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**Taxes and the Location of Production**

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# **Taxes and the Location of Production**

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## **Abstract**

In this paper I examine dynamic tax competition in the context of an endogenous market structure. I therefore consider the tensions between proximity versus concentration, taxation and firm mobility while I also consider strategic interaction by governments (to induce multinationality) and asymmetric firms (for market share). The paper explores how strategic tax setting by rival governments may induce footloose firms to remain committed to initial location decisions, even when faced with adverse taxation regimes. In this instance, sunk costs resulting from the operation of additional plants may confer a first mover advantage on governments that can prevent relocation of firms.

# Taxes and the Location of Production

## 1.1 Introduction

This paper explores how strategic tax setting by rival governments may induce footloose firms to remain committed to initial location decisions, even when faced with adverse taxation regimes. In this instance, sunk costs resulting from the operation of additional plants may confer a first mover advantage on governments that can prevent relocation by firms.

In the literature on multinationals, the emergence of multinational behaviour is often examined in the absence of government involvement and in the context of monopolistic competition or simple oligopoly models. This literature focuses on the well-documented proximity versus concentration argument for multinationality, whereby multinationalism is associated with high transport costs and low plant-, as opposed to firm-specific fixed costs.<sup>1</sup> Other locational determinants of multinational activity such as market size, relative factor endowments and taxation (although to a lesser extent) have also been considered in the literature. In order to focus on strategic interaction between governments, the tax competition literature often assumes that governments use taxation levels to compete for a single multinational firm. Consequently, rarely have the two forces of government and firm strategic behaviour been examined simultaneously in a model of tax competition. Furthermore, the scope for taxation when firms have alternative production strategies (exporting or multinationality) has also been ignored.

The aim of this paper is to consider the roles of two types of non-cooperative agents (governments and firms) in determining multinational behaviour. It contributes to the tax competition literature by examining tax competition in the context of duopoly and, consequently, the role of strategic firm interaction. In this model, competing firms respond to tax differentials by relocating production to the rival host country. For governments, inducing multinationality as opposed to exporting behaviour offers rewards in terms of higher consumer surplus and positive tax revenues. Therefore, I consider the extent to which governments can promote multinational behaviour while at the same time extract positive tax revenues. Tax competition among rival governments is characterised, justifiably so, by non-cooperative behaviour (as governments compete to induce multinational firms away from their competitor). Therefore in this model, the tax rate is an endogenous variable and is the result of competitive behaviour amongst rival governments. In this paper I therefore focus on the effects of firm mobility on the tax rate that is

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<sup>1</sup> See, for example Horstmann & Markusen (1992).

set strategically by governments and its consequences for multinationality when firms are either symmetric or asymmetric.

As previously mentioned, the literature on tax competition is dominated to a large extent, by models in which taxation is the only strategic variable, i.e. monopoly and often multinationality, characterises firm behaviour and government actions are the result of a duopoly game setting. Furthermore, as will be seen below, tax competition is usually characterised by non-cooperative behaviour. Consequently, these models examine (tax) competition among countries for a single firm when it is faced with alternative location possibilities for production.

Janeba (1998) examines the consequences of firm mobility on taxation in a third country model.<sup>2</sup> Unusually he considers the duopoly case,<sup>3</sup> whereby one firm is located in the home country (the home firm) and the second firm (the foreign firm) is located in the foreign country. Firms produce a homogenous good, which is sold for consumption in a third market. The model is represented in a two-stage game. In stage one, governments simultaneously choose tax rates and in the second stage, firms simultaneously choose outputs. Governments are assumed to maximise net domestic surplus (or welfare) which is defined as the sum of producer surplus (of the domestic firm) plus tax revenues collected. In the first scenario firms are immobile and as a result, taxation only affects domestic firms. Thus here, Janeba adopts the basic set-up of strategic trade policy models. Although he considers strategic behaviour, he does so using a third market model, which simplifies the analysis as firms meet in one market only (the third market) and strategic interaction and competition in domestic markets can be ignored. Recall that in the strategic trade policy literature the role of the government is to confer a strategic advantage on the domestic firm (over the foreign firm).<sup>4</sup> Following on from the strategic trade policy literature, under conditions of firm immobility and Cournot competition, the subgame perfect Nash equilibrium is characterised by negative taxes or subsidies. When firms are mobile, the results of the analysis are quite different. For example, because firms prefer higher subsidies (or lower taxes), they can now respond to tax/subsidy differentials by switching location, especially when the costs of changing location are low. In the model, firms respond to tax differentials by shifting production (completely) to the more favourable location. Anticipating firms' output and location decisions, governments set taxes strategically. In this model, the only subgame perfect Nash equilibrium is a policy of laissez-faire or zero taxation (in each country). The rationale is as follows. If one country has a positive tax rate, the other can undercut. If one country's tax rate is negative, (i.e.

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<sup>2</sup> The term "third market model" referred to in the text is due to Brander (1995), see also Brander & Spencer (1985).

<sup>3</sup> Although strategic interaction between firms is catered for, Janeba does not consider the tension between proximity versus concentration in determining multinational activity. Although firms can centralise production in either of two locations, the basic set-up of Brander & Spencer's (1985) model is retained i.e. firms serve the third market via exports only, the possibility of direct investment is not explored.

a subsidy), the other country could undercut it slightly in order to let the other country pay the subsidies for both firms. Finally, if the tax rate of one country is zero, the optimal response of the other country is to levy a zero tax rate also. Therefore, in this game, governments will be indifferent to the location decision of firms, since tax revenue is always zero. Thus, rather than focusing on tax competition to induce mobile firms into local markets, Janeba uses the assumption of firm mobility to modify the basic strategic trade policy prediction that optimal subsidies are positive.

More basic models of tax competition involving (tax) competition for a single mobile firm have been extended to consider the role of capacity choice and country size. In a later paper (2000), Janeba considers a multinational monopolist firm who can produce for the world from two alternative countries. The game set-up is as follows. Ex ante, the firm makes an investment in capacity in each of the two countries. This is followed by a round of tax competition, in which each government chooses a tax rate (on output), which is followed by Cournot competition, in which firms choose outputs. Without full commitment, and owing to the standard time-inconsistency problem, governments would like to set a confiscatory tax ex post. If there were only one country, firms realising this ex ante would make no investment. However with two countries, the firm invests in both countries to gain leverage ex post. Therefore, excess capacity induces tax competition for capacity utilisation among governments and helps overcome the lack of government commitment. The game is solved as follows.

In the final stage of the game, the firm chooses output given capacity costs are sunk and given the output decision has no impact on taxation policy. When tax rates are equal, the firm utilises all capacity (unless total capacity exceeds unit demand – i.e. unless there is excess capacity). If taxes differ, the firm first utilises its capacity in the country with the lower tax and production in the high tax country is equal to the minimum of the residual demand and available capacity in that country. Output from any single plant is zero if plant capacity is zero or the tax rate in that country exceeds 100%. In the second stage, governments choose their tax rates, taking into account how taxation policy affects the output decision of the firm. When capacity is less than one, there exists a unique equilibrium in pure strategies in which taxes in each country are equal to 100%, and the government appropriates the entire rent. When capacity is greater than one, there exists no equilibrium in pure strategies but a unique equilibrium in mixed strategies does exist. When capacity is equal to one, there exists a unique equilibrium in pure strategies in which taxes in both countries are zero and the firm obtains the entire rent. The first stage of the game addresses capacity choice, i.e. does the firm in equilibrium invest in excess capacity? If the firm enters both countries, then it chooses identical capacity levels in both countries and holds excess

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<sup>4</sup> In the Strategic Trade Policy literature, the domestic government transferred its' first mover advantage into an

capacity. This occurs for sufficiently small capacity costs. If capacity costs are sufficiently high, then the firm does not invest at all and entry does not take place. Thus the Nash equilibrium is discontinuous in the cost of capacity, i.e. the firm either over-invests or doesn't invest at all, it never holds capacity equal to one.

Therefore, when capacity costs are small, (tax) competition leads to tax rates that are low enough to justify the initial investment in excess capacity. The converse is also true. Therefore in this model, it is investment in excess capacity, which is similar to the threat of firms relocating production, that induces tax competition.

Haufler and Wooton (1998), examine tax competition between two countries of unequal size in an effort to induce multinational behaviour by a monopoly firm. The firm will be indifferent between alternative production locations if profits from locating in either country are equal. Owing to differences in country size, the firm is willing to pay a tax "premium" for locating in the bigger country. In other words, the optimal tax rate of the larger country can exceed that of the smaller country and still leave firms indifferent between the alternative production locations.

In these models, the choice of locating production in an alternative rival country poses a threat to host governments, whose aim is to maximise welfare via tax revenues. However, there also exists the possibility that firms may choose to export to the region in which the active government lies. This limits further the taxing power of authorities. Keeping this in mind, I examine tax competition when firms have two strategies of serving a foreign market: exporting and direct investment (becoming multinational). Unlike the models above, multinationality and monopoly are not assumed. I therefore consider the tensions between proximity and concentration, taxation and firm mobility, while I also consider strategic interaction by governments (to induce multinationality) **and** firms (for market share). In the models above, taxation influences patterns of multinational behaviour. Future taxation levels must accordingly, influence patterns of multinationality also. These features of taxation and multinational behaviour are presented here in an infinitely repeated game of tax and Cournot competition.

In section 1.2, I present the basic assumptions and set-up of the model, while in addition I explore the mechanics of a "one-shot" version of the game. Owing to the infinite time horizon of the game, in section 1.3 I consider the possibility of collusion between both agents. In section 1.4, I present the analysis for a "reference" or "base" game. The purpose of this game is to introduce the idea of dynamics, focusing on infinite repetition of the game in the absence of firm heterogeneity and government involvement. In section 1.5, I consider the active role of

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advantage for the domestic firm.

government in the form of taxation policy. In section 1.6, I extend the previous analysis to consider infinite repetition and firm heterogeneity, while in section 1.7, I present the analysis for the full model – tax competition with asymmetric firms in an infinitely repeated game. The final section of the paper presents some concluding remarks.

## 1.2 The Basic Model

The basic set-up of the model is as follows. Consider two firms who compete for market share in a third market. Firm 1 (located in Country 1) and Firm 2 (located in Country 2) each produce a homogenous good. Production of the good is characterised by constant marginal cost, determined by two parameters  $c$  and  $\lambda$ . Whereas  $c$  is the average variable cost component, common to both firms,  $\lambda$  measures the dispersion around variable cost. For simplicity, we shall assume that  $\lambda$  is positive, conferring on a definite cost advantage of Firm 1 over Firm 2. The marginal cost functions for each firm are:

$$\text{Firm 1: } c - \frac{1}{2}\lambda \quad (1)$$

$$\text{Firm 2: } c + \frac{1}{2}\lambda \quad (2)$$

without loss of generality

$$\lambda \geq 0 \quad (3)$$

Each firm must choose a method of meeting demand in the third market, which is not being met by indigenous industry. The firms have two basic options available to them. Firms can export the good from the domestic country to the foreign/third market, or alternatively, they can serve the market via local production by becoming multinational. Firms who choose to be multinational can do so in either of two locations within the foreign region. Transport costs ( $t$ ) are exogenous and must be paid on each unit of a good exported from the domestic countries to the foreign market. On the other hand, multinational firms must incur a fixed cost  $G$ , representing the cost of establishing an additional plant in the foreign location. This fixed cost is identical between alternative production sites. As a result, each firm's cost function is independent of its own and its rival's location decision. Hence as we will see later, each firm's location decision depends on tax differentials only.

