regime it is possible that economic integration increases the agglomeration rent and hence the taxing power of the core region. The present analysis reaches different conclusions with respect to the link between economic integration and the equilibrium level of tax rates and we discuss in detail which model assumptions are crucial for the divergent results. Our analysis develops as follows. In section 2 we present the basic model. Section 3 analyses the non-cooperative tax equilibrium and the allocation of firms in the case where countries are symmetric and in the case where they differ in size. Section 4 analyses the welfare effects of economic integration, again differentiating between the scenarios of symmetric and of asymmetric countries. In section 5 we analyse the robustness of our results by incorporating profit income and an excess burden of taxation into the objective function of national governments. Section 6 discusses the results and relates them to the existing literature. Section 7 concludes.

³For an extension that accounts for firm heterogeneity, see Burbidge *et al.* (2006). Another related analysis is Fuest (2005) who studies the implications for tax policy when economic integration reduces trade barriers but also increases the foreign ownership share of domestic firms.

2 The model

2.1 Consumers

We consider a region with two countries $i \in \{a, b\}$, which compete to attract a fixed number of firms. These firms produce a homogeneous good, labelled x , in an oligopolistic industry. A second, private good, the numeraire commodity z , is produced under conditions of perfect competition. Consumers in both countries have identical preferences for the goods, given by

$$u_i = \alpha x_i - \frac{\beta}{2} x_i^2 + z, \quad i \in \{a, b\}. \quad (1)$$

The two countries potentially differ in size. The population of the region is normalised to unity and, without loss of generality, we take country a to be the larger of the two countries. Hence let there be $n \geq 0.5$ consumers in country a and $(1 - n)$ consumers in country b . In most of our analysis, the residents of countries a and b earn only wage income, while profit income accrues to capital owners that reside in a third (outside) country.⁴ Each household in countries a and b exogenously supplies one unit of labour. In each country the wage rate w is fixed in the numeraire industry, which uses labour as the only input. Free trade in the numeraire good equalizes wages across the countries. Moreover, total income from the business tax (as detailed below), denoted by T_i , is redistributed equally and in a lump-sum fashion to the consumers in each country. The budget constraint for a representative consumer in each of the two countries is then

$$w + \frac{T_a}{n} = z + p_a x_a, \quad w + \frac{T_b}{1 - n} = z + p_b x_b, \quad (2)$$

where p_i is the price of good x in country i . Utility maximization leads to the inverse-demand curves

$$\alpha - \beta x_i = p_i, \quad i \in \{a, b\}. \quad (3)$$

Aggregating the demand for good x over all consumers yields market demand curves for each country, denoted X_i

$$X_a = \frac{n(\alpha - p_a)}{\beta}, \quad X_b = \frac{(1 - n)(\alpha - p_b)}{\beta}. \quad (4)$$

⁴In section 5 we will consider the more general case where all profit income accrues to the residents of countries a and b .

When $n > 0.5$, the market demand curve of the larger country a is flatter than that of country b . In this sense market a is the more profitable one for firms, as we will see below.

2.2 Firms

Each firm in the imperfectly competitive industry x requires one unit of capital to produce any output. There is a total of k units of capital in the world economy, implying that a maximum of k firms can engage in production.⁵ There are fixed and identical costs of setting up operations in each of the two countries. This ensures that each firm will locate in only one of the two countries, if it enters the region at all.⁶ The firms are assumed to be identical except with respect to the location of their production facilities. Location matters because, while all firms can sell their products in both countries, there are trade costs associated with exports to a firm's foreign market. Thus each country may be served by both "local" firms that produce domestically and "foreign" firms that are based in the other country.

We assume that labour is the only variable input with marginal costs of w .⁷ The cost of exporting each unit of output is τ , which effectively raises the marginal cost of serving the foreign market to $(w + \tau)$.⁸ Firms are assumed to behave as Cournot competitors and are able to segment their markets, choosing the quantities to sell on their domestic and export markets independently.⁹

⁵Our model treats k as a continuous variable. Hence the analysis only approximates the 'true' model when the number of firms is small and the relocation of a single firm has discrete implications for the equilibrium allocation. This will be further discussed in section 6. The main advantage of this procedure is that we can derive equilibrium allocations and policies as continuous functions of exogenous model parameters.

⁶For notational simplicity these fixed costs are suppressed in the equations below.

⁷Since wage costs are equalised between the two countries, they do not enter the location decision of firms in our model. For a recent analysis of tax competition for foreign direct investment which focuses on production cost differentials, see Davies (2005).

⁸These trade costs are real barriers to the free movement of goods across international frontiers. They make take the form of transport costs or of administrative formalities at the border that absorb resources. We are not considering tax instruments, such as tariffs.

⁹In equilibrium, firms will receive a lower producer price for their exports than for goods destined

Capital owners choose output levels in each market in order to maximise the total profit of each firm (which equals the return to capital) :

$$\begin{aligned}\pi_a &= (p_a - w) x_{aa} + (p_b - w - \tau) x_{ba}, \\ \pi_b &= (p_a - w - \tau) x_{ab} + (p_b - w) x_{bb},\end{aligned}\tag{5}$$

where π_j is the pre-tax profit of a firm based in country j and x_{ij} represents sales in country i by a firm based in country j ($i, j \in \{a, b\}$). Given that the marginal cost of exports is relatively higher than that for domestic sales, a firm's perceived marginal revenue in its export market must be comparably larger. In equilibrium, this will arise when each foreign firm has a relatively smaller market share than that of a domestic firm (as perceived marginal revenue is inversely related to market share). Essentially, a firm is at a cost disadvantage in its export markets and will sell less than an indigenous rival.

Suppose that m firms are located in country a and the remaining $(k - m)$ firms produce in country b . Maximising (5) taking into account demand (4), yields firm output levels:

$$\begin{aligned}x_{aa} &= \frac{n[\alpha - w + (k - m)\tau]}{\beta(k + 1)}; & x_{ba} &= \frac{(1 - n)[\alpha - w - (1 + k - m)\tau]}{\beta(k + 1)}; \\ x_{ab} &= \frac{n[\alpha - w - (1 + m)\tau]}{\beta(k + 1)}; & x_{bb} &= \frac{(1 - n)[\alpha - w + m\tau]}{\beta(k + 1)}.\end{aligned}\tag{6}$$

Note that x_{ab}/x_{aa} , $x_{ba}/x_{bb} < 1$, confirming the assertion that a foreign firm's share of a market is always less than that of a local firm whenever there are trade costs ($\tau > 0$).¹⁰

The corresponding equilibrium market outputs and prices are:

$$\begin{aligned}X_a &= \frac{n[k(\alpha - w) - (k - m)\tau]}{\beta(k + 1)}; & X_b &= \frac{(1 - n)[k(\alpha - w) - m\tau]}{\beta(k + 1)}; \\ p_a &= \frac{\alpha + kw + (k - m)\tau}{k + 1}; & p_b &= \frac{\alpha + kw + m\tau}{k + 1}.\end{aligned}\tag{7}$$

Notice that consumer prices in both countries fall when the total number of firms k increases and competition in the oligopolistic industry is thereby intensified. Moreover, for any given level of k , increasing m , the number of firms that locate in country a ,

for the domestic market. The trade structure is simply a generalisation of the "reciprocal dumping" model of Brander and Krugman (1983).

