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FDI, Trade Costs and Regional Asymmetries

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FDI, Trade Costs and Regional Asymmetries

Abstract

We set up a trade model where three countries compete for an exogenous number of firms. Our innovation lies in the geography of the model. Of the three countries, one is the hub through which all trade takes place. First, we establish the *natural geography* of the region, which is given by the equilibrium distribution of industrial activity in the absence of taxes or subsidies. We then examine the implications for corporate taxes when the countries compete with each other to attract firms. We find that, even when all countries are the same *size*, the *centrality* of the hub gives it an advantage in tax setting, such that its equilibrium tax can be larger than that of the spokes and yet it still attracts a disproportionate share of industry. Thus geographic advantage in tax competition has a second dimension, centrality in addition to size.

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1. Introduction

This paper examines international tax competition to attract foreign direct investment (FDI) in a regional model with trade costs between countries. Our innovation lies in the geography of the region. If there are only two countries in a region, international trade would take place across the common frontier of the countries.¹ If there are three countries or more, past work (e.g., Haufler and Wooton, 2006) has assumed that each country pair shares a frontier and trade between the nations takes place across this line. But this excludes the possibility that, in regions composed of three or more nations, the most direct or cheapest route for goods traded between two nations might be through the territory of a third. Thus a 3-country region may be composed of one *hub* country and two *spoke* nations, where each spoke accesses the market of the other spoke by shipping its products through the hub. Clearly, this implies an asymmetry in international transport costs, favouring the centrally placed hub.² We wish to investigate how the adoption of this *hub-and-spoke* geography affects the established results for the outcome of tax competition for FDI.

This research was suggested by the debate regarding increased autonomy for regional administrations in the United Kingdom. There are strong political pressures to devolve corporate tax-setting powers to the constituent regions of the UK and, given the geography of the country, this raises questions as to how such fiscal independence might affect the level and geographic distribution of economic activity and impact on the welfare of the citizens of the regions.³ Thus the “hub and spoke” geographic structure we have adopted is an attempt to

¹ Of course, the countries may be islands in which case a body of water separates them but there is still a common frontier to be crossed at some cost.

² Previous work on tax competition with three countries assumed a “triangular” geography, where the countries were the corners of a triangle and each country traded directly with the other two. Our innovation is the hub-and-spoke geography: implicitly, we are assuming that the direct trade cost between the two spokes exceeds the cost of shipping through the hub.

³ The Scottish Government argues “that a unified UK rate of corporate tax is neither desirable nor economically efficient. (...) Given the competitive advantages of London relative to other parts of the UK (such as London’s position as one of the largest financial centres in the world, and its transport links with major cities worldwide etc.) there is clear evidence that London (and indeed the South East of England) already has an in-built competitive

reflect the economic and spatial relationships within the UK and between it and the wider European market. However, despite the genesis of our modelling endeavour, the analysis is readily applicable to any situations where trade costs between countries are not symmetric. For example, North America is an obvious case of hub-and-spoke geography. The USA is the hub nation that both trades with each of two spokes of Canada and Mexico and is also the conduit for trade between the spokes.

At the centre of our analysis are the attempts by governments to attract inward FDI. FDI results in increased local production and employment and we assume that this local production of the good yields higher social benefits than imports. This reflects what seems to be a widely-held government view. There are many possible reasons why, independently of capital income and tax/subsidy payments, host countries may favour local production. In the analysis in this paper, trade between any two countries is costly. As a result, the market price is lower (and consumer surplus higher) when goods are locally produced as compared to being imported from another country in the region. Benevolent governments will recognise this and seek to attract FDI.⁴

Our starting point is the two-country model of Haufler and Wooton (2010) in which two nations compete to attract firms from an oligopolistic industry. In models of this type, the existence of international trade costs confers an advantage on the larger country in the competition for firms, as a large country offers a big domestic market that can be served without trade costs. Thus size matters. We increase the number of countries to three and allow for different configurations of the population across the region.

advantage over not only Scotland but also other parts of the UK. Scotland needs the lever of corporate tax to consider a wider array of options than is currently the case to help address this imbalance.” Scottish Government (2011), p34.

⁴ Beyond this motivation, there may be labour market benefits from inward FDI. MNEs may offer wage premia above workers’ outside options, a polar case of which occurs when inward FDI relieves involuntary unemployment (Haaparanta, 1996 and Bjorvatn and Eckel, 2006). Alternatively, inward FDI may be associated with localised technological spillovers to indigenous firms (Fumagalli, 2003 and Olsen and Osmundsen, 2003).

What further distinguishes the current analysis is our assumption that one of the three countries occupies a central point geographically, such that all traded goods must pass across its frontiers at least once. This hub country can trade directly with each of the other two nations but, in contrast, firms located in either spoke country can only access the consumers of the other peripheral spoke country by shipping their goods through the core.⁵ As shipping goods across national frontiers is assumed to be costly, firms located in the spokes are at a disadvantage in serving their markets, as compared to those firms located in the hub. Consequently, we are adding *centrality*, in addition to *size*, as a determinant of national *geographic advantage* in the region.

There are alternative interpretations or applications of the model that might shine some light on current policy questions. One is that the model represents a single country whose geography means that trade between some provinces is more expensive than others. Thus it could represent industrial activity in a country such as the UK, where trade between Scotland and Wales must take place through much-larger England. The model could then be used to analyse the potential for the two relatively disadvantaged provinces to use devolved corporate tax-setting powers to offset their geographic disadvantages. Another modelling possibility would be to consider a two-country setting where one of the countries has two centres of economic activity that are physically distant from one another. This might characterise trade within the UK (between Scotland and England) and with the European market. The implication of this is that movement of goods between nodes within this “bicentric” country will also be costly and the location of firms within a country, as well as their number, will play a role. If one of this country’s nodes (England) is closer to the foreign market, this will be the hub through which all exports and imports pass. The other node (Scotland) is therefore

⁵ Haufler and Wooton (2006) have a 3-country, single-firm model of tax competition in a regional setting where the focus is on the implications of tax harmonisation between two of the nations. In our companion paper, Darby, Ferrett and Wooton (2012), we examine the outcome of tax competition between m heterogeneous countries but without a hub-and-spoke trading pattern.

geographically disadvantaged, both by its smaller size and peripheral location, in its chances of attracting the FDI of firms aiming to service consumers across the entire region. This has the potential to create a tension between citizens resident in one node relative to those in the other and may lead to calls for different rates of corporate taxation of firms in order to offset the locational disadvantages of one centre relative to the other.⁶

Our analysis develops as follows. In section 2 we present the basic hub-and-spoke model and examine the geographic distribution of firms in the absence of any corporate tax competition. We then consider the incentives facing a single country to use a lower tax (or subsidy) to attract additional firms in section 3. Section 4 extends the analysis to consider the non-cooperative tax equilibrium in the region where symmetry is imposed on the model, in that both spokes are assumed to be of the same size and have the same trade costs with the hub. Section 5 concludes.