Although (within the foreign market) there exist two alternative production sites (or countries), firms serve an integrated market.<sup>5</sup> The foreign region has the following linear inverse demand:

$$p = 1 - q_1 - q_2 \quad (4)$$

where  $q_1$  is the output supplied by Firm 1 and  $q_2$  is the output supplied by Firm 2.

The governments of the two potential production locations  $a$  and  $b$ , levy a pure profit tax on profits arising from production within their jurisdiction. It therefore impacts only on those firms who choose to be multinational. The prevailing tax rate is the result of a tax competition game between two governments. Full commitment to the announced tax rate is assumed. Consumers are distributed evenly between the two potential production locations. Therefore, each government seeks to maximise a social welfare function consisting of the sum of an equal share of consumer surplus plus any tax revenue.

Firms choose their site of production to take advantage of tax differentials and respond to tax differentials by locating or relocating production completely to the more favourable location. Governments anticipate the firms' location (and output) decisions and set taxes strategically. Firms choose their location after taxes have been set (since it is the aim of policy to attract multinational firms). The structure of each time period of the game is as follows:

**Stage 1:** Governments simultaneously choose tax rates

**Stage 2:** Firms simultaneously choose their location of production (domestic or foreign)

**Stage 3:** Firms simultaneously choose outputs

Non-cooperation by both governments and firms who meet each period in an infinitely repeated game is assumed.

Both agents (governments and firms) are forward looking and therefore must take into account further stages of the game when choosing their strategy. For example, when choosing taxation levels, governments must consider how it will affect the output and strategy choice of firms. Similarly for firms, when choosing their strategy choice, they must take into account taxation policy of governments. With (infinite) repetition of the game, forward looking agents must also look to future periods of the game when choosing strategies. For example when firms are choosing between the strategies of exporting or multinationalism, they must take into account not

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<sup>5</sup> One could perhaps imagine the set up as being two firms, for example a US and a Japanese firm, serving the EU from

only current taxation levels but also future taxation levels. In dynamic games, each agent can determine his behaviour or strategy choice at any period of the game as a function of the entire history of the game up until that point. Owing to the dynamic nature of the game, each firm must choose a strategy in order to maximise the present value of the stream of future expected profits. Assuming firms are somewhat impatient, the value of future profits will be discounted at a constant and positive rate denoted  $d$ .

The dynamic problem facing the agents cannot be solved without consideration of the relocation decision of firms. That is, since the model is dynamic, there exists the possibility that firms can revise previous investment decisions and possibly relocate production from one period to the next, as firm-mobility is also assumed. Similarly, there exists the possibility that governments can revise previous taxation decisions. Firms do not, however reverse strategy choices (exporting or multinationalism) from one period to the next. That is, firms choose their strategy choice in the first period of the game by comparison of the stream of profits associated with the alternative strategy options. If a firm deems multinationalism an unprofitable option in this period, for example due to large sunk costs (even though these costs may be spread over an infinite number of periods), there is no reason to assume that multinationalism will become a profitable option in subsequent time periods of the game. A similar argument holds for the exporting strategy option. Thus strategy choices (exporting or being multinational) in the first period of the game are irreversible, plant location decisions however are not. The subgame perfect Nash equilibrium (Nash for short) of the game can be characterised using backward induction.

As a preliminary step, it may be worthwhile to consider a simplified one-shot version of the game to exemplify the mechanics of the model. It must be noted however, that the remainder of this section repeats the material in section 3.3 of chapter three, and may be skipped if desired. To illustrate firms' choice of output in the last stage, consider a situation in which each firm operates a plant in country  $i$ , where  $i = a, b$  and where the tax rate is  $a_i$ . Firm 1 and 2 then solve the following maximisation problems:

$$\text{Firm 1: } \max_{q_1} (1 - \tau_i) \left[ \left( 1 - q_1 - q_2 - c + \frac{1}{2} \lambda \right) q_1 - G \right] \quad (5)$$

$$\text{Firm 2: } \max_{q_2} (1 - \tau_i) \left[ \left( 1 - q_1 - q_2 - c - \frac{1}{2} \lambda \right) q_2 - G \right] \quad (6)$$

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either Ireland or Portugal (assuming that they are multinational).

The profit-maximising outputs sold in the third market by Firm 1 and 2 are  $q_1^* = \frac{1}{3}\left(1-c+\frac{3}{2}\lambda\right)$  and  $q_2^* = \frac{1}{3}\left(1-c-\frac{3}{2}\lambda\right)$  respectively, whereas the equilibrium price in the third market is  $p^* = \frac{1}{3}(1+2c)$ .

Profits, post-tax are as follows:

$$\pi_1^* = (1-\tau_i) \left[ \frac{1}{9} \left\{ 1-c+\frac{3}{2}\lambda \right\}^2 - G \right] \quad (7)$$

$$\pi_2^* = (1-\tau_i) \left[ \frac{1}{9} \left\{ 1-c-\frac{3}{2}\lambda \right\}^2 - G \right] \quad (8)$$

Each firm's location decision in stage two of the game is based on a comparison of after-tax profits associated with the various alternative production strategies and location choices. Other possible production strategies include an exporting duopoly, Firm 1 a multinational and Firm 2 an exporter (and vice versa), a multinational monopoly or an exporting monopoly. The associated profit expressions are as follows:

#### Exporting Duopolists

$$\pi_1^* = \frac{1}{9} \left( 1-c+\frac{3}{2}\lambda-t \right)^2; \quad \pi_2^* = \frac{1}{9} \left( 1-c-\frac{3}{2}\lambda-t \right)^2 \quad (9)$$

#### Firm 1 a multinational, Firm 2 an exporter

$$\pi_1^* = (1-\tau_i) \left[ \frac{1}{9} \left\{ 1-c+\frac{3}{2}\lambda+t \right\}^2 - G \right]; \quad \pi_2^* = \frac{1}{9} \left( 1-c-\frac{3}{2}\lambda-2t \right)^2 \quad (10)$$

#### Firm 1 an exporter, Firm 2 a multinational

$$\pi_1^* = \frac{1}{9} \left( 1-c+\frac{3}{2}\lambda-2t \right)^2; \quad \pi_2^* = (1-\tau_i) \left[ \frac{1}{9} \left\{ 1-c-\frac{3}{2}\lambda+t \right\}^2 - G \right] \quad (11)$$

#### Firm 1 a multinational monopolist / Firm 2 a multinational monopolist

$$\pi_1^* = (1-\tau_i) \left[ \frac{1}{4} \left\{ 1-c+\frac{1}{2}\lambda \right\}^2 - G \right]; \quad \pi_2^* = (1-\tau_i) \left[ \frac{1}{4} \left\{ 1-c-\frac{1}{2}\lambda \right\}^2 - G \right] \quad (12)$$

#### Firm 1 an exporting monopolist / Firm 2 an exporting monopolist

$$\pi_1^* = \frac{1}{4} \left( 1-c+\frac{1}{2}\lambda-t \right)^2; \quad \pi_2^* = \frac{1}{4} \left( 1-c-\frac{1}{2}\lambda-t \right)^2 \quad (13)$$

In stage one, governments set taxes strategically. Each government chooses its taxation policy to maximise social welfare, taking as given the policy choice of the other country and taking into

account how its strategy will influence each firm's location and output choices. The utility (social welfare) of a representative country under conditions of a multinational duopoly presence is:

$$U_i^{MM} = \alpha_i \left[ \frac{2}{9} (1-c)^2 \right] + \tau_i \left[ \frac{1}{9} \left( 1-c + \frac{3}{2} \lambda \right)^2 + \frac{1}{9} \left( 1-c - \frac{3}{2} \lambda \right)^2 - 2G \right] \quad (14)$$

The first term is the country's share of consumer surplus,<sup>6</sup> whereas the second term represents tax revenue.

As can be seen from this last equation, the government's best tax policy would be to levy its maximum tax rate ( $\tau_i=1$ ). However, at this tax rate the rival government would be encouraged to set a lower tax rate to induce multinational behaviour in their country. This process of undercutting behaviour would repeat itself until countries can undercut no further. This occurs when taxes are zero in both countries. Subsidies are not optimal, as there would be no gain in consumer surplus,<sup>7</sup> while tax revenues would be negative. Thus with this Bertrand type result, the expression for social welfare would be reduced to that of consumer surplus only. The subgame perfect Nash equilibria would be that of the one-shot game with taxation as illustrated in Figure 1 below.

The Nash equilibrium outcomes for a given parameterisation are depicted in Figure 1 below. The equilibrium outcomes have the following representation: MM – two-plant duopoly; EE – export-duopoly; ME/EM - has Firm 1 (2) choosing to be multinational while Firm 1 (2) is an exporter; MO/OM – two-plant monopoly. Simply put, the strategy of exporting is denoted by “E” while “M” denotes the strategy of multinationalism.<sup>8</sup> The strategy representing a firm's choice not to serve the market in question is shown by an entry of “O”. The figure is generated by considering the various discounted profit boundaries for which firms are indifferent between alternative production strategies, when the game begins. For example, the boundary between the regions MM and EM/ME, gives the combinations of  $G$ ,  $t$  for which Firm 1 and Firm 2 are indifferent between one-plant and two-plant production (provided that the other firm is multinational) for the entire game.

For ease of interpretation, it may be convenient to divide the two-dimensional space of Figure 1 according to three main cost thresholds.

<sup>6</sup> It is assumed that each country maximises over an equal share of consumer surplus, thus setting  $\alpha_i=1/2$ .

<sup>7</sup> Since if the firm located in the rival country, this government would still maximise over the same consumer surplus. This result is due to the integrated market structure of the third market.

<sup>8</sup> The various multinational configurations are non-unique with respect to location decisions, i.e. with zero taxation, firms are indifferent between locating in country  $a$  or  $b$ . For simplicity we shall assume that, when indifferent between locations, multinationals locate together in country  $a$ .

- (a) Low transport costs:** At or below a cost level of  $t=(1-c)/2$ ,<sup>9</sup> each firm chooses between the strategies of exporting or becoming multinational. For sufficiently low levels of  $G$ ,<sup>10</sup> it is profitable for each firm to be multinational and we obtain the outcome MM, a two-plant duopoly or dual multinationalism. As  $G$  increases the multinational option becomes less and less attractive. Firstly, fixed costs reach a level such that it is feasible only for one firm to be multinational which leads us to the equilibria EM/ME.<sup>11</sup> Further increases in  $G$  induce both firms to opt out of the multinational option altogether and the EE equilibrium results.<sup>12</sup>
- (b) Intermediate transport costs:** For intermediate cost levels, and for sufficiently low levels of  $G$ ,<sup>13</sup> both firms choose to be multinational. Beyond this critical value of  $G$ , multinationality is profitable for one firm only if the other firm opts out of the market. At higher levels of  $G$ ,<sup>14</sup> the EE equilibrium emerges, as firms prefer to incur intermediate levels of transport costs than high fixed costs.
- (c) High transport costs:** At or beyond a cost level equal to  $t=1-c$ ,<sup>15</sup> firms must choose to either serve the market by being multinational or to remain out of the market. Again, for sufficiently low levels of  $G$ , the multinational strategy is preferred. For instance at a fixed cost level of  $G < \frac{1}{9} \left( \frac{(1-c)^2}{1-d} \right)$ ,<sup>16</sup> the multinational duopoly MM results, while for levels of  $G < \frac{1}{4} \left( \frac{(1-c)^2}{1-d} \right)$ ,<sup>17</sup> the multinational monopoly MO/OM are the Nash equilibrium outcomes. Firms opt out of the market altogether at a fixed cost level of  $G > \frac{1}{4} \left( \frac{(1-c)^2}{1-d} \right)$ .