¹⁰As our model allows for differences in country size, this is not inconsistent with the possibility that a firm may sell more in its export market than at home.

reduces the consumer price of good x in that country, but increases the price in country b . This is a consequence of the changes in the aggregate level of trade costs that follow from the relocation of firms.

Substituting (6) and (7) into (5) yields the pre-tax profits of firms located in each country:

$$\begin{aligned}\pi_a &= \frac{n[\alpha - w + (k - m)\tau]^2}{\beta(k + 1)^2} + \frac{(1 - n)[\alpha - w - (1 + k - m)\tau]^2}{\beta(k + 1)^2}; \\ \pi_b &= \frac{n[\alpha - w - (1 + m)\tau]^2}{\beta(k + 1)^2} + \frac{(1 - n)[\alpha - w + m\tau]^2}{\beta(k + 1)^2}.\end{aligned}\tag{8}$$

We assume that profits are taxed at source by the host countries of the firms.¹¹ Let t_i be the lump-sum tax imposed on each firm by country i . Thus total tax revenues are $T_a = t_a m$ and $T_b = t_b(k - m)$ for country a and country b , respectively. The tax differential between countries is $\Delta \equiv t_a - t_b$. In deciding upon where to invest, firms will compare profits net of taxes and locate in the more profitable country. The locational equilibrium for the industry will be characterised by $\pi_a - t_a = \pi_b - t_b$. Substituting (8) gives the equilibrium number of firms choosing to locate in country a :

$$m = \frac{k}{2} + \frac{(2n - 1)[2(\alpha - w) - \tau] - \Delta\beta(k + 1)}{2\tau}.\tag{9}$$

Suppose, initially, that each country charges the same tax, that is $\Delta = 0$. If the countries were the same size ($n = 0.5$), it is clear from (9) that $m = k/2$. That is, the firms would be evenly split between the two locations. In the absence of trade costs, neither country has a locational advantage and m is undefined. When trade is costly and country a is relatively large ($n > 0.5$), it attracts more than half of the firms. Differences in taxes will further affect the location of firms such that, if country a taxes firms more heavily than country b (that is, $\Delta > 0$), its share of the firms is relatively smaller than it would otherwise be.

¹¹There is a general agreement in the literature that international company taxation closely follows the source principle. This principle applies directly, if countries avoid international double taxation by exempting foreign-earned income from domestic tax. If countries grant an international tax credit instead, source taxation is still effective in many cases, because crediting applies only after profits have been repatriated and because countries do not rebate ‘excess’ taxes paid abroad.

How is the international distribution of firms affected by changes in relative country size, trade costs, and tax differences? Partial differentiation of (9) yields:

$$\begin{aligned}\frac{dm}{dn} &= \frac{2(\alpha - w) - \tau}{\tau} > 0; \\ \frac{dm}{d\tau} &= \frac{-(2n - 1)(\alpha - w)}{\tau^2} + \frac{\Delta\beta(k + 1)}{\tau^3} \leq 0; \\ \frac{dm}{d\Delta} &= \frac{dm}{dt_a} = \frac{-\beta(k + 1)}{2\tau^2} = -\frac{dm}{dt_b} < 0.\end{aligned}\tag{10}$$

Assume initially that profit taxes are the same in both countries ($\Delta = 0$). From (10), as n the asymmetry in country size increases, the country a attracts a greater share of the firms. In contrast, whenever country a is the larger country ($n > 0.5$), a rise in the trade cost increases the international dispersion of firms, moving more firms to the smaller country. When $\Delta > 0$, eq. (9) reveals a negative impact of a relatively high tax in country a on m . However, (10) shows that this effect is mitigated both when n and τ increase. The concentration of industry in country a is reinforced by increases in n but the effect of increasing trade costs on firm location becomes ambiguous. Lastly, increasing a country's tax clearly creates a disincentive for firms to locate there.

2.3 Governments

The governments of countries a and b impose a lump-sum tax on each firm that locates within their respective jurisdictions. Importantly, these taxes can be negative, acting as subsidies to attract investment to a particular country. If revenues from the business tax are positive, then these are redistributed equally and in a lump-sum way to the residents in the country in which they are collected. The costs of a negative business tax are raised through lump-sum taxation of consumers. Recall that, despite their lump-sum character, business taxes still distort the location decision of internationally mobile firms [eq. (9)].¹²

In addition to tax revenue, governments care about the total consumer surplus in their jurisdiction. Substituting the equilibrium market prices for good x [see (7)] into the

¹²Introducing an ad valorem profit tax instead of a unit lump-sum tax on firms would complicate the algebra, but it would cause no further distortions and hence would not change any of our qualitative results. The assumption that lump-sum taxes are available to cover the costs of subsidies to firms will be relaxed in section 5.

linear market demand curves (4), total consumer surplus, denoted S_i , in each of the two countries is given by

$$S_a = \frac{n[k(\alpha - w) - (k - m)\tau]^2}{2\beta(k + 1)^2}, \quad S_b = \frac{(1 - n)[k(\alpha - w) - m\tau]^2}{2\beta(k + 1)^2}. \quad (11)$$

It is straightforward to show that consumer surplus in both countries is rising in the total number of firms k , as this intensifies competition and reduces producer prices in both countries [cf. eq. (7)]. Moreover, a rise in m , the share of firms located in country a , raises consumer surplus in that country, but lowers it in country b . This effect derives from changes in the aggregate level of costs of importing products from the other country and gives each nation an incentive to attract firms to its home jurisdiction.¹³

We initially assume that firms' profits accrue to the residents of a third country.¹⁴ The objective of each government is then simply to maximise the sum of consumer surplus and tax revenue collected from locally producing firms. Consequently, the objective functions of the two governments are

$$W_a = S_a + t_a m(t_a, t_b), \quad W_b = S_b + t_b [k - m(t_a, t_b)]. \quad (12)$$

We substitute (11) in (12) and differentiate each country's welfare expression with respect to its own tax, using the derivative properties of the function $m(t_a, t_b)$ in (10). This gives the following first-order conditions for each country's tax rate:

$$t_a = \frac{\tau\{\tau m[2(k + 1) - n] - nk(\alpha - w - \tau)\}}{(k + 1)^2\beta},$$

$$t_b = \frac{\tau\{\tau(k - m)[2(k + 1) - (1 - n)] - k(\alpha - w - \tau)\}}{(k + 1)^2\beta}. \quad (13)$$

These expressions still include m , which is endogenous. To arrive at reduced-form expressions for the Nash equilibrium tax rates, eq. (9) must be substituted into the set of first-order conditions (13). To develop an intuition for our results we will first perform this analysis in the benchmark case of symmetric countries. In a second step, we then move to the more general case where countries differ in size.

¹³Clearly, savings in transportation cost are only one (analytically convenient) example of why governments may want to attract internationally mobile firms. This motive could, for example, be replaced by technological linkages that exist between the oligopolistic industry x and the production of the numeraire good z . Such a setting would yield similar qualitative conclusions, but would involve a more complex analysis.

¹⁴Section 5 will consider the case where firms' profits accrue to the residents of the taxing countries.

3 Equilibrium taxes and location

3.1 Benchmark: Symmetric countries

To analyze the benchmark case where countries are identical in all respects, we evaluate the first-order conditions for the two countries' optimal tax rates (13) at $n = 0.5$ and substitute the equilibrium allocation of firms (9), again using this restriction. This yields best response functions where each country's tax is a function of the tax set by the other nation's government:

$$t_i = \frac{k\tau\{4\tau(k+1) - [2(\alpha - w) - \tau]\}}{(k+1)\beta[8(k+1) - 1]} + t_j \frac{[4(k+1) - 1]}{[8(k+1) - 1]}, \quad i, j \in \{a, b\}, i \neq j. \quad (14)$$

These symmetric, best response functions are positive sloped, implying that an increase in one country's business tax rate will also raise that of the other country.