2. The model

We consider an economic region whose countries compete to attract a fixed number of firms. These firms produce a homogeneous good, labelled x , in an oligopolistic industry. A second good, the numeraire commodity z , is produced under conditions of perfect competition. The numeraire industry, which uses labour as the only input, is freely traded resulting in the international equalisation of the wage in that industry as w . Trade costs play an important role in the model. It is assumed that z is freely traded while x is subject to trade costs.

The region is composed of 3 countries, a hub country H , and two spoke countries A and B . The internationally immobile population is divided into households, each of which supplies labour effort and consumes both of the goods produced in the region. Every household in the

⁶ It is clear that many of Scotland's key exports do pass through England to access European markets. For example, Scottish Government (2009) reports that oil exports "are piped to England (or via England to Continental Europe)" (p46) while "much of the whisky destined for European consumption is transported by road to cross the Channel at Dover" (p52), and in the case of fish "significant road freight movement (...) is to the south of England before being transported to mainland Europe for distribution around the World"(p55).

region supplies a single unit of labour. The countries may differ in size where there are n_H households in the hub and n_A and n_B households in spoke country A and B , respectively. The population of the region is normalised to unity and so $n_H + n_A + n_B = 1$.

The cost of shipping a unit of good x between H and A is σ while the cost between H and B is τ . As there is no direct trade route between the two spokes, all shipments of good x between these two countries must pass through the hub and, consequently, face a higher cost for transshipment of $(\sigma + \tau)$.⁷ This regional trading situation is illustrated in Figure 1.

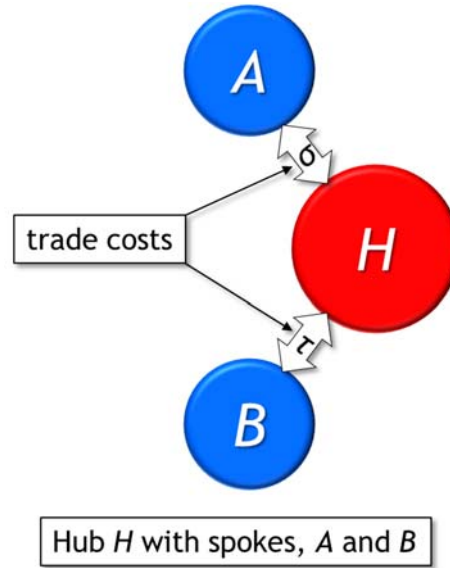


Figure 1. Geography of the region

2.1 Consumers

Consumers in all countries are assumed to have identical preferences for the goods, given by

$$u_i = \alpha x_i - \frac{\beta}{2} x_i^2 + z_i, \quad (1)$$

where $i \in \{A, B, H\}$. The residents of the countries earn only wage income, while profit income accrues to capital owners who reside outside of the region. Moreover, corporate tax revenue,

⁷ To keep the analysis relatively simple, we have assumed that there are no economies from long-distance shipping and that the cost of trade between the two spokes is the sum of the costs of each hub-to-spoke trade.

denoted by T_i , is redistributed as income in a lump-sum fashion equally to the households in the respective country. The budget constraint for a representative consumer in country i is then

$$w + \frac{T_i}{n_i} = z_i + p_i x_i, \quad (2)$$

where p_i is the price of good x in country i . Utility maximisation leads to inverse-demand curves $\alpha - \beta x_i$. Aggregating the demand for good x over all consumers yields market demand curves, denoted X_i :

$$X_i = \frac{n_i(\alpha - p_i)}{\beta}. \quad (3)$$

2.2 *The oligopolistic industry*

There are k firms in the x industry, all of which are based outside the region.⁸ Each of these firms possesses one unit of “knowledge capital” (such as a license or patent) that can be profitably employed in the imperfectly competitive industry x . This factor is indispensable for the production of good x but is limited in availability such that, at most, k firms can engage in production. In addition, each firm faces fixed and identical costs of setting up a production facility in any country. These costs are assumed to be sufficiently large to ensure that each firm will set up, at most, one production plant in the region. Thus each firm will serve the regional market from a single country in the region. Firms are assumed to be identical except with respect to the location of their production facilities. Where it locates matters to a firm both because of the size of its domestic market and the trade costs associated with its exports to consumers in foreign markets.

Labour is the only variable input in good x production. Each unit of good x requires the efforts of γ workers, where γ is chosen so that production of x does not exhaust each country’s

⁸ Examination of the impact of having some indigenous firms in the industry is left to future research.

labour supply. Given this, the marginal cost of production can be defined as $\omega \equiv \gamma w$.⁹ The cost of exporting each unit of output, as detailed above, raises the marginal cost of serving a firm's foreign markets relative to supplying domestic consumers. We are assuming that all of the trade costs are "real", taking the form of, say, transport costs or administrative barriers to the free movement of goods between countries; and also that all of the trade costs are non-prohibitive, so that every firm serves every product market. There are no (endogenously determined) tariffs between the countries, as we assume that the region is a free-trade-area.

Firms are assumed to behave as Cournot competitors and are able to segment their markets, choosing the quantities to sell on each market independently.¹⁰ The total operating profit of a firm based in each production location is therefore

$$\begin{aligned}\pi_A &= (p_A - \omega)x_{AA} + [p_H - (\omega + \sigma)]x_{HA} + [p_B - (\omega + \sigma + \tau)]x_{BA}, \\ \pi_H &= [p_A - (\omega + \sigma)]x_{AH} + (p_H - \omega)x_{HH} + [p_B - (\omega + \tau)]x_{BH}, \\ \pi_B &= [p_A - (\omega + \sigma + \tau)]x_{AB} + [p_H - (\omega + \tau)]x_{HB} + (p_B - \omega)x_{BB},\end{aligned}\tag{4}$$

where π_i is the pre-tax profit of a firm based in country i and x_{ji} represents sales in country j by a firm based in country $i, j \in \{A, B, H\}$. A firm is at a cost disadvantage in an export market as the marginal cost of exports is higher than that for domestic sales. Consequently we anticipate that an exporter will sell less in a market than its indigenous rival.