<sup>9</sup> The derivation of this condition on  $t$  can be found in Appendix A.4, equation (43).

<sup>10</sup> That is,  $G < \frac{4t}{9} [1-c-t]$  [See equation (44), Appendix A.4].

<sup>11</sup> That is,  $G > \frac{4t}{9} [1-c-t]$ .

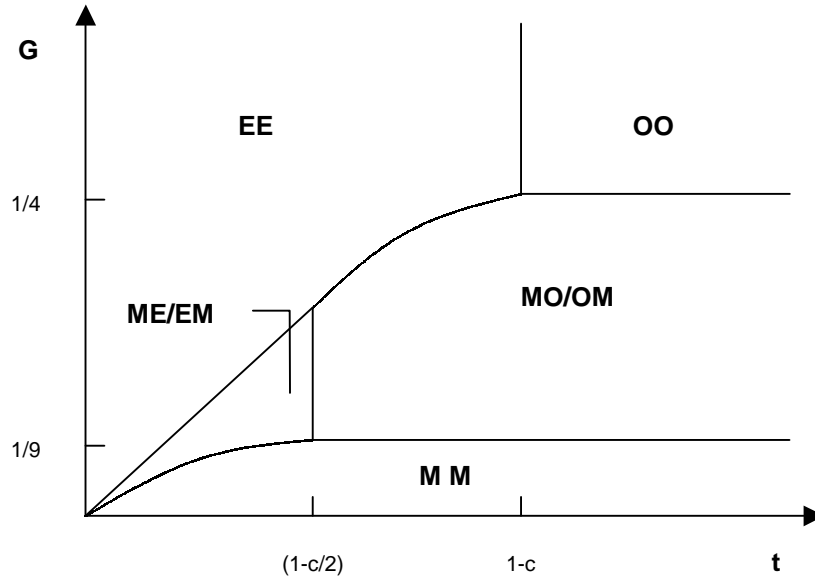
<sup>12</sup> That is,  $G > \frac{4t}{9} [1-c]$ . [See equation (45), Appendix A.4].

<sup>13</sup> That is,  $G < \frac{1}{9} [(1-c)^2]$ . [See equation (47), Appendix A.4].

<sup>14</sup> That is,  $G > \frac{1}{36} [5-10c+5c^2+8t-8ct-4t^2]$  [See equation (49), Appendix A.4].

<sup>15</sup> The derivation of this condition on  $t$  can be found in Appendix A.4, equation (46).

<sup>16</sup> See equation (47), Appendix A.4



**Figure 1:**  
*Equilibria with homogenous firms*

The Bertrand result for taxation policy also holds for the other multinational plant configurations mentioned above. Consideration of the levels of social welfare in each equilibria illustrates the incentives for governments to attract multinational activity in the foreign region. For example, consider the exporting duopoly case, the resulting social welfare for governments in the third market is:

$$U_i^{EE} = \alpha_i \left[ \frac{2}{9} (1-c-t)^2 \right] \quad (15)$$

Comparing equation (14) with equation (15), one can see that the governments have two motivations for inducing multinational activity. Firstly, multinational behaviour is associated with higher consumer surplus for the region. This result is independent of the firms' preferential location choice. Secondly, multinational activity generates (potential) tax revenues for the country in which firms choose to locate in.

The Nash equilibrium is considerably different when one considers repetition of the game. Now governments can revise taxation levels each period in the same way that firms can revise location decisions each period. As a result, when firms choose their strategy in the first period, they must take into account not only current taxation levels, but also taxation levels in subsequent periods.

<sup>17</sup> See equation (48), Appendix A.4

These issues are addressed in the remainder of the paper. Firstly, one must consider whether a non-cooperative equilibria will obtain in an infinitely repeated game. This is examined in the following section.

### 1.3 Cooperation in Infinitely Repeated Games

Infinite repetition brings about one more consideration, that is, the possibility of collusive behaviour. Although non-cooperative behaviour between agents, both firms and governments respectively has been assumed so far, the Folk Theorem<sup>18</sup> suggests that infinitely repeated games often facilitates collusive equilibrium outcomes. Infinite repetition may bring about additional equilibria as players can support desirable outcomes with threats to punish cheating by playing the non-cooperative Nash equilibria outcome. Therefore we must next examine the possibility that firms and governments choose between competitive and collusive behaviour. I assume that collusion between firms is tacit, as collusion in the form of explicit agreements is illegal. For firms, collusion involves the lowering of industry output below the Cournot level. More specifically, each firm produces one-half of the monopoly output to keep industry prices and profits higher than the non-cooperative outcome. In this instance I assume collusion may be sustained by a grim/trigger punishment strategy. Here, each firm initially chooses the collusive output and maintains this output as long as the other firm chooses this output, otherwise it chooses the Cournot output and continues to do so in all subsequent periods of the game. Thus defecting from the initial agreement triggers a punishment in the form of lower profits to time infinity. We must therefore examine the circumstances under which this strategy may or may not be sustained.

For ease of understanding, I shall assume initially that firms invest in the same way, i.e. firms are either both exporters or both multinationals. In addition, I also exclude any exogenous cost discrepancies between firms ( $\lambda=0$ ). For exporters, the payoffs if they collude (cooperate) or cheat are given by equations (65) and (66) in section A.5 of the Appendix. Cooperation is an equilibrium phenomenon as long as the gains from cheating today are less than the benefits of continued cooperation in the future. It can be shown that for a discount factor of  $d > 9/17$ , collusion yields at least as high a level of discounted profit as cheating. Instead, if both firms invest abroad, i.e. become multinational, the collusive and cheating profits are given by equations (67) and (68). Again, collusion is sustainable for a discount factor of  $d > 9/17$ .

For firms with asymmetric costs, derived from either investment strategies or exogenous factors, collusion is harder to sustain. For example, keeping the assumption of homogeneity between

firms, if either firm invests abroad while the other firm remains an exporter, the multinational firm will require a higher discount rate in order to commit to a strategy of collusion. The exporter on the other hand is willing to collude at a lower discount rate (See diagrams in Appendix A.5). Since both firms need to be in agreement before collusion can occur, it is the higher discount rate that matters. Heterogeneity in the form of asymmetric variable costs again poses problems for collusion. For example, simulations show that heterogeneous multinational firms may collude only for discount factors in excess of one. Thus tacit collusion is most easily sustained when firms are symmetric. In this instance it may be ruled out by assuming a discount factor below the critical value of  $d < 9/17$ . This assumption is adopted in the analysis that follows.

The method of collusion between governments of the two host countries is less clear cut. Hypothetically, the collusive agreement would involve one government permitting the other to maintain a tax level beyond that set by optimality. The opposing government would have to maintain a less attractive tax rate and refrain from undercutting the rate set by the other government. Side-payments would disperse the gains from collusion equally between governments. To keep the analysis simple, I assume a system of side-payments between governments of opposing countries is unsustainable, thus ruling out the possibility of government collusion.

## 1.4 Equilibria in an Infinitely Repeated Game: Symmetric Firms and no Taxation

In this section, I solve a simplified version of the infinitely repeated game by assuming symmetry between firms and a policy of laissez-faire by governments. These assumptions permit one to ignore (for the moment) the role of the asymmetry parameter  $\lambda$ , while at the same time ignoring the possibility of taxation. This game will be used as a reference point for subsequent versions of the game. It is useful in itself as it conveys to the reader, the consequences of game-repetition for the firm's choice of strategy, compared to that of the one-shot game of the previous section. Therefore, this version of the game should make explicit, the tension between two key parameters of the model  $G$  and  $t$  **and** their interaction over time in determining the equilibrium market structure and the emergence of multinational behaviour.

The game is solved in the usual way by backward induction. In addition, without government involvement each period of the game reduces to two stages:

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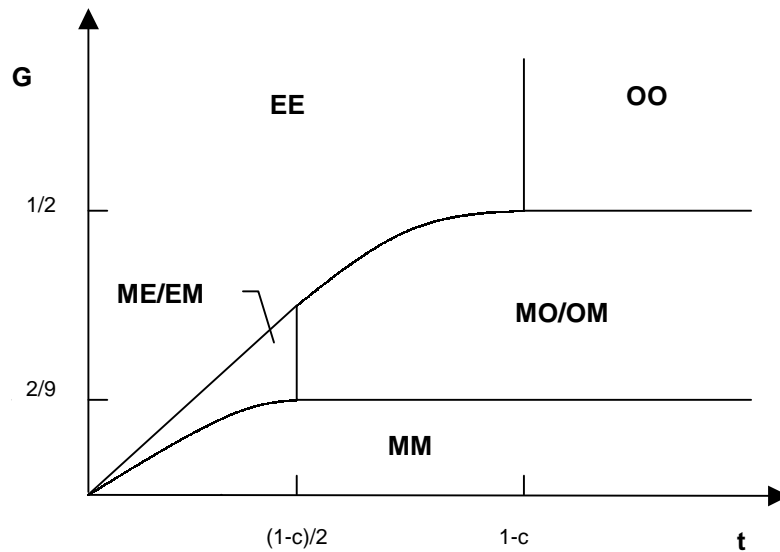
<sup>18</sup> For a comprehensive discussion of the Folk Theorem see Tirole (1993).

**Stage 1:** Firms simultaneously choose their location of production (domestic or foreign)

**Stage 2:** Firms simultaneously choose outputs

Thus, we first must obtain equilibrium outputs and hence prices and profits for each firm under every conceivable combination of the firms' stage one choice. The profit expressions for these outcomes can be found in section A.2 of the Appendix. Having ultimately solved the second stage of the game, one must turn to the optimal first stage strategy of each firm, given the strategy of the other firm. The equilibrium solution concept is Nash, where each firm makes an optimal choice given it has correct beliefs regarding its opponents choice. However the game is repeated and there is infinite interaction between firms in choosing strategies. Firms face each other in the third market, over an infinite number of time periods. So, each firm must decide upon its strategy in order to maximise the present value of the stream of future profits it can expect to accrue. Profits are discounted and the discount factor is represented by  $d$ . Provided that this rate is positive ( $>0$ ), with repetition, the profitability of pursuing **each** strategy is now increased. Furthermore, firms who choose to be multinational can now spread the associated sunk costs over an infinite number of time periods. To illustrate these two points we will refer to the beginning of the game, or the period when firms choose their strategy of serving the foreign market, as time period 0, or  $t_0$ . In this time period, firms choose their strategy taking into account the stream of future profits. Thus all firms will discount profits beyond this time period whereby multinational firms will incur a sunk cost in this period and not subsequently.