Solving the pair of simultaneous equations yields closed-form solutions for the common Nash equilibrium tax rate, where the superscript s stands for the symmetric case:

$$t_a^s = t_b^s = \frac{k\tau}{(k+1)\beta} \left[\tau - \frac{2(\alpha - w) - \tau}{4(k+1)} \right]. \quad (15)$$

The equilibrium tax rates (15) reflect the two fundamental effects that are at work in the present model.

The positive first term in the square brackets arises from a *competition effect*. Intuitively, starting from a symmetric equilibrium and moving one firm from country b to country a implies that each firm in country a now faces more intense competition in its home market. Since a firm's home market is relatively more profitable than its export market, the gross profits of each firm in country a fall, whereas the gross profits of each firm that remains in country b rise. This profit differential implies that a location rent arises for each firm even in a fully symmetric equilibrium, in the sense that the next best alternative (i.e., relocation to the other country) involves lower gross profits. This location rent can be taxed by the host government without causing a firm to move to the other jurisdiction.¹⁵ Finally, the competition effect is stronger, the higher is the

¹⁵Algebraically, this effect can be shown by differentiating the gross profits that each firm earns in a symmetric equilibrium [eq. (8)] with respect to m . The resulting profit differential between a firm that is located in country b and one that is located in a is just equal to the first term in (15).

level of trade costs and thus the larger is the difference in profitability between the home and the foreign markets.

On the other hand, the negative second effect in the brackets is a *consumer-price effect*. When an additional firm enters a country, consumer prices fall due to a reduced level of aggregate trade costs that must be borne by consumers. This effect provides each country with an incentive to grant location subsidies to firms.

From (15) we can determine the critical level of trade costs τ^* at which the two effects just offset one another such that equilibrium taxes are zero:

$$\tau^* = \frac{2(\alpha - w)}{4(k + 1) + 1}. \quad (16)$$

For trade costs $\tau > \tau^*$ the competition effect dominates and equilibrium tax rates are positive, whereas for $\tau < \tau^*$ the consumer price effect is relatively stronger and equilibrium taxes are negative (that is, subsidies are given). Finally, both effects fall to zero in the absence of trade costs ($\tau = 0$). In this case, the Nash equilibrium taxes are zero as both governments and firms are indifferent to the equilibrium pattern of firm location.¹⁶

It should be noted that taxes can only be raised as long as post-tax profits remain non-negative since otherwise firms would not produce at all. To derive this constraint for tax policy, we subtract the tax rate in the symmetric Nash equilibrium (15) from a firm's pre-tax profits (8). Setting the difference equal to zero and solving for the critical value of trade costs that is compatible with non-negative after-tax profits yields:

$$\tau \leq \bar{\tau} = \frac{(\alpha - w) [k - 2 + \sqrt{13k^2 + 8k - 4}]}{(3k^2 + 3k - 2)}. \quad (17)$$

Equation (17) defines a negative relationship between the total number of firms in the market and the critical (maximum) level of trade costs $\bar{\tau}$. For any given level of $(\alpha - w)$, a high k reduces the gross profits that can be earned by each firm in equilibrium. In contrast, a high level of τ increases the ability of a country to set higher taxes when

¹⁶This special case is related to the analysis by Janeba (1998), who introduces firm mobility to the standard model of strategic tax policy but does not include transport costs. He shows that equilibrium trade taxes will then be zero in both countries, in contrast to the trade subsidies that result in the absence of firm mobility (and with Cournot competition of firms).

these taxes are positive in the initial equilibrium.¹⁷

We can also derive a condition under which positive levels of trade will occur in equilibrium. In the symmetry of the benchmark case, this condition is the same for firms located in either country. From (8) and using $m = k/2$, we find that exporting to the other market is profitable as long as trade costs are less than prohibitive, that is, $\tau < \tau^P$, where the prohibitive trade cost is

$$\tau^P = \frac{2(\alpha - w)}{2 + k}. \quad (18)$$

If $\tau > \tau^P$, there will be no trade. Consequently, there will be $k/2$ firms selling in each autarkic market in equilibrium. Comparing the critical values in (17) and (18) shows that $\bar{\tau} \leq \tau^P$ for all $k \geq 2$. Hence eq. (17) is the binding constraint in our model. When this constraint is met, and after-tax profits are non-negative, then there will also be international trade in equilibrium.

How are the symmetric Nash equilibrium tax rates affected by changes in the exogenous parameters of the model? Consider first an increase in the total number of mobile firms in the economy. This yields

$$\frac{\partial t^s}{\partial k} = \frac{\tau\{4\tau(k+1) + (k-1)[2(\alpha-w) - \tau]\}}{4(k+1)^3\beta} > 0. \quad (19)$$

An increase in k will unambiguously raise equilibrium tax rates. Intuitively, a rise in the total number of firms lowers the costs that are perceived by each country from losing one of the firms to the other country. The decline in the consumer-price effect reduces the willingness of each country to grant location subsidies. Moreover a larger number of firms will strengthen the positive competition effect. This last result can be explained as follows. The stronger is competition, and hence the closer are prices to marginal costs, the more severe is the disadvantage from having to bear extra trade costs. This is seen from the model property that the market share of foreign firms falls when the total number of firms is increased [cf. eq. (6)]. Hence, starting from a symmetric equilibrium, the penalty rises for a firm that escapes high domestic taxes by

¹⁷It is easily checked that the critical level of τ at which equilibrium tax rates turn positive [eq. (16)] is below $\bar{\tau}$ and hence there is indeed a range of transport costs for which positive equilibrium taxes result. This is, of course, a consequence of firms earning positive gross profits in our model.

moving abroad, and this strengthens the ability of each country to tax location rents.¹⁸

Increasing the market size of both countries (a rise in α) has the opposite implications. In this case it is directly inferred from (15) that $\partial t^s/\partial\alpha < 0$. With higher sales per firm, each country has more to gain from attracting an additional firm so that the consumer-price effect becomes larger. On the other hand, the competition effect is not affected by an increase in the size of both markets. Hence each country will find it optimal to lower its profit tax, even though sales and gross profits per firm rise. This shows very clearly that there is no link in our model between equilibrium tax rates and the gross profits earned by each firm. What matters instead is only the countries' bargaining position *vis-à-vis* each mobile firm.