Suppose that of the k firms selling in country i , k_i firms are "local" in that they have their production facilities in the country, while the remaining $(k - k_i)$ firms serve the market from other countries within the region. Maximising (4), taking into account demand (3), and solving yields the total sales and price of good x in each location:

⁹ Since the wage w is equalised across the countries, it does not enter the location decision of firms in our model. Thus the firms' choice of location is not driven by labour costs.

¹⁰In equilibrium, firms will receive a lower producer price for their exports than for goods destined for the domestic market. The trade structure is simply a generalisation of the "reciprocal dumping" model of Brander and Krugman (1983).

$$\begin{aligned}
X_A &= n_A \frac{(\alpha - \omega)k - [\sigma k_H + (\sigma + \tau)k_B]}{\beta(k+1)}, & p_A &= \frac{\alpha + \omega k + [\sigma k_H + (\sigma + \tau)k_B]}{k+1}, \\
X_H &= n_H \frac{(\alpha - \omega)k - [\sigma k_A + \tau k_B]}{\beta(k+1)}, & p_H &= \frac{\alpha + \omega k + [\sigma k_A + \tau k_B]}{k+1}, \\
X_B &= n_B \frac{(\alpha - \omega)k - [(\sigma + \tau)k_A + \tau k_H]}{\beta(k+1)}, & p_B &= \frac{\alpha + \omega k + [(\sigma + \tau)k_A + \tau k_H]}{k+1},
\end{aligned} \tag{5}$$

while sales of firms in each country are:

$$\begin{aligned}
x_{AA} &= \frac{n_A(p_A - \omega)}{\beta}, & x_{AH} &= \frac{n_A(p_A - \omega - \sigma)}{\beta}, & x_{AB} &= \frac{n_A(p_A - \omega - \sigma - \tau)}{\beta}, \\
x_{HA} &= \frac{n_H(p_H - \omega - \sigma)}{\beta}, & x_{HH} &= \frac{n_H(p_H - \omega)}{\beta}, & x_{HB} &= \frac{n_H(p_H - \omega - \tau)}{\beta}, \\
x_{BA} &= \frac{n_B(p_B - \omega - \sigma - \tau)}{\beta}, & x_{BH} &= \frac{n_B(p_B - \omega - \tau)}{\beta}, & x_{BB} &= \frac{n_B(p_B - \omega)}{\beta}.
\end{aligned} \tag{6}$$

In each country, the consumer price is a rising function of the number of firms located in the other countries and serving the market through exports. In other words, whatever the size of the industry, having more firms producing locally intensifies domestic competition and drives down consumer prices.

Substituting the prices (5) and quantities (6) into (4) yields the pre-tax profits of firms dependent on the location of their production facilities:

$$\begin{aligned}
\pi_A &= \frac{n_A[A + \sigma k_H + (\sigma + \tau)k_B]^2 + n_H[A - \sigma(k_H + 1) + (\tau - \sigma)k_B]^2 + n_B[A - \sigma k_H - (\sigma + \tau)(k_B + 1)]^2}{\beta(k+1)^2}, \\
\pi_H &= \frac{n_A[A - \sigma(k_A + 1) + \tau k_B]^2 + n_H[A + \sigma k_A + \tau k_B]^2 + n_B[A + \sigma k_A - \tau(k_B + 1)]^2}{\beta(k+1)^2}, \\
\pi_B &= \frac{n_A[A - \tau k_H - (\sigma + \tau)(k_A + 1)]^2 + n_H[A - \tau(k_H + 1) + (\sigma - \tau)k_A]^2 + n_B[A + \tau k_H + (\sigma + \tau)k_A]^2}{\beta(k+1)^2},
\end{aligned} \tag{7}$$

where $A \equiv \alpha - \omega$. Notice the symmetry in the profits expressions for A and B , as all of their exports must pass through the hub, H .

We let Γ_{ij} denote the *geographic advantage* of country i relative to country j . This is defined as the difference between the total variable profits of a firm located in country i and those of a firm producing in country j . That is, $\Gamma_{ij} \equiv \pi_i - \pi_j$.

2.3 Location in the absence of tax competition

Suppose, initially, that firms face no corporate taxes on their earnings or that all countries impose the same tax on firms.¹¹ In either situation, the equilibrium location of firms will be characterised by the variable profits of all firms in the region being equalised, that is $\pi_A = \pi_H = \pi_B$. Equating the terms in (7) and solving, reveals the “natural geography” of the region, the allocation of industry that is consistent with equal pre-tax profits for all k firms. Thus k_i^* is the equilibrium number of firms that locate in country i in the absence of fiscal inducements, where:

$$\begin{aligned}
 k_A^* &= \frac{(\sigma + \tau)(k + 1 - 4n_H n_A) - 2\tau n_H (k - 1 + 2n_H) - 8An_H n_B}{8\sigma n_H (1 - n_H)}, \\
 k_B^* &= \frac{(\sigma + \tau)(k + 1 - 4n_H n_B) - 2\sigma n_H (k - 1 + 2n_H) - 8An_H n_A}{8\tau n_H (1 - n_H)}, \\
 k_H^* &= k - k_A^* - k_B^*.
 \end{aligned} \tag{8}$$

We can use (8) to investigate the relationship between trade costs and the sizes of countries in determining the degree to which industry agglomerates in particular countries. The hub country, H , always has the advantage of centrality, in that its aggregate costs of servicing its foreign markets are always less than those of the spoke countries, as the hub transports its goods directly to consumers in each spoke. This aspect of geographic advantage can be enhanced, or offset, by the distribution of the region’s population between hub and spokes. We illustrate this in Figure 2.

¹¹ The latter situation could arise when the countries in the region cooperate in setting their corporate taxes in order to avoid a “race to the bottom.” Equally this could describe a single country prior to the devolution of tax-setting powers to provincial governments.