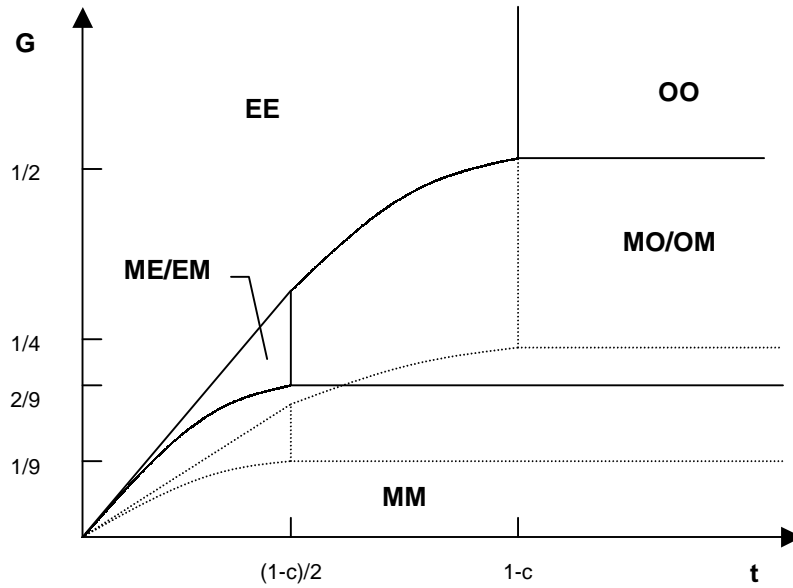
It is perhaps worthwhile to note that when firms choose their strategy (export/multinationality) they do so by consideration of future and present profits arising from that strategy choice. Consequently, when a firm chooses a particular strategy, it is the strategy they pursue from period  $t_0$  to infinity. The equilibria outcomes are presented in Figure 2 below.



**Figure 2:**  
*Equilibria in an infinitely repeated game with homogenous firms ( $d=0.5$ )*

Although similar to Figure 1, Figure 2 is dynamic, and shows the profitability between the alternative production strategies over an infinite, as opposed to a single time period.<sup>19</sup> That is, in this game, firms choose strategies to maximise the present value of the stream of future profits that it can expect to accrue. Compared to a one-shot game, in an infinitely repeated game the strategy of multinationalism is more profitable relative to the strategy of exporting. As previously mentioned, multinational firms must incur the additional sunk cost of being multinational in time period  $t_0$  only. As a consequence multinational firms enjoy even higher profits in all subsequent periods. Exporters on the other hand must incur transport costs in each period and thus has lower outputs and hence market share. This feature of the infinitely repeated game can be seen when one compares the one-shot with the infinitely repeated game. This comparison is featured in Figure 3 below.

One can see that for the given discount rate, the scale of the infinitely repeated game is twice that of the one-shot version. Furthermore, the spaces hosting the (multinational) outcomes i.e. MM; ME/EM; MO/OM, double in size. In essence, with game repetition, multinationality is now profitable for higher fixed cost levels, this is true for every given level of  $t$ . As a consequence, the regions hosting the outcomes EE and OO both contract. Thus not only is time encouraging multinational as opposed to exporting behaviour, but in addition, it also increases the possibility that the market will be served. These results become even more exaggerated the more importance firms place on future profits (i.e. the lower is the discount rate).



**Figure 3**  
*Equilibria in a one-shot and in an infinitely repeated game ( $d=0.5$ )*

In summary, this infinitely repeated game with symmetric firms generates the following symmetric equilibrium outcomes: MM; EE; OO. Asymmetric outcomes, namely: ME/EM and MO/OM<sup>20</sup> obtain for particular  $G, t$  levels and represent the presence of the fixed cost parameter. In a particular range of  $G$ , the market, over an infinite number of time periods can at most support one multinational. Provided transport costs are below the critical value of  $t < (1-c)/2$  we obtain the outcomes ME or EM. Beyond this critical value (and assuming that the other firm is multinational) the exporting option disappears and the outcome OM or MO emerges. Overall, Figure 2 displays the following pattern: increases in  $t$  bring about the emergence of multinationalism whereas increases in  $G$  make the exporting option more popular. For sufficiently high levels of both  $t$  and  $G$ , firms do not serve the market and the OO outcome obtains in equilibrium. Alternatively, dual multi-plant production arises when fixed costs are small relative to transport cost. For intermediate values of fixed costs and transport costs, the asymmetric equilibrium ME or EM arises. Finally, when transport costs are large relative to fixed costs, the multinational monopoly structure becomes dominant. These results are analogous to that of Horstmann and Markusen (1992) and supports the tension between the two key parameters,  $G$  and  $t$ , namely fixed and transport cost, in determining individual firm plant configuration type.<sup>21</sup> The results do however

<sup>19</sup> Note that for a discount factor of 0.5, the scale of the infinitely repeated game exactly doubles compared to that of the one-shot game.

<sup>20</sup> The determination of which outcome will emerge as an equilibrium outcome, i.e. either EM or ME, MO or OM is beyond the scope of this model.

<sup>21</sup> With the exception that in their model, certain equilibria (namely EM/ME) are ruled out with appropriate qualifications.

extend their analysis in that here, firms' strategy choices depend on a stream of, as opposed to "once-off" profits. The results show that with repetition, and for a given discount rate, multinational firms obtain a strategic advantage over exporters, with time conferring positive future profits, which are independent of the fixed costs associated with being multinational.

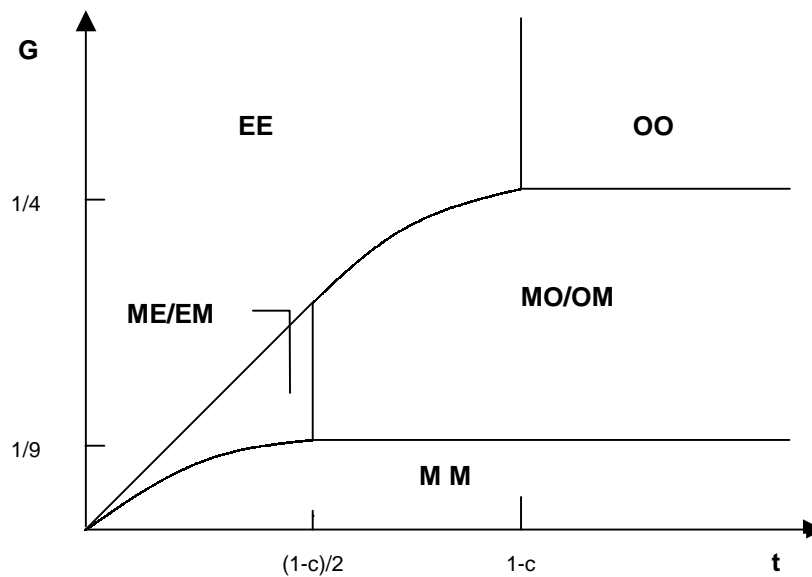
## 1.5 Equilibria in an Infinitely Repeated Game: Symmetric firms and Taxation

Keeping the assumption of symmetry between firms, this section analyses the extent to which taxation affects multinational activity. That is, in this model, each government places a profit tax on total profits arising from production within their jurisdiction. As a consequence, it becomes effective only if the firms from Country 1 and 2 become multinational. Similarly, it can be avoided by choosing the alternative exporting strategy. Thus the following analysis will concentrate on the extent to which strategic taxation policy will prohibit/promote multinational activity. Recall, in this model, each government's incentive to induce multinational activity in their country arises from the gain of higher consumer surplus and (potentially) positive tax revenues. With strategic interaction between governments and with repetition of the game, the implications of taxation are not as straight forward as in a one-shot game. Consider the following. In this model, each government will bid against the other to induce multinational behaviour in their country. In time period  $t_0$ , this will result in zero tax rates as governments undercut each other in an attempt to gain a competitive advantage. Thus we obtain a variation of the well-known Bertrand result. With zero taxation (in each location) within the third market, each firm must choose its configuration type as before, by consideration of the two key parameters of the model,  $G$  and  $t$  (exhibiting the tension between the alternative production strategies). For various combinations of  $G$ ,  $t$ , we obtain different representations of multinational behaviour. As can be seen from the one-shot game (with zero tax rates), for very low fixed cost levels the equilibrium MM results, for intermediate fixed cost levels and for low  $t$  values, the equilibrium EM/ME results. Similarly, for intermediate levels of  $G$  and  $t$ , the equilibrium MO/OM results. These various configurations of multinational behaviour are non-unique with regard to location decisions, i.e. under zero taxation; firms have no preferences for locating in country  $a$  or  $b$ . For simplicity, we assume that owing to factors outside this model, one country "wins" multinational activity, we shall assume that this is Country  $a$ . However, these plant configuration types are by no means the equilibria of the game, for they are the results of strategic firm behaviour in a static or once-off game, whereas in this model, the subgame perfect Nash equilibria is obtained by considering also, the future stream of profits. However, they are nonetheless, the equilibria results for time period  $t_0$ .

The game is played again in time period  $t_1$  (and indeed all subsequent time periods), and again, governments will choose tax rates. Those firms who have previously located production in the third market will also have the option of relocating production to the other host country (if needs be). The mechanism is as follows. In this second time period, the government who previously won multinationals, (Country  $a$ ) will attempt to increase taxation levels. They do so in an attempt to extract positive tax revenues. Governments are aware of how taxation will effect the outputs and profits of firms, and must set a non-prohibitive tax rate. By this I refer to a rate of taxation that will not induce firms to relocate out of their country. Their optimal tax policy would be to set a tax that leaves firms indifferent between enduring the additional tax burden and incurring relocation costs ( $G^R$ , which is equivalent to  $G$ ) associated with setting up a production plant in the other country. Thus the government of Country  $a$  will set the profit tax in accordance to relocation costs. For example, if relocation costs ( $G^R$ ) are zero, firms (located in Country  $a$ ) faced with the prospect of taxation hikes, can costlessly relocate production to Country  $b$ . Consequently, the government of country  $a$  who wishes to maintain a multinational presence must set a zero tax rate. As the cost burden of relocation increases, the government of Country  $a$  can exploit firms, increasingly so, by levying a positive tax. Thus, in this model the optimal tax rate is set in accordance to relocation costs and in equilibrium, the optimal tax rate ( $\tau^*$ ) is set equal to the fixed cost ( $G^R$ ) of relocation.

For the government of Country  $b$ , it must undercut the government of Country  $a$  by the full amount if it wishes to induce multinational behaviour in their country. If Country  $a$  maintains a taxation level within the limits set by optimality, it will never lose multinational firms, and its taxation policy will promote multinational behaviour in that country. The argument also holds if Country  $b$  was initially the “winner”. The profit functions, taking into consideration this setting of tax rates, appear as equations (31) to (42) in section A.3 of the Appendix.

We can now turn to the sub-game perfect Nash equilibria of the infinitely repeated game with taxation. Firms, in period  $t_0$ , choose their strategy choice by considering the stream of profits under the alternative production regimes. Due to the way the “winner” sets taxation, i.e. by levying taxes that just offset relocation costs, it is as though firms are incurring  $G$  each period. Thus the equilibria of the infinitely repeated game with an endogenous tax rate is that of the one-shot game without taxation (See Figure 1). This is illustrated in Figure 4 below.



**Figure 4:**  
*Equilibria in an infinitely repeated game with homogenous firms and taxation*

The impact of taxation becomes more apparent if one considers, once again, Figure 3. We can now interpret the broken lines as the boundary lines for the infinitely repeated game with taxation. With taxation and for the given discount rate, the space in which the multinational outcomes MM; MO/OM; ME/EM previously occupied is now reduced, or more precisely, halved. On the other hand, the region EE and OO expand with taxation. Thus, with multinationality being less attractive than before, firms now opt for the exporting option of serving the foreign region. Furthermore, taxation also means that it is now more likely that the market will not be served at all.