Finally, we turn to changes in trade costs. Differentiating (15) with respect to τ gives

$$\frac{\partial t^s}{\partial\tau} = \frac{k[4\tau(k+1) - (\alpha - w - \tau)]}{2(k+1)^2\beta},$$

which may be positive or negative. However, we can determine a critical threshold value for τ , for which this derivative is zero. This is

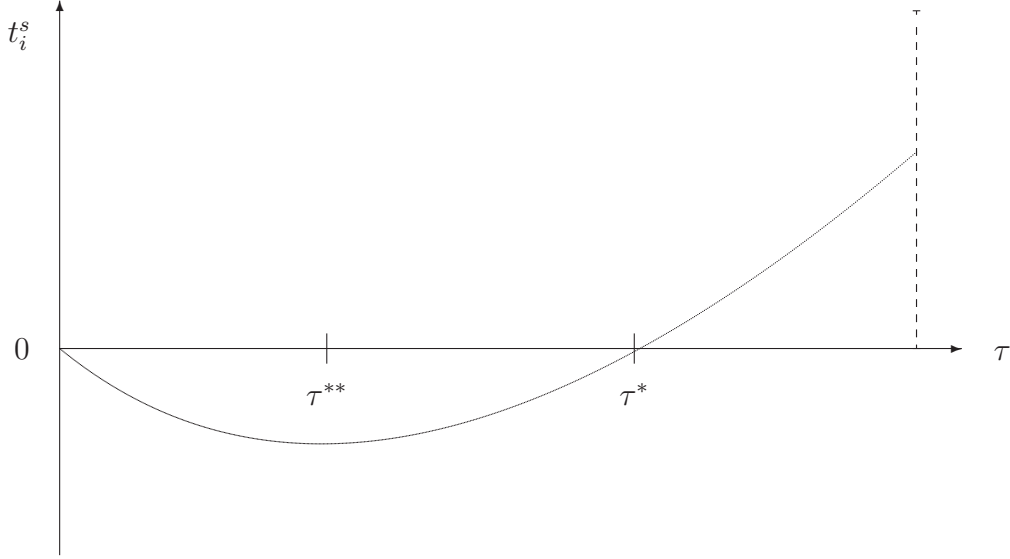
$$\tau^{**} = \frac{\alpha - w}{4(k+1) + 1} = \frac{\tau^*}{2}. \quad (20)$$

For $\tau > \tau^{**}$, the tax rate is rising in trade costs, whereas for $\tau < \tau^{**}$ it is falling in τ . Moreover, comparing (20) with (16) shows that $\tau^{**} < \tau^*$. The relationship between the level of trade costs and the equilibrium tax rates in the symmetric Nash equilibrium is then as shown in Figure 1.

The figure shows that, starting from high levels of trade costs ($\tau > \tau^*$), a fall in these costs (commonly interpreted as economic integration) will reduce the ability of symmetric countries to raise positive business taxes. Beyond τ^* taxes turn negative and continue to fall until they reach a minimum (i.e., a maximum subsidy) at τ^{**} . To explain this negative relationship for relatively high levels of trade costs, note both that the competition effect and the consumer price effect are weakened when trade costs are reduced. However, the ability of countries to extract location rents falls more quickly

¹⁸This effect underlies the different results in models where two countries compete for a single monopolist and pay subsidies in equilibrium, and those where they compete for two mobile firms and are able to levy positive taxes (see Ferrett and Wooton, 2005). Our analysis show that this effect holds more generally, and also applies to continuous increases in the number of firms.

Figure 1: Nash equilibrium tax rates in the symmetric equilibrium



as long as $\tau > \tau^{**}$. If trade costs fall still further ($\tau < \tau^{**}$), the relative strength of the competition and consumer price effects is reversed and tax rates rise again until they reach zero at $\tau = 0$. Our results are summarised in

Proposition 1 *Symmetric equilibrium tax rates are falling in market size and rising in the number of mobile firms. As economic integration proceeds (trade costs fall), equilibrium tax rates first fall and then rise again. There is a critical value of trade costs τ^* , where equilibrium taxes switch from positive to negative (i.e., to subsidies).*

3.2 Differences in country size

Having discussed the basic working of our model in the special case of symmetry, we now turn to the more general case where countries differ in size. Substituting m from (9) into (13) we obtain closed-form solutions for the asymmetric Nash equilibrium tax rates, which are derived in the appendix:

$$\begin{aligned}
 t_a^* &= \frac{k\tau}{\beta(k+1)} \left[\tau - \frac{n\mu}{2(k+1)} \right] + \frac{\tau\mu(2n-1)(3k+2)[2(k+1)-n]}{2\beta(k+1)^2[6(k+1)-1]}, \\
 t_b^* &= \frac{k\tau}{\beta(k+1)} \left[\tau - \frac{n\mu}{2(k+1)} \right] - \frac{\tau\mu(2n-1)[2(k+1)+n(3k+2)]}{2\beta(k+1)^2[6(k+1)-1]},
 \end{aligned} \tag{21}$$

where $\mu \equiv [2(\alpha - w) - \tau] > 0$.

The first term in (21) is identical for both countries. This term captures the counter-acting competition and consumer-price effects that have been discussed above.¹⁹ The second terms in (21) show how the overall bargaining position of countries *vis-à-vis* individual firms is modified by an additional *home-market effect*. Each firm will save aggregate trade costs and thereby make higher gross profits when it locates in the larger country. This allows the larger country *a* to impose a higher tax than in the symmetric equilibrium, whereas the smaller country *b* has to compensate firms for its location disadvantage by offering a lower tax (or a higher subsidy). The equilibrium tax differential is given by

$$\Delta^* \equiv t_a^* - t_b^* = \frac{3\tau(2n-1)[2(\alpha-w)-\tau]}{\beta[6(k+1)-1]} > 0. \quad (22)$$

This differential increases as the disparity in country size *n* becomes greater and as the size of the market α expands, but it falls as the total number of firms in the industry *k* increases.

The home-market effect is strengthened by high trade costs, as is seen from differentiating (22) with respect to τ :

$$\frac{\partial \Delta^*}{\partial \tau} = \frac{6(2n-1)(\alpha-w-\tau)}{\beta[6(k+1)-1]} > 0. \quad (23)$$

This derivative is unambiguously positive when international trade occurs [cf. (18)]. Economic integration, in the form of a decline in trade costs, unambiguously reduces the absolute tax differential between the large and the small country.

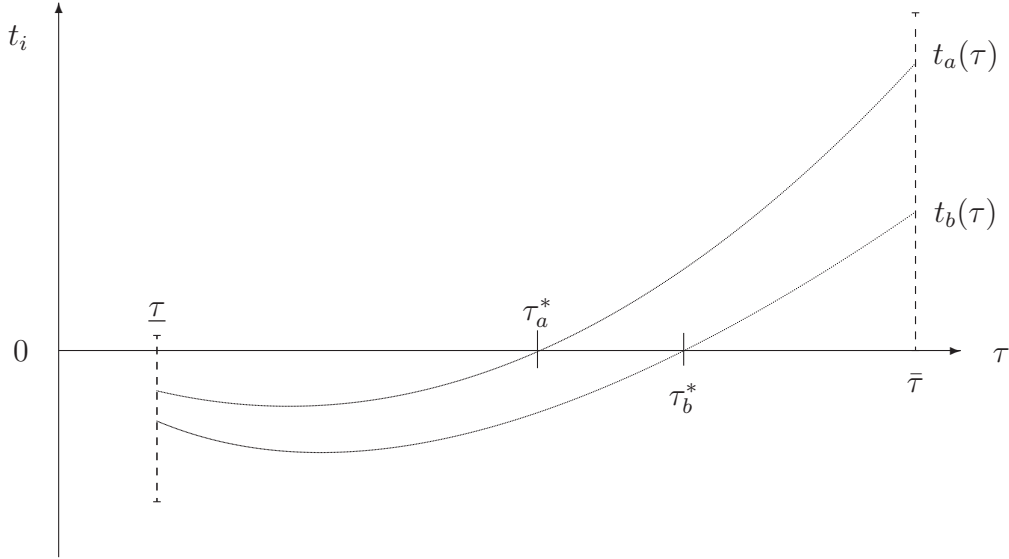
To look more closely at the effects of changes in trade costs, differentiating the tax levels in each country [eq. (21)] and re-substituting their values in the initial equilibrium yields:

$$\frac{\partial t_i^*}{\partial \tau} = \frac{2[(\alpha-w-\tau)t_i^* + (\alpha-w)]}{\tau[2(\alpha-w)-\tau]} \quad \forall i \in \{a, b\}. \quad (24)$$

Hence, for either of the two countries, a positive tax rate in the initial equilibrium is sufficient (but not necessary) to ensure that a fall in trade costs reduces the optimal tax rate. This result parallels that for symmetric countries. However, from (21), the critical level of trade costs at which the large country's tax rate turns positive is now reduced, relative to the symmetric case, whereas the critical level of trade costs at which the small country is able to levy positive taxes is increased.