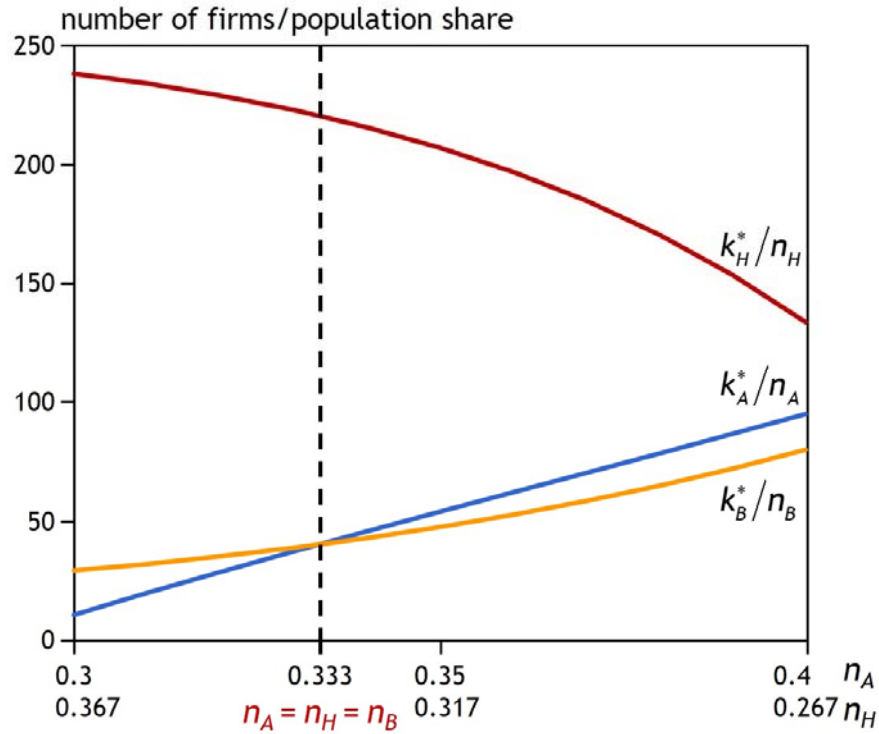


Figure 2. Natural geography and agglomeration of industry

The benefit of centrality is clearly shown in Figure 2 along the dotted line, corresponding to each country having the same share of the region's population.¹² In this case, the number of firms per household in the hub is substantially greater than that in each of the two spokes. Country size reinforces centrality to the left of the dotted line where n_H rises at the expense of the population of spoke A , while B 's population remains unchanged at $n_B = 1/3$. To the right of the dotted line, the spokes are allocated greater shares of the region's population than the hub, and size increasingly offsets centrality. While both A and B grow in size relative to the hub, the population of A also increases relative to the constant n_B and therefore A attracts proportionately more industry than B , reflecting the agglomerative nature of this type of model of firm location.

¹² The parameters for this and subsequent numerical simulations are: $k = 100$, $\alpha = 26$, $\beta = 1$, $\omega = 1$, $\sigma = \tau = 0.2$.

We now consider the role of trade costs in the natural geography of the region. In Figure 3 each country is the same size but trade costs are changed. When trade costs between the hub and both spokes are the same on the left-hand side of the figure ($\sigma = \tau$), the hub's centrality results in its attracting much more industry than either spoke. As the trade cost between the hub and spoke A increases, while that between H and B remains unchanged, the hub's access to A 's consumers is reduced. Effectively, A is becoming more isolated from the rest of the region and firms that previously located in H and served A 's consumers from that location have the incentive to relocate to that spoke.

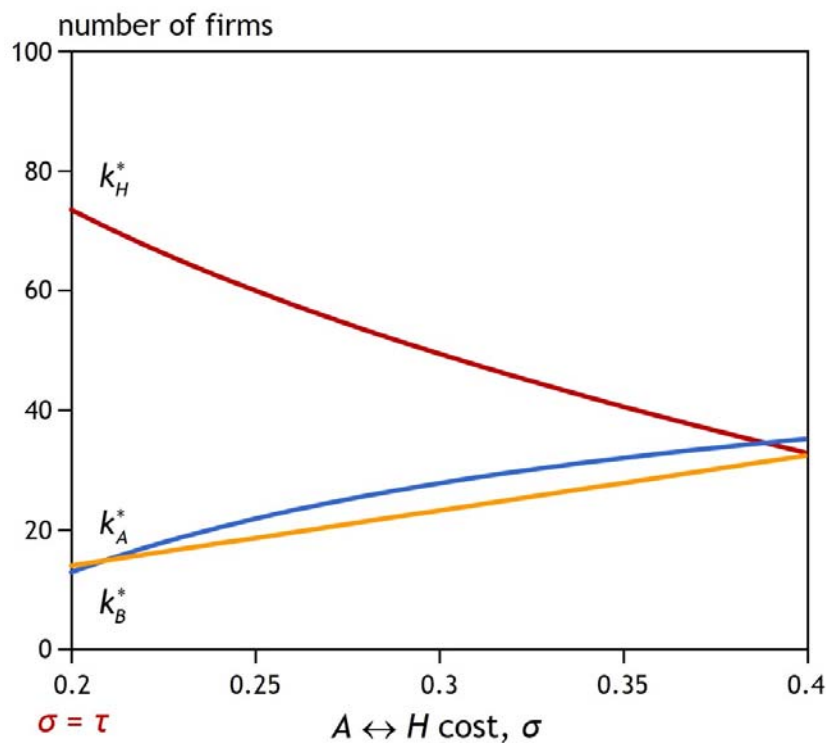


Figure 3. Natural geography and asymmetric trade costs

Of particular interest is what happens in the other spoke. B does not experience any change in its direct trade costs (τ), though its costs of trading with A rise. However, the increase in trade costs between H and A has a larger impact on the profitability of firms in the hub (as the initial trade volume is higher), resulting in some of the firms relocating to the relatively more profitable B . Consequently, both spokes can experience an increase in the concentration

of industry despite only one of the trade costs increasing as the centrality of the hub is undermined.