## 1.6 Equilibria in an Infinitely Repeated Game: Asymmetric Firms and no Taxation

Reverting to the assumption of laissez-faire, I now introduce and consider the role of the parameter  $\lambda$ . Recall,  $\lambda$  is a variable cost parameter that measures that cost discrepancy between the two firms. Positive values of  $\lambda$  place firm 1 at a cost advantage whereas negative values of  $\lambda$  place firm 2 at a cost advantage. Again, I limit the analysis to consider positive values only, conferring a definite cost advantage of Firm 1 over Firm 2.

With asymmetry, the regions corresponding to the various equilibrium regimes will undoubtedly alter in the  $G, t$  space. Furthermore, it will also be responsible for the emergence of new regions corresponding to asymmetric equilibria, namely MO/EM, MO and EO. In addition, one must also consider the dynamics of this game compared to that of the simplified one-shot version of the game. In this instance, the game is repeated (infinitely). As was the case with the symmetry game, dynamics impact on multinational firms in a different manner to exporting firms. For instance, to pursue the strategy of multinationality, firms must incur a once-off sunk cost in time period  $t_0$ , and not subsequently. Firms, who choose a strategy of exporting, must incur a per-unit transport cost, each period from  $t_0$  to infinity. Thus dynamics (in the form of infinite repetition) favours multinational firms over exporters. However, time favours efficient firms more, this can be seen from the diagram below. Not only do the multinational regions expand at the consequence of exporting regions (hence giving all multinational firms more opportunity), but the regions in which the efficient firms have gained a monopoly (MO) or multinationality (ME) have expanded also. I proceed by dividing the  $G, t$  space of Figure 5 according to the following threshold values referred to as  $t_1^*$ - $t_4^*$  in equations (50) to (53) of the Appendix.

**(a)  $0-t_1^*$ :** At or below a cost level of  $t_1^* = \frac{1}{2} \left( 1 - c - \frac{3}{2} \lambda \right)$ , each firm chooses between the strategies of exporting or becoming multinational. For sufficiently low levels of  $G$ <sup>22</sup>, it is profitable for both firms to engage in multinational behaviour and the equilibrium outcome MM obtains in equilibrium. With cost asymmetry, increases in  $G$  mean that the cost inefficient firm finds it increasingly difficult to absorb the fixed cost associated with becoming multinational. As a result, for fixed costs immediately beyond the initial value for  $G$ ,<sup>23</sup> the equilibrium outcome ME is dominant. There also exists a small region, within the region corresponding to the ME outcome,<sup>24</sup> where both firms find it profitable to be multinational provided that the rival firm is not (i.e. the rival firm will be an exporter in this region). It may be worth noting that the following regions corresponding to multinational behaviour, EM/ME and MM have contracted in comparison to the symmetric case (Figure 1). In addition we witness the emergence of a new region, namely ME. That is, firm one who is faced with a cost advantage is now in a better position to absorb the fixed costs of opening an additional plant. Firm two, on the other hand, being at a cost disadvantage, is now less willing to become multinational. Furthermore, Firm 2 finds it increasingly difficult to be an exporter competing with a cost-

<sup>22</sup> That is,  $G < \frac{4t}{9(1-d)} \left( 1 - c - \frac{3}{2} \lambda - t \right)$  [See equation (54) in section A.4 of the Appendix.]

<sup>23</sup> That is,  $G > \frac{4t}{9(1-d)} \left( 1 - c - \frac{3}{2} \lambda - t \right)$  [See equation (54) in section A.4 of the Appendix].

<sup>24</sup> That is,  $G > \frac{4t}{9(1-d)} \left( 1 - c + \frac{3}{2} \lambda - t \right)$  and  $G < \frac{4t}{9(1-d)} \left( 1 - c - \frac{3}{2} \lambda \right)$  [See equations (55) and (56) in section A.4 of the Appendix].

efficient multinational. For sufficiently high fixed cost levels,<sup>25</sup> both firms choose to be exporters and the equilibrium outcome EE results.

**(b)  $t_1^* - t_2^*$ :** In this region, where,  $t_1^* = \frac{1}{2}\left(1-c-\frac{3}{2}\lambda\right)$  and  $t_2^* = \frac{1}{2}\left(1-c+\frac{3}{2}\lambda\right)$  each firm chooses between the strategies of exporting or becoming multinational. However, it is now no longer profitable for Firm 2 (as an exporter) to compete with Firm 1 (as a multinational). As a result, in this region the equilibrium outcome ME disappears and is replaced by the equilibrium outcome MO. For sufficiently low levels of  $G$ ,<sup>26</sup> both firms choose the multinational option and the dual-plant duopoly MM emerges in equilibrium. Beyond this value of  $G$ , the market can at most support one multinational firm. Initially this opportunity is afforded to Firm 1 and the multinational monopoly outcome MO emerges. As fixed costs increase,<sup>27</sup> Firm 2 will enter as a multinational only if Firm 1 chooses the exporting option. Otherwise it opts out of the market altogether. This brings us to the region EM/MO in the figure below. Further increases in fixed cost  $G$ <sup>28</sup> leads to Firm 1 choosing to enter the market as a multinational. Since Firm 2 cannot compete (profitably) with a multinational in this region, the outcome MO obtains in equilibrium. As fixed costs increase further,<sup>29</sup> both firms can enter the market as exporters and the exporting duopoly emerges again in equilibrium.

**(c)  $t_2^* - t_3^*$ :** In this region, where  $t_2^* = \frac{1}{2}\left(1-c+\frac{3}{2}\lambda\right)$  and  $t_3^* = 1-c-\frac{3}{2}\lambda$ , both firms choose between the strategy of exporting and becoming multinational. It emerges that in a particular range of  $G$ , it is only profitable for a firm to be multinational only if the rival firm opts out of the market. For sufficiently low levels of  $G$ <sup>30</sup> the dual-plant duopoly emerges again. Beyond this value of  $G$ , it is profitable for Firm 1 to stay multinational in this region; on the other hand, Firm 2 cannot compete with a multinational in this region and opts out of the market leading to the MO outcome. For higher levels of  $G$ ,<sup>31</sup> it is profitable for either of the two firms to become multinational, provided that the rival firm opts out. In other words, the market can at most

<sup>25</sup> That is,  $G > \frac{4t}{9(1-d)}\left(1-c+\frac{3}{2}\lambda\right)$  [See equation (57) in section A.4 of the Appendix].

<sup>26</sup> That is,  $G < \frac{1}{18(1-d)}\left(1-c-\frac{3}{2}\lambda\right)^2$  [See equation (58) in section A.4 of the Appendix].

<sup>27</sup> That is  $G > \frac{4t}{9(1-d)}\left(1-c+\frac{3}{2}\lambda-t\right)$  [See equation (55) in section A.4 of the Appendix].

<sup>28</sup> That is,  $G < \frac{4t}{9(1-d)}\left(1-c-\frac{3}{2}\lambda\right)$  [See equation (56) in section A.4 of the Appendix].

<sup>29</sup> That is,  $G > \frac{1}{144(1-d)}(20-40c+32t-12\lambda+20c^2-32ct-16t^2+12\lambda c+48\lambda t-27\lambda^2)$  [See equation (59) in section A.4 of the Appendix].

<sup>30</sup> See Footnote 26.

<sup>31</sup> That is,  $G > \frac{1}{18(1-d)}\left(1-c+\frac{3}{2}\lambda\right)^2$  [See equation (60) in section A.4 of the Appendix].

support one multinational firm. As fixed costs increase further,<sup>32</sup> this possibility is no longer feasible for Firm 2 and the equilibrium MO results. For sufficiently high levels of  $G$ ,<sup>33</sup> neither firm finds a dual-plant strategy profitable and the exporting duopoly outcome EE results in equilibrium.

**(d)  $t_3^* - t_4^*$ :** In this region of both high transport and fixed cost, where  $t_3^* = 1 - c - \frac{3}{2}\lambda$  and

$t_4^* = 1 - c + \frac{1}{2}\lambda$ , Firm 1 chooses between the strategies of exporting and becoming multinational.

Firm 2 however, no longer finds exporting a profitable strategy. It must therefore incur the fixed cost associated with a dual-plant structure if it wishes to enter the market. For low levels of  $G$ ,<sup>34</sup> the dual-plant duopoly emerges and the MM outcome emerges in equilibrium. Beyond this fixed cost level, Firm 1 chooses to remain multinational. Firm 2 cannot compete with a multinational in this region and so the equilibrium MO results. As fixed costs continue to increase,<sup>35</sup> the market can once again, support one multinational, either Firm 1 or Firm 2 and the region MO/OM persists in the equilibrium space. Further increases in  $G$ <sup>36</sup> make it unprofitable for the inefficient firm to remain in the market and Firm 1 enjoys a multinational monopoly while as fixed costs increase further,<sup>37</sup> Firm 1 enjoys an exporting monopoly and the region EO emerges for the first time.

**(e)  $t > t_4^*$ :** In this final region, where  $t_4^* = 1 - c + \frac{1}{2}\lambda$ , the exporting strategy is no longer profitable

for either firm. Consequently, each firm chooses either to be multinational or to remain out of the market. Again, for sufficiently low fixed cost levels,<sup>38</sup> the dual-plant duopoly MM emerges. As  $G$  increases Firm 1 persists with the strategy of multinationalism and as a consequence Firm 2 opts out of the market and we obtain the region MO. For higher fixed cost levels,<sup>39</sup> Firm 2 finds it profitable to compete with Firm 1 for the multinational monopoly, which moves us into the region MO/OM. Further increases in  $G$  drive the inefficient firm out of the market leaving Firm 1 to enjoy a multinational monopoly. Finally, as  $G$  increases

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<sup>32</sup> That is,  $G > \frac{1}{144(1-d)} (20 - 40c + 32t + 12\lambda + 20c^2 - 32ct - 16t^2 - 12\lambda c - 48\lambda t - 27\lambda^2)$  [See equation (61) in section A.4 of the Appendix].

<sup>33</sup> See Footnote 29.

<sup>34</sup> See Footnote 26.

<sup>35</sup> See Footnote 31.

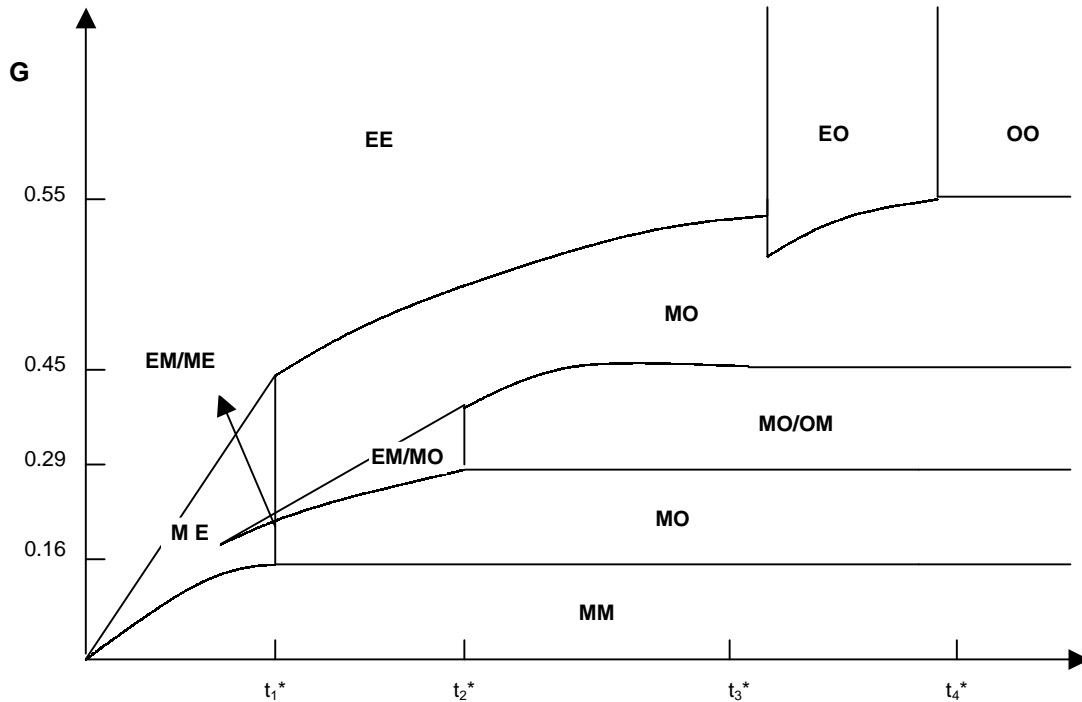
<sup>36</sup> That is,  $G > \frac{1}{4(1-d)} \left(1 - c - \frac{\lambda}{2}\right)^2$  [See equation (62) in section A.4 of the Appendix].