¹⁹It is easily checked that the first terms in (21) reduce to eq. (15) for the symmetric case $n = 0.5$.

Figure 2: Nash equilibrium taxes in the asymmetric equilibrium



Next we turn to the equilibrium pattern of firm location. This is determined by substituting the optimal tax rates in (21) into equation (9). This yields

$$m = \frac{k}{2} + \frac{(2n-1)[2(\alpha-w)-\tau]}{2\tau} \frac{[3(k+1)-1]}{[6(k+1)-1]}. \quad (25)$$

Equation (25) implies that a threshold level of trade costs, denoted $\underline{\tau}$, must be exceeded in order to meet the restriction that the number of firms in the small country b is positive ($m < k$). This lower bound for τ in the presence of size asymmetries is given by

$$\underline{\tau} = \frac{2(\alpha-w)(2n-1)[3(k+1)-1]}{k[6(k+1)-1] + (2n-1)[3(k+1)-1]}.$$

The lower bound $\underline{\tau}$ is zero in the case of symmetric countries and it rises as the size differential between countries a and b increases. In other words, if low levels of trade costs (and thus a high degree of economic integration) are to be considered in our model, then the size asymmetries between the two countries must not be ‘too large’. The relationship between trade costs and equilibrium tax rates in each of the two countries is then as shown in Figure 2.²⁰

²⁰To simplify the graph, Figure 2 ignores the fact that the maximum levels of trade costs that are compatible with non-negative profits ($\bar{\tau}$) will generally differ for the two countries. The country-specific levels of $\bar{\tau}$ are computed by substituting (25) in (8) and setting the resulting gross profit levels equal to the lump-sum taxes (21).

We have already established that the number of firms that locates in the larger of the two countries (country a) is rising in the size difference n . However, the effects of trade costs on the equilibrium location of firms are ambiguous, in general, when the level of tax rates is exogenous [see (10)]. We can now evaluate the comparative static effect of a change in τ at the asymmetric tax equilibrium. Differentiating (25) with respect to τ yields

$$\frac{\partial m}{\partial \tau} = \frac{(2n-1)[3(k+1)-1]}{2\tau[6(k+1)-1]} \left\{ -1 - \frac{[2(\alpha-w)-\tau]}{\tau} \right\} < 0. \quad (26)$$

Hence, in equilibrium, a fall in trade costs will unambiguously increase the number of firms that locate in the larger country a. The additional effect incorporated in (26) is that country a lowers its taxes by more than country b as economic integration proceeds. Our results are summarised in

Proposition 2 *When countries differ only in size, the country with the larger home market imposes the higher tax rate. A fall in trade costs lowers the equilibrium tax differential and increases the concentration of firms in the larger country.*

4 Economic integration and national welfare

We now turn to the welfare effects of economic integration and start again with our benchmark case of identical countries ($n = 0.5$). Substituting (11) and (15) in (12) and setting $m = k/2$ yields the maximized welfare for each country

$$W^s = \frac{k^2}{16\beta(k+1)^2} \{ [2(\alpha-w)-\tau]^2 + 2\tau^2[4(k+1)+1] - 4\tau(\alpha-w) \}. \quad (27)$$

Differentiating with respect to τ yields

$$\frac{\partial W^s}{\partial \tau} = \frac{k^2}{16\beta(k+1)^2} \{ [8(k+1)+3]\tau - 4(\alpha-w) \}. \quad (28)$$

For high levels of trade costs, economic integration (a fall in τ) is welfare-reducing for both countries while for low trade costs, a further reduction is instead welfare-increasing. The critical value of trade costs, where welfare reaches a minimum is obtained by setting $\partial W^s / \partial \tau$ in (28) equal to zero. This gives

$$\tilde{\tau} = \frac{4(\alpha-w)}{[8(k+1)+3]}. \quad (29)$$

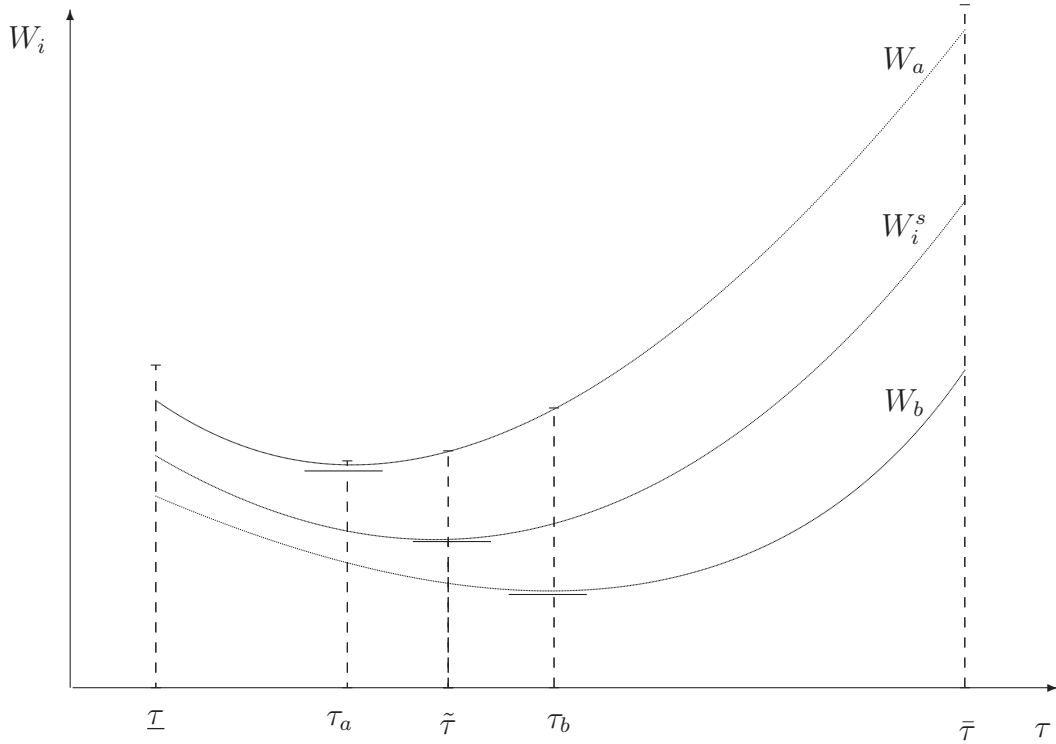
This U -shaped relationship between national welfare and trade costs closely mirrors the relationship between equilibrium tax rates and trade costs. At high levels of trade costs, a reduction in these costs weakens the *competition effect*, reducing the tax power of governments in the symmetric equilibrium, and lowering both tax revenue and welfare. At low levels of τ , a further fall in trade costs reduces the gains for each country from granting location subsidies to firms. This alleviates subsidy competition and increases each country's welfare. Comparing the critical level $\tilde{\tau}$ to the level of trade costs that induces the minimum tax τ^{**} [see eq. (20)], shows that $\tilde{\tau} > \tau^{**}$. Thus, as trade costs fall below $\tilde{\tau}$, tax rates continue to decline initially while welfare starts to climb again. The increase in welfare is explained by the fact that the falling tax revenues (alternatively, the increasing subsidy payments) are more than compensated by the rise in consumer surplus associated with the reduction in trade costs.