We can use the natural geography of industrial production to determine the levels of economic activity in each country. Substituting the equilibrium allocations of industry (8) into (5) to find the prices and sales in each of the countries, yields

$$\begin{aligned}
X_A &= \frac{n_A}{\beta} \left\{ A - \sigma + \frac{\sigma - \tau}{4(1-n_H)} - \frac{n_B [2A - (\sigma + \tau)]}{(k+1)(1-n_H)} \right\}, & p_A &= \omega + \sigma - \frac{\sigma - \tau}{4(1-n_H)} + \frac{n_B [2A - (\sigma + \tau)]}{(k+1)(1-n_H)}; \\
X_H &= \frac{n_H}{\beta} A - \frac{\sigma + \tau}{4\beta}, & p_H &= \omega + \frac{\sigma + \tau}{4n_H}; \\
X_B &= \frac{n_B}{\beta} \left\{ A - \tau + \frac{\tau - \sigma}{4(1-n_H)} - \frac{n_A [2A - (\sigma + \tau)]}{(k+1)(1-n_H)} \right\}, & p_B &= \omega + \tau - \frac{\tau - \sigma}{4(1-n_H)} + \frac{n_A [2A - (\sigma + \tau)]}{(k+1)(1-n_H)}.
\end{aligned} \tag{9}$$

We see from (9) that trade costs impact on both the price in each national market and the quantity that is sold there. For a spoke country, its trade cost with the hub has a direct effect, but the rival spoke's trade cost also affects the level of economic activity.

3. Governments

Each national government is assumed to have as its goal the maximisation of the welfare of its households, where welfare is the sum of the consumer surplus, tax revenue, and wage income.¹³

$$W_i \equiv S_i + T_i + n_i w, \tag{10}$$

S_i is country i 's total consumer surplus in the market for the imperfectly competitive good,

$$\begin{aligned}
S_A &= \frac{n_A [Ak - \sigma k_H - (\sigma + \tau) k_B]^2}{2\beta(k+1)^2}, \\
S_H &= \frac{n_H [Ak - \sigma k_A - \tau k_B]^2}{2\beta(k+1)^2}, \\
S_B &= \frac{n_B [Ak - \tau k_H - (\sigma + \tau) k_A]^2}{2\beta(k+1)^2},
\end{aligned} \tag{11}$$

¹³ We are assuming that all profits from the activities of the imperfectly competitive firm are repatriated to their foreign owners.

Consumer surplus in each country is rising in the total number of firms in the industry, k , as this intensifies competition and reduces producer prices in all countries. High trade costs reduce consumer surplus as they lower international competition. In addition, a greater number of firms located in other countries reduces consumer surplus, as consumer prices are lower when more firms produce locally. This gives each nation an incentive to attract firms to its home jurisdiction.

T_i is the total corporate tax revenue collected by country i ,

$$T_i = t_i k_i. \quad (12)$$

We assume that profits are taxed at source by the host countries of the firms, with t_i being the lump-sum tax imposed on each firm by country i . The tax differential between countries i and j is defined to be $\Delta_{ij} \equiv t_i - t_j$. Higher taxes expand the budget sets of the nation's households, but will drive away firms to lower tax regimes.

The third term of national welfare is assumed to be unchanging, as wage income remains the same regardless of where workers are employed. We assume that the jobs provided by the oligopolistic industry offer the same wage as that in the numeraire industry.¹⁴

3.1 Corporate taxation

Firms are concerned with their after-tax earnings, thus they must subtract from their pre-tax profits (7) the lump-sum tax of the country in which they are located. In deciding upon where to invest, firms will compare profits net of taxes and locate in the most profitable location. If all countries host a strictly positive number of firms, then the locational equilibrium for the industry is characterised by

$$\Gamma_{ij} - \Delta_{ij} = 0 \quad (13)$$

for every pairwise combination of investment locations.

¹⁴ It is possible to include some sort of wage premium for jobs in the footloose industry. This is likely to create the same incentives for attracting firms as consumer surplus, so we do not pursue it in this paper.

We can solve for the distribution of firms in the presence of taxes as deviations from the natural geography of the region, the allocation of industry in the absence of taxes. Let k_{it} be country i 's equilibrium number of firms in the presence of taxes. From (7), (8) and (13), we find:

$$\begin{aligned}
k_{At} &= k_A^* - \frac{\beta(k+1)}{8n_H(1-n_H)} \frac{\Delta_{AH}}{\sigma^2} + \frac{\beta(k+1)(2n_H-1)}{8\sigma\tau n_H(1-n_H)} \Delta_{BH}, \\
k_{Ht} &= k_H^* + \frac{\beta(k+1)(\sigma+\tau)}{8\sigma\tau n_H(1-n_H)} \left(\frac{\Delta_{AH}}{\sigma} + \frac{\Delta_{BH}}{\tau} \right) - \frac{\beta(k+1)}{4\sigma\tau(1-n_H)} (\Delta_{AH} + \Delta_{BH}), \\
k_{Bt} &= k_B^* - \frac{\beta(k+1)}{8n_H(1-n_H)} \frac{\Delta_{BH}}{\tau^2} + \frac{\beta(k+1)(2n_H-1)}{8\sigma\tau n_H(1-n_H)} \Delta_{AH}.
\end{aligned} \tag{14}$$

It is immediately obvious that only differences in taxes, not the levels of taxes, matter for industrial location in the region. If all countries have set the same tax, firm numbers in each country are the same as in the absence of any corporate taxes.

When taxes differ we can see, from the second terms of the equations in (14), that spoke countries lose firms as a result of their imposing taxes higher than those set in the hub. The impact is mitigated by the (square of the) trade cost between the spoke and the hub. If the trade costs σ and τ are sufficiently similar in size, then the spoke's loss of firms directly benefits the hub.¹⁵ In addition, there may also be an increase in firms in the other spoke. Thus, in each of the expressions for the number of firms in a spoke country, the third term is positive if the population of the hub is at least half of the total population in the region ($2n_H > 1$). This means that, if the hub is sufficiently large, a spoke's tax increase will cause an exodus of firms to both the hub and the other spoke.

¹⁵ Technically, k_{Ht} is increasing in Δ_{AH} (Δ_{BH}) iff $\sigma + \tau$ is strictly greater than $2n_H\sigma$ ($2n_H\tau$). Both conditions hold if $\sigma = \tau$.