<sup>37</sup> That is,  $G > \frac{t}{2(1-d)} \left(1 - c + \frac{\lambda}{2} + \frac{1}{2}t\right)$  [See equation (63) in section A.4 of the Appendix].

<sup>38</sup> See Footnote 26.

<sup>39</sup> See Footnote 31.

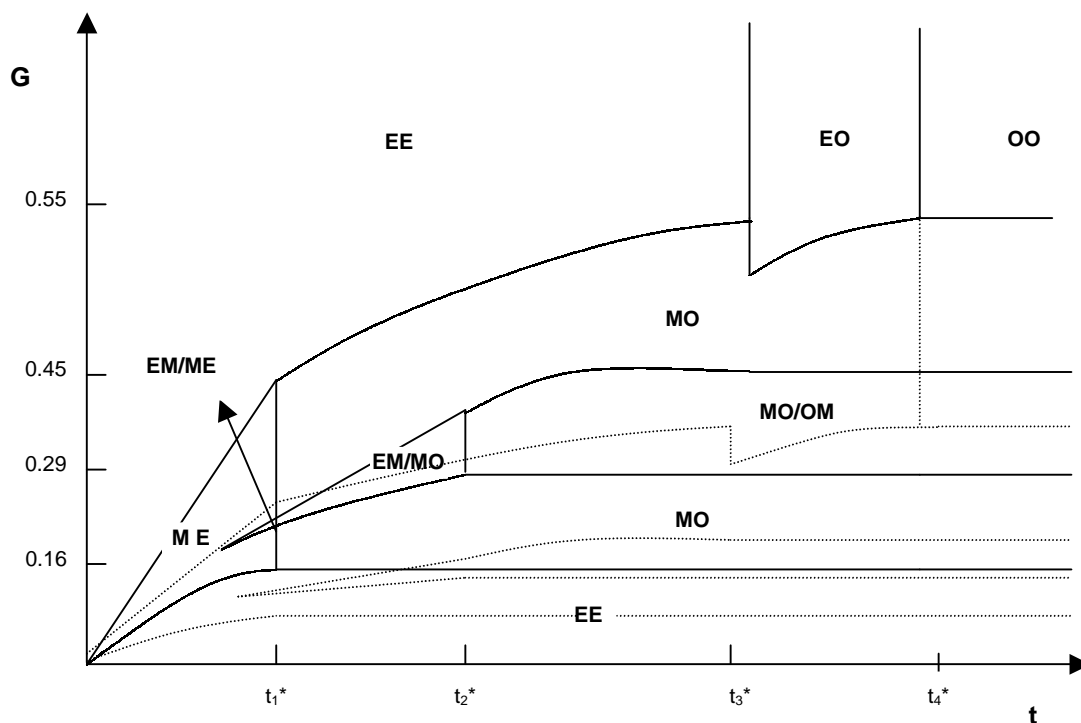
further,<sup>40</sup> neither firm will choose to serve the market and the equilibrium outcome OO obtains.



**Figure 5**  
*Equilibria in an infinitely repeated asymmetric game without taxation ( $d=0.5$ )*

Figure 6 compares the infinitely repeated game with that of the once off. The broken lines of Figure 6 represent the boundary lines from the one-shot version of the game. Again, for the given discount rate, the scale of the infinitely repeated game doubles compared to that of the one-shot game. As a result the regions hosting the (multinational) outcomes MM; ME; EM/ME; EM/MO; MO/OM; MO double in size. As a consequence, the outcomes EE; EO; OO, all contract. Thus the possibility of spreading fixed costs over an infinite number of time periods encourages both types of firms to be multinational as opposed to exporters, as firms are now willing to be multinational at higher fixed cost levels.

<sup>40</sup> That is,  $G > \frac{1}{4(1-d)} \left(1 - c + \frac{\lambda}{2}\right)^2$  [See equation (64) in section A.4 of the Appendix].



**Figure 6**  
*Equilibria in an infinitely repeated asymmetric game with taxation ( $d=0.5$ )*

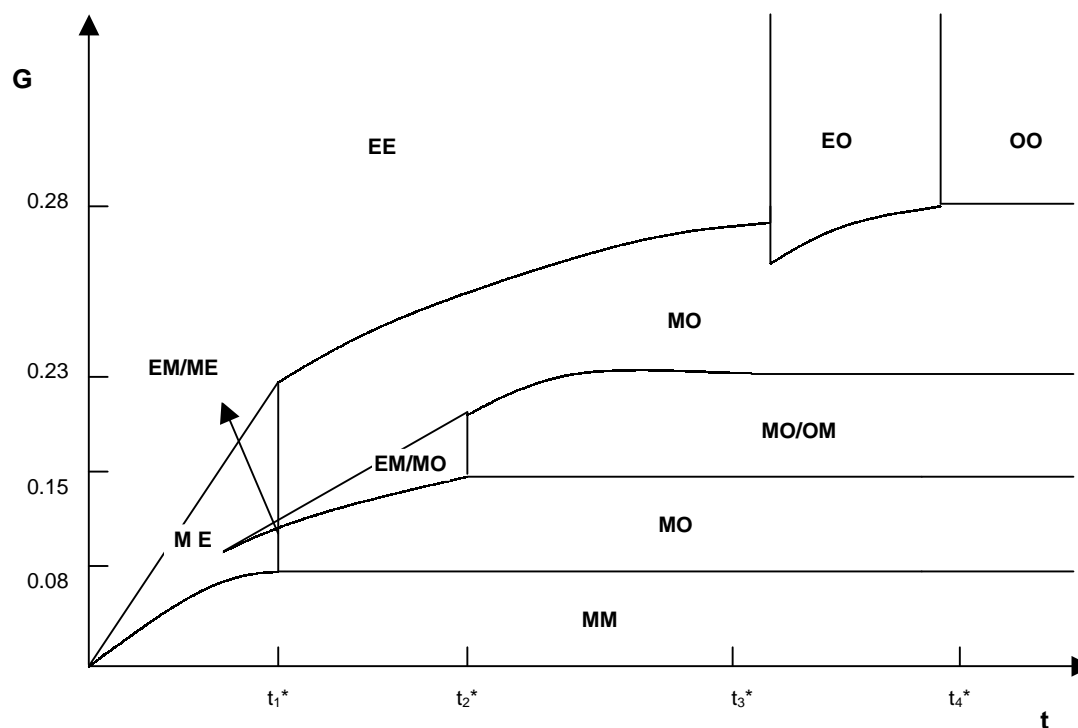
## 1.7 Equilibria in an Infinitely Repeated game: Asymmetric Firms & Taxation

In this section, I analyse the equilibria of the full game i.e. tax competition for heterogeneous firms. These equilibrium outcomes are summarised in Figure 7 below. Recall once more, that each government's incentive to induce multinationality as opposed to exporting behaviour stems from the attempt of governments to claim higher consumer surpluses and positive tax revenues. Despite the introduction of firm heterogeneity, the analysis of taxation with strategic government behaviour is similar to that of section 1.4. Thus, in a one-shot version of the game, we would expect that bidding by governments would result in a zero tax rate, in both countries – the previously mentioned Bertrand result. Indeed, this is how the optimal tax rate is chosen in the first stage of the game, time period  $t_0$ . With zero tax rates, the high and low-cost firms must choose their plant configuration type by consideration of profits under the alternative strategies of serving the third market. Firm 1, having a definite cost advantage over Firm 2, is better able to serve the foreign market locally, by being multinational. The converse is also true. Again, for various  $G, t$  combinations, we can obtain the equilibrium market structure. The various

representations of multinational behaviour; MM; EM/ME; ME; EM/MO; MO; MO/OM, are non-unique with respect to location decisions, but again for simplicity, we shall assume firms who choose to be multinational do so in country *a*. However, these location decisions are by no means the equilibria of the full game, for the game is played an infinite number of times. Thus, a firm's strategy choice will be based on future as well as present profits.

We must therefore consider what happens when the game is played in period  $t_1$  (and subsequent time periods). The government of country *a*, who obtained multinationals in  $t_0$  knows that firms are to some degree "tied" to country *a*. By this I mean that firms have chosen to incur the fixed cost  $G$  there and will be therefore reluctant to relocate production and in effect, re-incur  $G$ . This feature of the model provides the government of country *a* the opportunity to levy a punitive tax rate on multinational firms. As in section 1.4, governments must set a non-prohibitive tax rate that leaves firms indifferent between incurring the additional tax burden and relocating production. The government of country *a* must keep taxation within this boundary if it is to maintain the multinational presence. On the other hand, the government of country *b* must undercut the government of country *a* by the full amount if it wishes to induce multinational behaviour away from country *a* into country *b*. Provided the government of country *a* maintains taxation levels within the boundaries set by optimality, it will never lose multinational firms and its taxation regime will continue to promote multinational activity in their country.

Because governments set taxes to just offset relocation costs ( $\tau^* = G^R$ ), it is as though firms are incurring  $G$  each period. Thus the equilibria of the infinitely repeated game with taxation (see Figure 7) is that of a one-shot game without taxation. Therefore to compare the before and after taxation equilibria of the infinitely repeated case, one can use as a guide, Figure 6. The results are as follows. As one might expect, taxation discourages multinational activity with the regions hosting multinational outcomes; MM; EM/ME; EM/MO; MO; MO/OM halving in size. As a consequence exporting, as a means of serving the foreign market is now relatively more attainable. This can be seen as the regions EE and EO increase. The region OO increases as for given levels of  $G$  and  $t$ , exporters and now multinationals find this method of serving the market unprofitable. It is perhaps interesting to note that since the relocation burden ( $G = G^R$ ) is identical between asymmetric firms, there is no discrimination of the tax burden between cost-efficient and cost-inefficient firms. Indeed, the burden of taxation ( $\tau^* = G^R$ ) is the same for all multinational firms, whether the firm is cost-efficient or cost-inefficient, or whether it is a multinational monopolist or duopolist. Thus, asymmetry holds no role in tax-setting.