Moving beyond the benchmark case, to analyse the effects on national welfare when countries differ in size, we substitute (11), (9) and (21) in (12). Equilibrium taxes are substantial in both countries when trade costs are high and a reduction in τ will cause taxes and welfare to fall in both countries. However the welfare-minimizing levels of τ will differ for the two countries. Given that welfare in each country is a non-monotonic function of trade costs, there is the possibility that economic integration will have the opposite welfare effect in each country over a certain range of τ . In particular, this is the case when the trade cost is equal to $\tilde{\tau}$, as defined in (29). It is shown in the appendix that the following holds at this level of trade costs:

$$\left. \frac{\partial W_a}{\partial \tau} \right|_{\tilde{\tau}} > 0, \quad \left. \frac{\partial W_b}{\partial \tau} \right|_{\tilde{\tau}} < 0. \quad (30)$$

Hence, at $\tilde{\tau}$ (and, from continuity, in the neighbourhood of this value), economic integration lowers welfare in the large country a , but raises welfare in the small country b . This result is explained from the fact that both the *competition effect* and the *consumer-price effect* are weaker for the small country. The smaller country is the less attractive location from the perspective of firms, but it also has fewer consumers and therefore fewer incentives to grant location subsidies. For this reason, the smaller country's welfare level W_b reaches its minimum at a higher level of trade costs as compared to W_a . Figure 3 illustrates these results. In the graph, economic integration has opposing welfare effects on the two countries if trade costs are in the range $\tau_a < \tau < \tau_b$,

Figure 3: Welfare effects of economic integration



where τ_i is the turning point of W_i with respect to τ . This result is summarised in the following proposition.

Proposition 3 *There is a range of trade costs for which economic integration (a fall in τ) reduces welfare in the larger country but increases welfare in the smaller country.*

Proof: See the appendix.

Finally, we illustrate the results of our basic model by means of a simulation analysis. The results are summarised in Table 1. The table shows that country b 's tax rate turns negative at a higher level of trade costs (more precisely, at $\tau_b^* \approx 0.27$) than that of country a (which turns negative at $\tau_a^* \approx 0.17$). Moreover, for $0.25 > \tau > 0.17$, a fall in trade costs lowers welfare in country a , but raises welfare in country b . For the example given, the upper limit of trade costs that still ensures non-negative after-tax profits is $\bar{\tau} \approx 0.68$. For this level of trade costs, the tax rates *in percent of gross profits*, given in the last two columns of the table, approach unity for both the large and the small country. On the other hand, the lower limit for τ that ensures a non-negative number of firms in the smaller country is $\underline{\tau} \approx 0.10$.

Table 1: Simulation results for the basic model

τ	t_a	t_b	W_a	W_b	m	π^a	π^b	t_a/π_a	t_b/π_b
0.680	0.318	0.260	12.162	11.608	5.675	0.319	0.261	0.998	0.998
0.550	0.191	0.143	11.237	10.534	5.846	0.279	0.231	0.687	0.622
0.450	0.115	0.075	10.766	9.982	6.045	0.253	0.214	0.454	0.352
0.350	0.057	0.026	10.415	9.667	6.357	0.233	0.202	0.245	0.128
0.250	0.018	-0.005	10.218	9.590	6.920	0.217	0.195	0.081	-0.025
0.200	0.005	-0.013	10.178	9.641	7.412	0.212	0.193	0.023	-0.069
0.150	-0.003	-0.017	10.176	9.752	8.233	0.207	0.193	-0.016	-0.088
0.100	-0.007	-0.016	10.213	9.922	9.874	0.204	0.194	-0.034	-0.082

numerical specification: $k=10$, $\alpha - w=5$, $n=0.6$, $\beta=1$

5 Domestic profit income and distortionary taxes

We now consider two extensions to the model. First, we change the ownership structure of firms by letting all (after-tax) profit income accrue to the residents of the host countries. Additionally, we force governments to use distortionary taxes in order to finance subsidies to firms. As both of these extensions increase the complexity of the algebra, we restrict the analysis to our benchmark case of symmetric countries.

In this setting, the residents of each country own $k/2$ firms and receive the resulting profit income after taxes. Since after-tax profits are equalized by mobile firms, it does not matter whether firms are located in country a or country b . Total after-tax profit income in country i is

$$\Pi_i = \frac{k}{2} (\pi_a - t_a) = \frac{k}{2} (\pi_b - t_b), \quad (31)$$

where π_a and π_b are given in (8). These profit incomes expand the individual budget constraints in (2) but, due to the quasi-linear specification of utility, do not change the individual and market demands for good x [eqs. (3)–(4)].

We weight tax revenue in each country by an exogenous factor $\lambda \geq 1$. This captures the fact that governments typically do not have access to lump-sum taxes in order to pay subsidies to firms, but must resort to distortionary taxes on personal income or commodity purchases. Hence $(\lambda - 1)$ represents the excess burden of this alternative

tax instrument. In the opposite case where equilibrium taxes on firms are positive, distortionary taxes can be reduced and the value of one unit of profit-tax revenue is once again given by λ .²¹

With these specifications, national welfare in countries a and b is given by

$$W_a = S_a + \Pi_a + \lambda t_a m, \quad W_b = S_b + \Pi_b + \lambda t_b (k - m).$$

Substituting from (9), (11) and (31) and evaluating all terms at $n = 0.5$ gives the following equilibrium tax rates, which are derived in the appendix:

$$\tilde{t}_a = \tilde{t}_b = \frac{k\tau}{(k+1)\beta\lambda} \left[\tau \left(\lambda - \frac{1}{2} \right) - \frac{2(\alpha - w) - \tau}{4(k+1)} \right]. \quad (32)$$

The structure of the tax rate expression in equation (32) is very similar to that in the benchmark analysis [eq.(15)]. The two main differences reflecting the changes in assumptions are both incorporated in the first term in the square bracket (the competition effect). On the one hand, the benefits from taxing profit income are now reduced because, in the symmetric equilibrium, one half of the incidence of the tax falls on domestic capital owners. On the other hand, the gains from taxation are increased, because each unit of tax revenue now receives a value above one in the national welfare function. If the excess burden is sufficiently high ($\lambda > 1.5$) the latter effect dominates and the critical value of τ^* in Figure 1 moves to the left. In the reverse case where $\tau < 1.5$, positive tax rates will now be levied only for a smaller range of high trade costs. In any event, the positive competition effect will still be present in this extended model, because each country's profit tax will partly fall on foreign capital owners.