3.2 Unilateral taxation

Suppose that the corporate tax is the same across all of the countries. This might reflect the situation where the three countries are, in fact, constituent nations of a federal state that sets the corporate tax for the entire region. For simplicity, we assume that this initial tax level is zero. We now allow for the possibility that these tax powers are devolved to one or more of the countries and investigate how its optimal tax might deviate from that of the rest of the region.¹⁶

By differentiating (10), taking into account (11) and (14), we can find the optimal tax that would be chosen unilaterally by each of the countries.

$$\begin{aligned}
 t_A^* &= \frac{4n_H(1-n_H)}{\beta(k+1)} \frac{\sigma \left\{ 4\sigma(1-n_H)(k+1)k_A^* - n_A \left[Ak - \sigma k_H^* - (\sigma + \tau) k_B^* \right] \right\}}{4(1-n_H)(k+1) - n_A n_H}, \\
 t_H^* &= \frac{4n_H(1-n_H)}{\beta(k+1)} \frac{\sigma \tau \left\{ 4\sigma \tau (k+1) k_H^* - (\sigma + \tau) \left[Ak - (\sigma k_A^* + \tau k_B^*) \right] \right\}}{(\sigma + \tau)^2 (4k + 3 + n_H) - 16\sigma \tau (k+1) n_H}, \\
 t_B^* &= \frac{4n_H(1-n_H)}{\beta(k+1)} \frac{\tau \left\{ 4\tau(1-n_H)(k+1)k_B^* - n_B \left[Ak - \tau k_H^* - (\sigma + \tau) k_A^* \right] \right\}}{4(1-n_H)(k+1) - n_B n_H}.
 \end{aligned} \tag{15}$$

For each of the spoke countries, the denominators in (15) are positive whenever the hub is not overwhelmingly large (that is, n_H is sufficiently less than one). For these countries, the size of the tax is proportionate to the trade cost with the hub. Whether the tax is positive or negative (a subsidy) depends upon the relative sizes of the two terms in the numerator of the second term in each of the expressions. The first of these is proportional to the number of firms located in the country and reflects the fact that a higher tax increase revenues for the government. The second term is directly related to (5), the level of sales in the domestic market: a higher tax will drive out some firms, leaving the local market less competitive.¹⁷ The denominator of the

¹⁶ This can be seen as an extremely stylised approach to the issue of devolving taxation powers within the UK, where the competition to attract firms is focused on those enterprises already located within the borders of the country but sufficiently footloose that they may be induced to relocate due to a more favourable tax environment.

¹⁷ Thus, when contemplating an increase in corporate taxation, a country typically faces a trade-off between (rising) tax revenue and (falling) consumer surplus. Of course, a welfare-maximising government will never raise its tax to such a level that the resulting loss of firms leads to a fall in its aggregate tax revenues.

second term in the optimal tax of the hub is less easily signed, though the numerator shares similar components to those of the other nations' tax expressions.

These results are illustrated in Figure 4, which shows the impact of a corporate subsidy offered by spoke A on the allocation of firms across the region as the population of the region is reallocated internationally.¹⁸ The vertical dashed line reflects an equal distribution of workers while the other dashed lines remind us of the distribution of economic activity in the absence of corporate taxes or subsidies. A 's subsidy attracts more firms at the expense of H . In addition, as $n_H < 1/2$, spoke A 's subsidy results in spoke B also increasing the number of firms that it can attract.

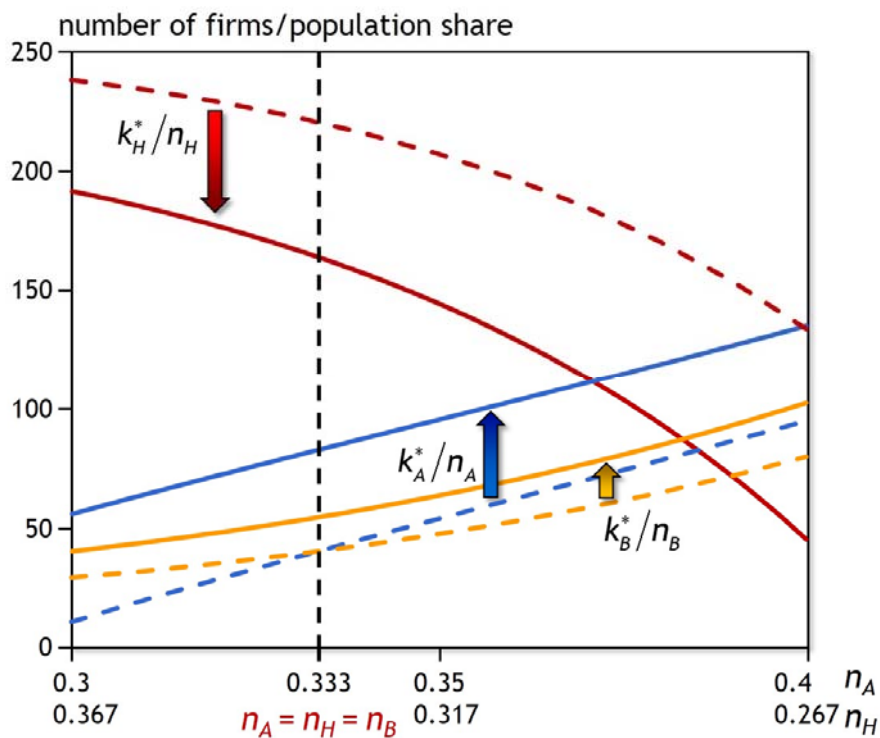


Figure 4. Unilateral subsidy and industrial location

It is clear from (15) that the countries have incentives to deviate from the tax levels of their trading partners and, indeed, respond to any shifts in taxes that the other countries may

¹⁸ $\Delta_{AH} = -0.01$ while $\Delta_{BH} = 0$.

make. The task is then to determine what the equilibrium taxes will be in such a strategic setting. We therefore turn to finding the Nash taxes.

4. Symmetry

In order to examine the relative importance of being at the core of the region as opposed to being on the periphery, it will be useful to introduce a degree of symmetry across the spoke countries. Suppose that the two spokes are identical in size, each having a population of $n_S = (1 - n_H)/2$, while their costs of transporting goods to and from the hub are the same and equal to τ . This configuration of countries is illustrated in Figure 5.