**Figure 7**  
*Equilibria in a asymmetric game with taxation*

## 1.8 Conclusion

This paper analyses tax competition in the context of imperfect competition when firms are mobile and have alternative methods of serving markets. Tax competition is motivated by rivalry between governments to attract multinational firms in order to extract higher consumer surplus and (potentially) positive tax revenues. However, firms respond to tax differentials by relocating production (completely) to the rival country. The analysis suggests that multinational firms who initially choose a particular location for production, will remain committed to that location when faced with the possibility of relocation provided taxation in the initial location remains “non-prohibitive”. In addition, the “non-prohibitive” taxation level is identical between heterogeneous firms. Beyond this taxation level, locations that previously won multinationals will lose multinational firms to their rival as multinational firms relocate production. Thus, although intertemporal time commitment is not assumed, it is as though firms, in the first period, are committing to actions in the second (and indeed all subsequent) time period(s).

Extensions include the introduction of location specific fixed costs. Here, the location of multinational production would be deterministic, with mobile firms choosing to locate in the low-

cost environment. This may be a way of introducing country- as opposed to firm-specific advantages.

## Appendix

The Appendix is arranged as follows. The first section, section A.1, is a guide to how equilibrium outputs and profits are solved for in a one-shot Cournot game. The next section, section A.2, introduces dynamics and gives the profit expressions of an infinitely repeated Cournot game. Section A.3 presents the profit expressions for the full game – asymmetry in an infinitely repeated game with endogenous taxation. Section A.4, should act as an accompaniment to the diagrams presented throughout the body of the text. More specifically, it shows how the various critical values and boundary lines were solved for in the symmetric and asymmetric games with infinite repetition. The last section, section A.5, explores the possibility of collusion in a symmetric model.

### A.1

In Cournot duopoly models, each firm maximises profit over output, given the output of the other firm. In these models, there exists the following standard expression for equilibrium profit:

$$\pi_i^* = q_i^{*2} - G_i \quad (16)$$

where, in an asymmetric cost game, equilibrium outputs are:

$$\begin{aligned} q_1^* &= \frac{1}{3}(1 - 2c_1 + c_2) \\ q_2^* &= \frac{1}{3}(1 - 2c_2 + c_1) \end{aligned} \quad (17)$$

The parameters  $c_1$  and  $c_2$  represent variable costs for Firm 1 and 2 respectively, they are defined as follows:

$$c_1 \equiv \begin{cases} c - \frac{\lambda}{2} + t & \text{if an exporter} \\ c - \frac{\lambda}{2} & \text{if not} \end{cases} \quad (18)$$

$$c_2 \equiv \begin{cases} c + \frac{\lambda}{2} + t & \text{if an exporter} \\ c + \frac{\lambda}{2} & \text{if not} \end{cases} \quad (19)$$

In addition, there exist fixed or sunk costs associated with opening an additional plant:

$$G_i \equiv \begin{cases} G & \text{if multinational} \\ 0 & \text{if not} \end{cases} \quad (20)$$

The resulting equilibrium profit expressions are:

**(A) Both firms export**

$$\pi_1^* = \frac{1}{9} \left( 1 - c + \frac{3}{2} \lambda - t \right)^2 \quad (21)$$

$$\pi_2^* = \frac{1}{9} \left( 1 - c - \frac{3}{2} \lambda - t \right)^2 \quad (22)$$

**(B) Both firms are multinational in country *a* or *b***

$$\pi_1^* = \frac{1}{9} \left( 1 - c + \frac{3}{2} \lambda \right)^2 - G \quad (23)$$

$$\pi_2^* = \frac{1}{9} \left( 1 - c - \frac{3}{2} \lambda \right)^2 - G \quad (24)$$

**(C) Firm 1 is multinational (in either country *a* or *b*) Firm 2 exports**

$$\pi_1^* = \frac{1}{9} \left( 1 - c + \frac{3}{2} \lambda + t \right)^2 - G \quad (25)$$

$$\pi_2^* = \frac{1}{9} \left( 1 - c - \frac{3}{2} \lambda - 2t \right)^2 \quad (26)$$

**(D) Firm 1 is an exporter. Firm 2 is multinational (in either country *a* or *b*)**

$$\pi_1^* = \frac{1}{9} \left( 1 - c + \frac{3}{2} \lambda - 2t \right)^2 \quad (27)$$

$$\pi_2^* = \frac{1}{9} \left( 1 - c - \frac{3}{2} \lambda + t \right)^2 - G \quad (28)$$

For monopoly cases, outputs are:

$$\begin{aligned} q_1^* &= \frac{1}{2}(1 - c_1) \\ q_2^* &= \frac{1}{2}(1 - c_2) \end{aligned} \tag{29}$$

where access and fixed costs are defined as above. The expressions for profit are as follows:

**(E) Firm 1 as a multinational monopolist (in either country *a* or *b*)**

$$\pi_1^* = \frac{1}{4} \left( 1 - c + \frac{1}{2} \lambda \right)^2 - G \tag{30}$$

**(F) Firm 2 as a multinational monopolist (in either country *a* or *b*)**

$$\pi_2^* = \frac{1}{4} \left( 1 - c - \frac{1}{2} \lambda \right)^2 - G \tag{31}$$

**(G) Firm 1 as a monopolist exporter**

$$\pi_1^* = \frac{1}{4} \left( 1 - c + \frac{1}{2} \lambda - t \right)^2 \tag{32}$$

**(H) Firm 2 as a monopolist exporter**

$$\pi_2^* = \frac{1}{4} \left( 1 - c - \frac{1}{2} \lambda - t \right)^2 \tag{33}$$

## A.2

When games are repeated, firms have the potential to earn positive profits now and in all subsequent periods in which the game is played. To obtain profits in an infinitely repeated game, one must add current profits to the future profits firms can expect to accrue until time infinity. All future profits must be discounted;  $\delta$  denotes the discount factor rate. Whereas the cost structure for exporters remains unchanged from one period to the next, multinational firms incur a once-off fixed cost at the beginning of the game and not subsequently.

### Profits in an infinitely repeated game

**Both firms export**

$$\pi_1^* = \frac{1}{9(1-d)} \left[ 1-c + \frac{3}{2}\lambda - t \right]^2 \quad (34)$$

$$\pi_2^* = \frac{1}{9(1-d)} \left[ 1-c - \frac{3}{2}\lambda - t \right]^2 \quad (35)$$

**Both firms are multinational**

$$\pi_1^* = \frac{1}{9(1-d)} \left[ 1-c + \frac{3}{2}\lambda \right]^2 - G \quad (36)$$

$$\pi_2^* = \frac{1}{9(1-d)} \left[ 1-c - \frac{3}{2}\lambda \right]^2 - G \quad (37)$$

**Firm 1 is multinational, Firm 2 is an exporter**

$$\pi_1^* = \frac{1}{9(1-d)} \left[ 1-c + \frac{3}{2}\lambda + t \right]^2 - G \quad (38)$$

$$\pi_2^* = \frac{1}{9(1-d)} \left[ 1-c - \frac{3}{2}\lambda - 2t \right]^2 \quad (39)$$

**Firm 1 is an exporter, Firm 2 is multinational**

$$\pi_1^* = \frac{1}{9(1-d)} \left[ 1-c + \frac{3}{2}\lambda - 2t \right]^2 \quad (40)$$

$$\pi_2^* = \frac{1}{9(1-d)} \left[ 1-c - \frac{3}{2}\lambda + t \right]^2 - G \quad (41)$$

**Firm 1 is a multinational monopolist**

$$\pi_1^* = \frac{1}{4(1-d)} \left[ 1-c + \frac{1}{2}\lambda \right]^2 - G \quad (42)$$

**Firm 2 as a multinational monopolist**

$$\pi_2^* = \frac{1}{4(1-d)} \left[ 1-c - \frac{1}{2}\lambda \right]^2 - G \quad (43)$$

**Firm 1 as a monopolist exporter**

$$\pi_1^* = \frac{1}{4(1-d)} \left[ 1-c + \frac{1}{2}\lambda - t \right]^2 \quad (44)$$

### Firm 2 as a monopolist exporter

$$\pi_2^* = \frac{1}{4(1-d)} \left[ 1 - c - \frac{1}{2} \lambda - t \right]^2 \quad (45)$$

## A.3

Governments tax firms up until the point where firms are indifferent between enduring the tax burden and relocating production i.e.,  $\tau^* = G_R$ . For multinational firms, profits depend positively on the difference between the sunk cost  $G$  and the relocation cost  $G_R$ , i.e. the lower is relocation costs relative to the initial fixed cost, the lower is taxation in the host country and the higher is profit/gain from being multinational.

### Profits in an infinitely repeated game with taxation

#### Both firms export

$$\pi_1^* = \frac{1}{9(1-d)} \left[ 1 - c + \frac{3}{2} \lambda - t \right]^2 \quad (46)$$

$$\pi_2^* = \frac{1}{9(1-d)} \left[ 1 - c - \frac{3}{2} \lambda - t \right]^2 \quad (47)$$

#### Both firms are multinational

$$\pi_1^* = \frac{1}{1-d} \left[ \frac{1}{9} \left( 1 - c + \frac{3}{2} \lambda \right)^2 - G \right] + \frac{d}{1-d} (G - G_R) \quad (48)$$

$$\pi_2^* = \frac{1}{1-d} \left[ \frac{1}{9} \left( 1 - c - \frac{3}{2} \lambda \right)^2 - G \right] + \frac{d}{1-d} (G - G_R) \quad (49)$$

#### Firm 1 is multinational, Firm 2 is an exporter

$$\pi_1^* = \frac{1}{1-d} \left[ \frac{1}{9} \left( 1 - c + \frac{3}{2} \lambda + t \right)^2 - G \right] + \frac{d}{1-d} (G - G_R) \quad (50)$$

$$\pi_2^* = \frac{1}{9(1-d)} \left[ 1 - c - \frac{3}{2} \lambda - 2t \right]^2 \quad (51)$$

#### Firm 1 is an exporter, Firm 2 is multinational

$$\pi_1^* = \frac{1}{9(1-d)} \left[ 1 - c + \frac{3}{2} \lambda - 2t \right]^2 \quad (52)$$

$$\pi_2^* = \frac{1}{1-d} \left[ \frac{1}{9} \left( 1-c - \frac{3}{2} \lambda + t \right)^2 - G \right] + \frac{d}{1-d} (G - G_R) \quad (53)$$

**Firm 1 is a multinational monopolist**

$$\pi_1^* = \frac{1}{1-d} \left[ \frac{1}{4} \left( 1-c + \frac{1}{2} \lambda \right)^2 - G \right] + \frac{d}{1-d} (G - G_R) \quad (54)$$

**Firm 2 is a multinational monopolist**

$$\pi_2^* = \frac{1}{1-d} \left[ \frac{1}{4} \left( 1-c - \frac{1}{2} \lambda \right)^2 - G \right] + \frac{d}{1-d} (G - G_R) \quad (55)$$

**Firm 1 is a monopolist exporter**

$$\pi_1^* = \frac{1}{4(1-d)} \left[ 1-c + \frac{1}{2} \lambda - t \right]^2 \quad (56)$$

**Firm 2 as a monopolist exporter**

$$\pi_2^* = \frac{1}{4(1-d)} \left[ 1-c - \frac{1}{2} \lambda - t \right]^2 \quad (57)$$

## A.4

### Solving for critical values

- (a) To solve for the value of  $t$  beyond which profit from the market structure EM/ME is negative, set Firm 1's (Firm 2's) profit arising from the market structure EM (ME) equal to zero and solve for  $t$  as a function of the other variables.

$$\bar{t}_1 = \frac{1}{2} (1-c) \quad (58)$$

- (b) To solve for the value of  $G$  which makes a multinational firm indifferent between multi- and single plant production, given the other firm is multinational, set Firm 1's (Firm 2's) profits for the market structure MM equal to profit from the market structure EM (ME) and solve for  $G$ .