6 Discussion

We start the discussion in this section by comparing our results with those from previous work that has considered tax competition for a small number of mobile firms. Note that the use of calculus in the present paper carries the implicit assumption that the number of firms changes continuously in response to tax changes. This is clearly inappropriate when the number of firms is small and the relocation of a single firm involves

²¹See e.g. Keen and Lahiri (1998) for a similar procedure.

a discrete change in the location equilibrium. This is most obvious with a monopoly ($k = 1$). In that case, the equilibrium tax formula in eq. (15) exhibits a competition effect, as the analysis implicitly assumes that this firm is divisible. However, in the ‘true’ model a single, indivisible firm will not face any competition if it relocates to the other country. Hence in models of competition for a monopoly firm the competition effect is zero. This explains why models of tax competition for a monopolist typically feature negative tax rates in equilibrium (see e.g. Haaparanta, 1996; Fumagalli, 2003; Davies, 2005).

The competition effect first arises with two firms; either when there is a pre-existing firm in one of the two countries (Bjorvatn and Eckel, 2006) or when the countries compete for two mobile firms (Ferrett and Wooton, 2005). These results are generalised in our setting where the equilibrium tax rate is a rising function of the number of mobile firms k [see eq. (19) and Proposition 1]. Moreover, as in Ferrett and Wooton (2005), it is possible in our analysis that all gross profits can be extracted by the host countries, even if they set tax rates non-cooperatively. This is the case whenever the constraint (17) is binding, which will be more likely the larger the number of mobile firms.

In contrast to the literature that considers tax competition in models of monopoly or duopoly, our analysis derives equilibrium tax rates as a continuous function of exogenous model parameters. This allows us to also compare our results to those found in the new economic geography literature. These models generally distinguish between two qualitatively different regimes. If all firms are concentrated in one country, they earn agglomeration rents that can be fully taxed away by the country that hosts this core (Baldwin and Krugman, 2004). If, instead, firms are regionally dispersed in the locational equilibrium, then equilibrium tax rates in both countries will be negative (Ottaviano and van Ypersele, 2005).²² In the present model, in contrast, location rents can arise and tax rates can be positive, even if the equilibrium features a completely symmetric distribution of firms. The core difference is that the number of firms is exogenously fixed in our analysis, and firms make positive profits in equilibrium. In contrast the new economic geography models assume endogenous market entry, which

²²See their Proposition 3. Note that there is an error in part (i) of this proposition, as equilibrium tax rates will also be negative in the fully symmetric case. We thank Tanguy van Ypersele for clarifying discussions on this issue.

drives each firm's profit to zero. In that case, no taxable location rent can arise in either country, and the competition effect accordingly disappears.²³

The competition effect is also crucial in explaining contrasting conclusions with respect to the effects of economic integration. In the agglomeration case of Baldwin and Krugman (2004), the taxable agglomeration rent earned by firms in the core country is concave (bell-shaped) in the level of trade costs. This implies that economic integration may lead to rising tax rates in the core countries before tax rates eventually fall. In contrast, tax rates are a convex function of trade costs in the present model and economic integration leads to falling tax rates throughout the range where the taxes are positive. The difference is most obvious at the maximum level of trade costs. In the economic geography setting, this upper bound represents a no-trade condition where no location rents arise and equilibrium tax rates are zero. Hence agglomeration rents and positive tax rates can only arise for trade costs below this critical threshold. In the present model, in contrast, the upper bound on trade costs represents a non-negativity condition for net profits [eq. (17)]. Hence tax rates are at a maximum at this level of trade costs.

Finally, we compare the results of our model with the empirical evidence on the development of statutory and effective average tax rates, as given in Table A.1 in the appendix.²⁴ By both measures corporate taxation has declined since 1985, and in both large and small countries. This is consistent with the results of our model in the earlier phases of economic integration. It contradicts, however, the theoretical prediction that the economic geography models of tax competition derive for the (large) 'core' countries. Moreover, at each point in time, the average tax rate levied by large countries is higher than that of small countries, as stated in our Proposition 2. A closer look at the time pattern of tax adjustments shows that in 1985, at the onset of economic integration, tax rates were at a 'maximum' level that was similar for large and small

²³Effectively profits are turned into capital income in the new economic geography models. These capital incomes, however, are not affected by the lump-sum tax on firms.

²⁴The effective average tax rate (EATR) is computed as a weighted average of the statutory tax rate and the effective marginal tax rate (EMTR). In contrast to the EMTR, which measures the tax burden on a marginal investment project that just earns a competitive rate of return, the EATR also includes the taxation of pure economic profit. This makes it the most relevant measure for analysing the discrete location choices of profit-making firms. See Devereux et al. (2002) for more details.

countries. In the early phases of economic integration, tax rates fell more in the small countries, leading to a substantial tax gap between large and small countries by 1995. As economic integration continued, the large countries also cut their tax rates and the tax gap between large and small countries narrowed during the period 1995-2005 (but remained positive). To relate these developments to the results of our model it is necessary to transform the lump-sum tax rate on each firm, which we have used for tractability reasons in our theoretical analysis, into ad valorem profit tax rates. The latter are given, for a specific numerical example, in the last two columns of Table 1. It is seen there that the initial widening and later narrowing of the tax gap between large and small countries is indeed compatible with the results of our model.

7 Conclusion

In this paper we have set up a simple model where two countries of different size compete for the location of an exogenous, but variable, number of profit-making firms in an oligopolistic industry. In this setting the relocation of firms affects the degree of competition and hence the gross profits earned by a firm located in one market or the other. These profit differentials give rise to location rents that exist even in a symmetric equilibrium where firms are fully dispersed. At the same time national governments in our model have the incentive to attract internationally mobile firms in order to save on trade costs. Whether taxes are positive or negative in the location equilibrium depends on the interplay of these two counteracting forces.

In this model economic integration leads to a U -shaped relationship between the degree of economic integration and the level of equilibrium tax rates. This pattern of tax adjustments in response to economic integration is just the opposite of the hump-shaped relationship that the economic geography literature predicts for the core countries, and in our view it is more compatible with the empirical evidence to date. A second result, which distinguishes our model from most of the existing work in the field, is that positive tax rates are turned into location subsidies as economic integration proceeds. Clearly, this prediction cannot be correct if we look at corporate tax rates in isolation. However, the combination of falling statutory and effective corporate taxes, the proliferation of preferential tax regimes for internationally mobile firms and the increasingly

widespread use of investment subsidies may in sum lead to net effective tax payments of mobile firms that are close to zero or even negative. Moreover, most observers seem to expect that this trend will continue as global economic integration proceeds further, despite some attempts at policy coordination among the EU and OECD member states. Finally, one implication of our model is that economic integration can simultaneously benefit small countries and harm large countries. This may explain a line of division that has been visible in several recent policy debates (including, for example, the EU's interest withholding tax directive): the conflicting interests between large countries, which favour coordination measures to cushion the effects of economic integration, and the small countries that don't.