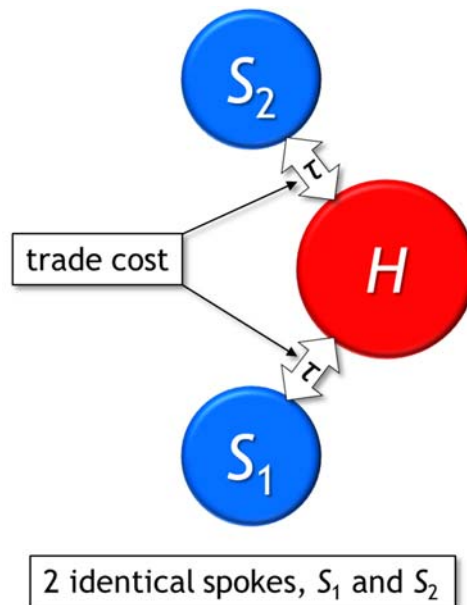


Figure 5. Symmetrical hub and spoke region

This simplifies the expressions substantially. Thus the number of firms in each country in the absence of corporate taxes collapses from (8) to

$$k_S^* = \frac{(k+1)\tau - 2n_H A}{4\tau n_H}, \quad k_H^* = \frac{2(A + k\tau)n_H - (k+1)\tau}{2\tau n_H}. \quad (16)$$

It is apparent from (16) that the hub/spoke trade cost and the relative size of the markets in the hub and the spokes determines whether the spokes capture any of the firms in the oligopolistic

industry. Each spoke has to have a large-enough home market, which is sufficiently isolated from the hub, to make it worthwhile for firms to locate away from the core. Thus, only if $\tau > 2n_H A / (k + 1)$ will the hubs produce both goods. When corporate taxes are imposed, (14) changes to

$$\begin{aligned} k_{Hi} &= k_H^* + \frac{\beta(k+1)(\Delta_{S1H} + \Delta_{S2H})}{4\tau^2 n_H}, \\ k_{Sii} &= k_S^* - \frac{\beta(k+1)[\Delta_{SiH} - (2n_H - 1)\Delta_{SjH}]}{8\tau^2 n_H (1 - n_H)}, \end{aligned} \quad (17)$$

where $\{\Delta_{SiH}, \Delta_{SjH}\} \in \{\Delta_{S1H}, \Delta_{S2H}\}$, $i \neq j$.

4.1 Optimal taxes

Suppose that each of the countries now sets a corporate tax to maximise its welfare, conditional on the taxes set by the other countries in the region. The reaction functions for the countries are

$$\begin{aligned} t_H &= \frac{2\tau n_H \{2\tau[(k+1)k_H^* + k_S^*] - Ak\}}{\beta(k+1)(4k+3)} + \frac{2k+1}{2(4k+3)}(t_{S1} + t_{S2}), \\ t_{Si} &= \frac{4\tau n_H (1 - n_H) \{ \tau(k_H^* + 2(4k+5)k_S^*) - Ak \}}{\beta(k+1)[8(k+1) - n_H]} + \frac{8(1 - n_H)(k+1)}{8(k+1) - n_H} t_H - \frac{4(k+1) - (8k+7)n_H}{8(k+1) - n_H} t_{Sj}. \end{aligned} \quad (18)$$

Solving (18), substituting (16) yields the Nash corporate taxes t_{SN} and t_{HN} for a spoke nation and the hub, respectively:

$$\begin{aligned} t_{SN} &= \Theta(1 - n_H) \left[4\tau(k+1)^3 + \tau k n_H (8k^2 + 20k + 11) - A n_H (16k^2 + 23k + 8) \right], \\ t_{HN} &= \Theta \left\{ \tau(2k+1)(k+1)^2 + \tau k n_H \left[(12k^2 + 26k + 13) - n_H (2k+3)(4k+3) \right] \right. \\ &\quad \left. - A n_H \left[(4k^2 + k - 2) - k n_H (6k+5) \right] \right\}, \end{aligned} \quad (19)$$

where $\Theta \equiv \tau / \left\{ \beta(k+1)^2 [8k+7 - 4(k+1)n_H] \right\} > 0$.

The tax levels in the Nash equilibrium associated with different distributions of the region's population are illustrated in Figure 6. It is clear that the relatively larger a country is, the higher its tax. Thus when the hub is small (e.g., with 25% of the population in the hub compared to 37.5% in each spoke), the hub provides a subsidy to its firms while the spokes charge taxes. The reverse is true when the spokes have relatively small shares of the population. Three additional aspects are worth noting. Firstly the race to the bottom is limited, as there is a range of the population allocation over which all countries impose taxes. Secondly, the central position of the hub still confers benefits, in that when the countries are equally sized, the hub sets a higher tax than either spoke.

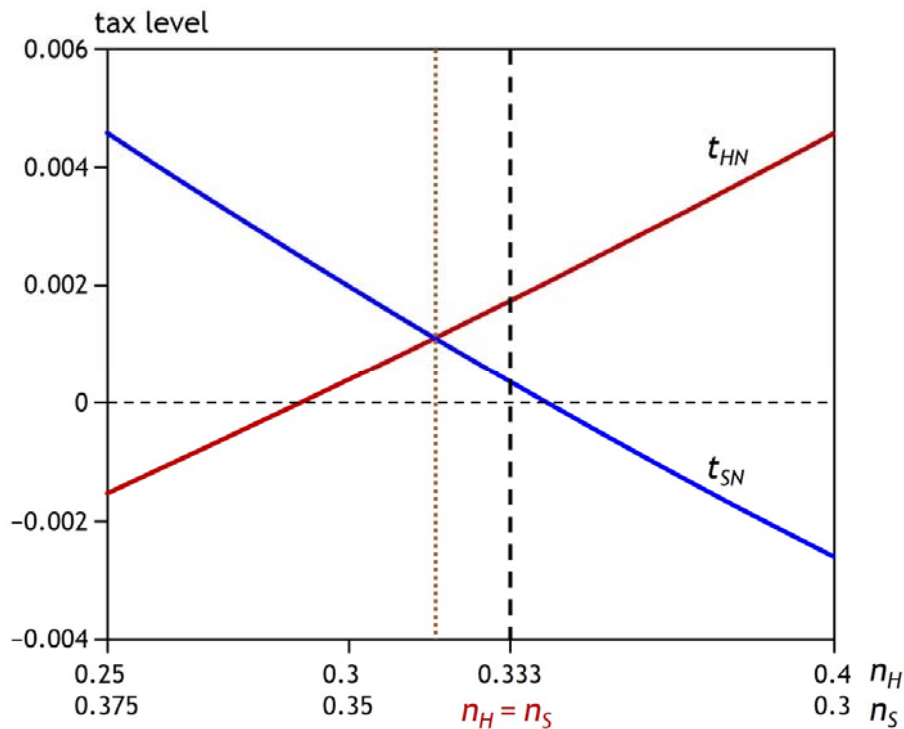


Figure 6. Nash taxes and country size

Finally, the trade cost has a strong positive impact on the levels of tax in both hub and spokes. Thus efforts to reduce trade costs may result in lower corporate taxes and, from (16), further concentration of firms in the hub. Consequently, depending upon the impact on

consumer surplus, transport infrastructure investments may have a negative impact on the region.¹⁹