Appendix

Table A.1: Corporate taxation in OECD countries

	statutory tax rate ^a			effective aver- age tax rate ^b		
	1985	1995	2005	1985	1995	2005
large countries (> 20 million)						
Australia	50	36	30	37	31	26
Canada	45	36	36	28	28	28
France	50	37	34	34	27	25
Germany	63	57	38	45	41	32
Italy	46	52	37	31	36	26
Japan	56	50	40	45	40	32
Spain	35	35	35	27	24	26
Un. Kingdom	40	33	30	28	26	24
United States	50	39	39	32	29	29
\emptyset large countries ^c	48.3	41.7	35.4	34.1	31.3	27.6
small countries (< 20 million)						
Austria	61	34	25	37	24	22
Belgium	45	40	34	35	31	26
Finland	60	25	26	45	19	21
Greece	44	40	32	36	33	21
Ireland	10	10	13	5	8	11
Netherlands	43	35	32	34	28	25
Norway	51	28	28	36	24	24
Portugal	55	40	28	48	29	20
Sweden	60	28	28	45	21	21
Switzerland	35	35	34	26	26	25
\emptyset small countries ^c	46.4	31.5	28.0	34.7	24.3	21.6
\emptyset all countries ^c	47.3	36.3	31.5	34.4	27.6	24.4

^a including local taxes

^b base case: real discount rate: 10%, inflation rate: 3.5%, depreciation rate: 12.25%, rate of economic rent: 10% (financial return: 20%)

^c unweighted average

Source: Devereux *et al.* (2002), updated; www.ifs.org.uk/publications.php?publications_id=3210.

**Table A.2: Approved investment subsidies in EU member states
(2001-2004)**

company (sector ^a)	date of approval	host country (city/region)	state aid (million € ^b)	aid intensity (%) ^c
Nissan	01/2001	U.K. (Sutherland)	60	18.6
Volkswagen	07/2001	Germany (Dresden)	75	12.3
Daimler Chrysler	12/2001	Germany (Thuringia)	57	30.9
Infineon (semiconductors)	04/2002	Germany (Saxony)	219	19.8
ST Microelectronics	04/2002	Italy (Sicily)	542	26.3
Renault	06/2002	Spain (Valladolid)	18	14.3
Vauxhall	09/2002	U.K. (Ellesmere Port)	15	6.4
Iveco (utility vehicles)	10/2002	Italy (Puglia)	109	44.0
BMW	12/2002	Germany (Leipzig)	363	30.1
Solar World (solar cells)	03/2003	Germany (Saxony)	73	35.0
BMW	05/2003	Austria (Steyr)	16	15.3
Volkswagen	06/2003	Spain (Navarra)	20	6.4
AMD (microelectronics)	02/2004	Germany (Saxony)	545 ^d	22.7 ^d
DHL Airways (logistics)	04/2004	Germany (Leipzig)	70	28.0
Peugeot Citroen	09/2004	U.K. (Ryton)	30	9.8

^a automobiles, unless otherwise stated

^b 1 British Pound is converted to 1.5 €

^c present value of state aid divided by present value of investment

^d upper limit

Source: Official Journal of the European Communities, C and L (<http://eur-lex.europa.eu>)

Derivation of equation set (21)

Substituting m from (9) into (13) and rearranging gives each country's best response function

$$\begin{aligned} t_a &= \frac{2\tau^2 k}{\beta [4(k+1) - n]} + \frac{\tau\mu\{(2n-1)[2(k+1) - n] - nk\}}{\beta(k+1)[4(k+1) - n]} + t_b \frac{[2(k+1) - n]}{[4(k+1) - n]}, \\ t_b &= \frac{2\tau^2 k}{\beta [4(k+1) - u]} - \frac{\tau\mu\{(2n-1)[2(k+1) - u] + uk\}}{\beta(k+1)[4(k+1) - u]} + t_a \frac{[2(k+1) - u]}{[4(k+1) - u]} \end{aligned} \quad (\text{A.1})$$

where $\mu \equiv [2(\alpha - w) - \tau] > 0$ and $u \equiv (1 - n)$. Solving the set of simultaneous equations (A.1) yields the reduced-form expressions for the Nash equilibrium taxes in the asymmetric equilibrium, given in (21).

Proof of Proposition 3

Substituting (21) and (25) in country a 's welfare function [eq. (12)] and differentiating with respect to τ gives

$$\frac{\partial W_a}{\partial \tau} = \frac{\partial S_a}{\partial \tau} + t_a \frac{\partial m}{\partial \tau} + m \frac{\partial t_a}{\partial \tau}.$$

Performing the derivations gives, in a first step

$$\begin{aligned} \frac{\partial W_a}{\partial \tau} &= \frac{\tau[2mk(k+1) + nk^2 - nm(k-m)] - nk^2(\alpha - w)}{\beta(k+1)^2} \\ &\quad - \frac{t_a(2n-1)(3k+2)(\alpha - w)}{\tau^2(6k+5)} + \frac{(2n-1)(3k+2)[2k+2-n]m(\alpha - w - \tau)}{\beta(k+1)^2(6k+5)}. \end{aligned} \quad (\text{A.2})$$

It is easily checked that this expression collapses to (28) when countries are symmetric ($n = 0.5$ and hence $m = k/2$).

Evaluating (A.2) at $\tilde{\tau}$, as given in (29), yields

$$\begin{aligned} \frac{\partial W_a}{\partial \tau} \Big|_{\tilde{\tau}} &= \frac{(\alpha - w)(2n-1)\Omega}{\beta(k+1)^2(6k+5)} \\ \Omega &\equiv \frac{2k(k+1)(12k^2 + 33k + 18)}{8k+11} + \frac{k(3k+2)[n + (k+1)(4n-1)]}{2} + \frac{(2n-1)(8k+9)^2}{4(8k+11)(6k+5)} \\ &\quad + \frac{(3k+2)[2(k+1) - n][k(48k^2 + 82k + 35) - (2n-1)(48k^2 + 86k + 36)]}{2(6k+5)(8k+11)}. \end{aligned}$$

Since $\Omega > 0$ for all $k > 1$ and $n > 0.5$ by assumption, it follows that $\partial W_a / \partial \tau|_{\tilde{\tau}} > 0$.

For country b we proceed analogously. Using (21) and (25) in W_b [eq. (12)] and differentiating with respect to τ gives

$$\frac{\partial W_b}{\partial \tau} = \frac{\partial S_b}{\partial \tau} - t_b \frac{\partial m}{\partial \tau} + (k - m) \frac{\partial t_b}{\partial \tau}.$$

Performing the derivations yields

$$\begin{aligned} \frac{\partial W_b}{\partial \tau} = & \frac{\tau[(k - m)k(2k + 2 + n) + m^2(1 - n)] - k(\alpha - w)[(1 - n)m + n(k - m)]}{\beta(k + 1)^2} \\ & + \frac{t_b(2n - 1)(3k + 2)(\alpha - w)}{\tau^2(6k + 5)} - \frac{(2n - 1)(k - m)(\alpha - w - \tau)[2(k + 1) + n(3k + 2)]}{\beta(k + 1)^2(6k + 5)}, \end{aligned} \quad (\text{A.3})$$

which again collapses to (28) when $n = 0.5$.

(...)

Derivation of equation set (32)

We start from the following expressions for national welfare

$$W_a = S_a + \Pi_a + \lambda t_a m, \quad W_b = S_b + \Pi_b + \lambda t_b (k - m).$$

Substituting in from (9), (11) and (31) and evaluating all terms at $n = 0.5$ gives for country i 's best response function ($i, j \in \{a, b\}$, $i \neq j$)

$$\frac{t_i \beta}{8\tau^2} [8\lambda(k + 1) - (2k + 1)] = \frac{k}{2} \left[\lambda - \frac{1}{2} - \frac{[2(\alpha - w) - \tau]}{4\tau(k + 1)} \right] + \frac{t_j \beta}{8\tau^2} [4\lambda(k + 1) - (2k + 1)]$$

Combining the two best responses and manipulating terms yields the Nash equilibrium tax rates given in (32).

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