While messy, the expressions in (19) seem to reflect the tension facing nations between generating revenue from high taxes on local firms with the desire to retain domestic industry in order to maximise consumer surplus.²⁰ Figure 7 illustrates how taxes in the Nash equilibrium mitigate some of the effects of natural geography. The dashed lines indicate the numbers of firms captured by countries as a function of their populations in the absence of tax differences. The solid lines show that the distribution of firms across the region is less responsive to population changes when countries set their corporate taxes endogenously, imposing taxes when locations are attractive to firms (large) and offering subsidies when they are geographically disadvantaged (small).

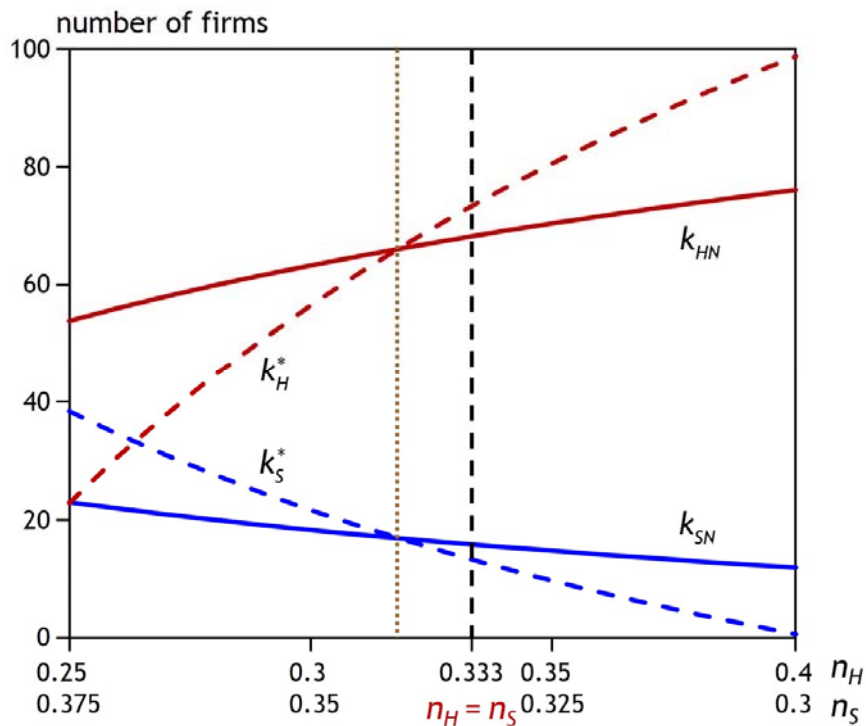


Figure 7. Nash taxes and location of industry

¹⁹ Becker and Fuest (2010) consider the implications for tax competition and welfare of transport infrastructure investments in a 3-country model.

²⁰ If the oligopolistic industry were to bring “better” jobs, this latter incentive to retain domestic firms would be reinforced.

5. Conclusions and future research

In this paper we have set up a simple model of intra-regional tax competition for foreign direct investment. The novelty in our approach is the geography of the region, where we have assumed that one of the nations is a hub through which all international trade must take place. We believe that this structure is applicable to trade amongst countries at the periphery of a large region. Indeed, the implications of devolving tax-setting powers to sub-national governments in the UK generated the initial motivation for this paper.

In Haufler and Wooton (1999, 2010), size was the only advantage in a tax competition game. Now centrality is also an advantage. The former results in larger countries setting higher corporate taxes while the latter gives a similar incentive to hub nations. Thus, depending on the relative sizes of the countries within the region, the two effects may work together for a large hub or centrality may offset the disadvantage of being a small hub.

If this hub-and-spoke trading structure exists within an individual country (such as the UK), we can analyse the implications of that country shifting from setting a single, corporate tax on firms operating anywhere in the country to a devolved tax-setting regime where each devolved government sets a corporate tax that recognises the different trading conditions facing firms investing in its part of the larger nation. Our goal would then be the comparison of the equilibria associated with the two regimes, in terms of the impact of devolution on the aggregate level of economic activity in the country, how it is divided and the consequent impact on the welfare of citizens of each part of the nation.

6. References

Becker, Johannes, and Clemens Fuest (2010), "EU regional policy and tax competition."

European Economic Review 54, 150-161.

- Bjorvatn, Kjetil, and Carsten Eckel (2006), "Policy competition for foreign direct investment between asymmetric countries." *European Economic Review* 50, 1891-1907.
- Brander, James A., and Paul Krugman (1983), "A 'reciprocal dumping' Model of international trade." *Journal of International Economics* 15, 313-323.
- Darby, Julia, Ben Ferrett and Ian Wooton (2012), "Intra-regional competition for FDI amongst heterogeneous nations." Mimeo.
- Fumagalli, C., (2003), "On the welfare effects of competition for foreign direct investment." *European Economic Review* 47, 963–983.
- Haaparanta, P., (1996), "Competition for foreign direct investment." *Journal of Public Economics* 63, 141–153.
- Haufler, Andreas, and Ian Wooton (1999), "Country size and tax competition for foreign direct investment." *Journal of Public Economics* 71, 121-139.
- Haufler, Andreas, and Ian Wooton (2006), "The effects of regional tax and subsidy coordination on foreign direct investment." *European Economic Review* 50, 285-305.
- Haufler, Andreas, and Ian Wooton (2010), "Competition for firms in an oligopolistic industry: the impact of economic integration." *Journal of International Economics* 80, 239-248.
- Olsen, T., and P. Osmundsen (2003), "Spillovers and international competition for investments." *Journal of International Economics* 59, 211-238.
- Scottish Government (2009), "Freight in Scotland." Freight Statistics Project, <http://www.scotland.gov.uk/Publications/2009/08/03104646/0>.
- Scottish Government (2011), "Corporation Tax: Discussion Paper Options for Reform." <http://www.scotland.gov.uk/Publications/2011/08/corporation-tax-paper>.