$$G = \frac{4t}{9} (1-c-t) \quad (59)$$

- (c) To solve for the value of  $G$  which makes a multinational firm indifferent between multi- and single plant production, given the other firm is an exporter, set Firm 1's (Firm 2's) profit from

the market structure EE equal to the profits from the market structure ME (EM), and solve for G.

$$G = \frac{4t}{9}(1-c) \quad (60)$$

- (d) To solve for the value of t beyond which profit from the market structure EE is negative, set profit from the market structure EE (for either firm) equal to zero and solve for t.

$$\bar{t}_2 = 1 - c \quad (61)$$

- (e) To solve for the value of G at which a multinational is indifferent between serving and not serving the market, given the other firm is multinational, set Firm 1's (Firm 2's) profit from the market structure MM equal to the profit from the market structure OM (MO) and solve for G.

$$G = \frac{1}{9}((1-c)^2) \quad (62)$$

- (f) To solve for the value of G which makes a multinational indifferent between serving and not serving the market, given the other firm is not serving the market, set Firm 1's (Firm 2's) profit from the market structure OO equal to profits from the market structure MO (OM) and solve for G:

$$G = \frac{1}{4}((1-c)^2) \quad (63)$$

- (g) To solve for the value of G which makes a firm indifferent between a multinational monopoly and an exporting duopoly, set Firm 1's (Firm 2's) profit from the market structure MO (OM) equal to profit from the market structure EE and solve for G:

$$G = \frac{1}{36}(5 - 10c + 5c^2 + 8t - 8ct - 4t^2) \quad (64)$$

- (h) To solve for the value of t beyond which Firm 2's profit arising from the market structure ME is negative, set Firm 2's profits from the market structure ME equal to zero and solve for t:

$$t_1^* = \frac{1}{2} \left( 1 - c - \frac{3}{2}\lambda \right) \quad (65)$$

- (i) To solve for the value of t beyond which Firm 1's profit arising from the market structure EM is negative, set Firm 1's profit from the market structure EM equal to zero and solve for t:

$$t_2^* = \frac{1}{2} \left( 1 - c + \frac{3}{2} \lambda \right) \quad (66)$$

- (j) To solve for the value of  $t$  beyond which Firm 2's profit from an exporting duopoly is negative, set Firm 2's profit from the market structure EE equal to zero and solve for  $t$ :

$$t_3^* = 1 - c - \frac{3}{2} \lambda \quad (67)$$

- (k) To solve for the value of  $t$  beyond which Firm 1's profit from an exporting monopoly is negative, set Firm 1's profit from the market structure EO equal to zero and solve for  $t$ :

$$t_4^* = 1 - c + \frac{1}{2} \lambda \quad (68)$$

- (l) To solve for the value of  $G$  which Firm 2 is indifferent between multi- and single plant production, given Firm 1 is multinational, set Firm 2's profit from the market structure MM equal to profit from the market structure ME and solve for  $G$ :

$$G = \frac{4t}{9(1-d)} \left( 1 - c - \frac{3}{2} \lambda - t \right) \quad (69)$$

- (m) To solve for the value of  $G$  at which Firm 1 is indifferent between multi- and single plant production, given Firm 2 is multinational, set Firm 1's profit from the market structure MM equal to profit from the market structure EM and solve for  $G$ :

$$G = \frac{4t}{9(1-d)} \left( 1 - c + \frac{3}{2} \lambda - t \right) \quad (70)$$

- (n) To solve for the value of  $G$  which makes Firm 2 indifferent between multi- and single plant production, given Firm 1 is an exporter, set Firm 2's profit from the market structure EM equal to profit from the market structure EE and solve for  $G$ :

$$G = \frac{4t}{9(1-d)} \left( 1 - c - \frac{3}{2} \lambda \right) \quad (71)$$

- (o) To solve for the value of  $G$  at which Firm 1 is indifferent between multi- and single plant production, given Firm 2 is an exporter, set Firm 1's profit from the market structure ME equal to profit from the market structure EE and solve for  $G$ :

$$G = \frac{4t}{9(1-d)} \left( 1 - c + \frac{3}{2}\lambda \right) \quad (72)$$

- (p) To solve for the value of G which makes Firm 2 indifferent between being multinational and not serving the market, given Firm 1 is multinational, set Firm 2's profit from the market structure MM equal to profit from the market structure MO and solve for G:

$$G = \frac{1}{18(1-d)} \left( 1 - c - \frac{3}{2}\lambda \right)^2 \quad (73)$$

- (q) To solve for the value of G which makes Firm 1 indifferent between an exporting duopoly and a multinational monopoly, set Firm 1's profit from the market structure MO equal to profit from the market structure EE and solve for G:

$$G = \frac{1}{144(1-d)} (20 - 40c + 32t - 12\lambda + 20c^2 - 32ct - 16t^2 + 12\lambda c + 48\lambda t - 27\lambda^2) \quad (74)$$

- (r) To solve for the value of G which makes Firm 1 indifferent between being a multinational and not serving the market, given Firm 2 is multinational, set Firm 1's profit from the market structure MM equal to profit from the market structure OM and solve for G:

$$G = \frac{1}{18(1-d)} \left( 1 - c + \frac{3}{2}\lambda \right)^2 \quad (75)$$

- (s) To solve for the value of G which makes Firm 2 indifferent between an exporting duopoly and a multinational monopoly, set Firm 2's profit from the market structure OM equal to profit from the market structure EE and solve for G:

$$G = \frac{1}{144(1-d)} (20 - 40c + 32t + 12\lambda + 20c^2 - 32ct - 16t^2 - 12\lambda c - 48\lambda t - 27\lambda^2) \quad (76)$$

- (t) To solve for the value of G which makes Firm 2 indifferent between a multinational monopoly and not serving the market, given Firm 1 will serve the market, set Firm 2's profit from the market structure MO or EO equal to profit from the market structure OM and solve for G:

$$G = \frac{1}{4(1-d)} \left( 1 - c - \frac{\lambda}{2} \right)^2 \quad (77)$$

- (q) To solve for the value of  $G$  which makes Firm 1 indifferent between a multinational monopoly and an exporting monopoly, set Firm 1's profit from the market structure MO equal to profit from the market structure EO and solve for  $G$ :

$$G = \frac{t}{2(1-d)} \left( 1 - c + \frac{\lambda}{2} - \frac{1}{2}t \right) \quad (78)$$

- (r) To solve for the value of  $G$  at which Firm 1 is indifferent between a multinational monopoly and not serving the market, given Firm 2 does not serve the market, set Firm 1's profit from the market structure MO equal to profit from the market structure OO and solve for  $G$ :

$$G = \frac{1}{4(1-d)} \left( 1 - c + \frac{\lambda}{2} \right)^2 \quad (79)$$

## A.5

This section considers the possibility of collusion between firms.

### Both firms export

With collusion, each firm produces half the monopoly output, discounted profit is therefore:

$$\pi_i = \frac{1}{8(1-d)} (1 - c - t)^2 \quad (80)$$

Given that the other firm is producing the collusive output, a firm's best response under a strategy of cheating is to produce a higher output. If a firm defects, the other firm switches from playing the collusive output to the Nash equilibrium output level, resulting in all future profits for both firms being at the Cournot level:

$$\pi_i = \frac{3}{8} (1 - c - t)^2 + \frac{d}{9(1-d)} (1 - c - t)^2 \quad (81)$$

Firms will co-operate as long as the gains from cheating today are less than the benefits of continued co-operation in the future. By equating equations (65) and (66) and solving for  $d$ , it can be shown that for a discount factor of  $d > 9/17$ , collusion yields at least as high a level of discounted profit as cheating.

### Both firms multinational

With collusion, each firm produces half the monopoly output, discounted profit is therefore:

$$\pi_i = \frac{1}{8(1-d)}(1-c)^2 - G \quad (82)$$

Given that the other firm is producing the collusive output, a firm's best response under a strategy of cheating is to produce a higher output. If a firm defects, the other firm switches from playing the collusive output to the Nash equilibrium output level, resulting in all future profits for both firms being at the Cournot level:

$$\pi_i = \frac{3}{8}(1-c)^2 - G + \frac{d}{9(1-d)}(1-c)^2 \quad (83)$$

Again, firms will co-operate as long as the gains from cheating today are less than the benefits of continued co-operation in the future. By equating equations (67) and (68) and solving for  $d$ , it can be shown that for a discount factor of  $d > 9/17$ , collusion yields at least as high a level of discounted profit as cheating.

### One firm is multinational, the other firm is an exporter

With collusion, each firm produces half the monopoly output, discounted profits (under the configuration ME) are therefore:

$$\pi_1 = \frac{1}{8(1-d)}(1-c)^2 - G \quad (84)$$

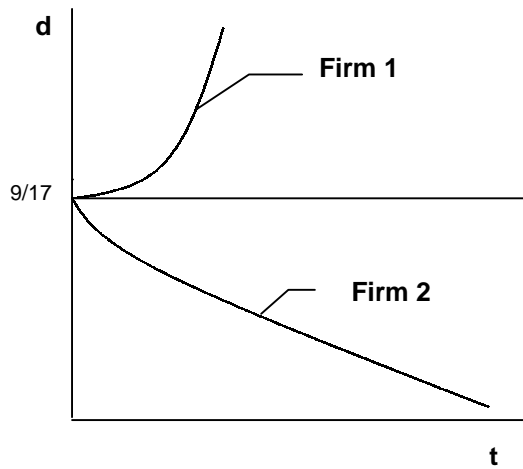
$$\pi_2 = \frac{1}{8(1-d)}(1-c-t)^2 \quad (85)$$

Given that the other firm is producing the collusive output, a firm's best response under a strategy of cheating is to produce a higher output. If a firm defects, the other firm switches from playing the collusive output to the Nash equilibrium output level, resulting in all future profits for both firms being at the Cournot level:

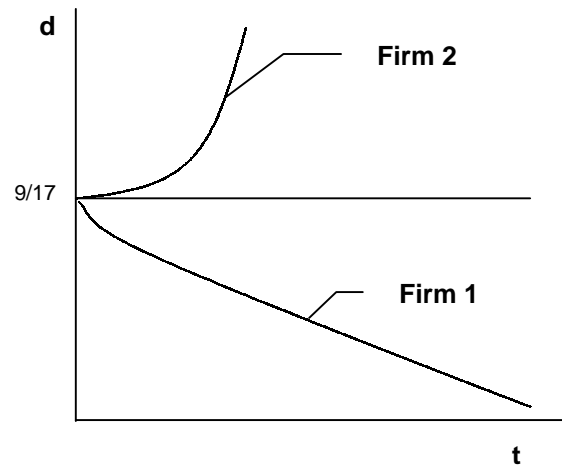
$$\pi_1 = \frac{1}{8}(3-3c+t)^2 - G + \frac{d}{3(1-d)}(1-c+t)^2 \quad (86)$$

$$\pi_2 = \frac{1}{8}(3-3c-4t)^2 + \frac{d}{3(1-d)}(1-c-2t)^2 \quad (87)$$

Firms will co-operate as long as the gains from cheating today are less than the benefits of continued co-operation in the future. By equating equations (69) and (71) and equations (70) and (72) we can solve for the discount factors above which collusion yields at least as high a level of discounted profit as cheating. The results are summarised in the following diagrams:



**Firm 1 multinational,  
Firm 2 is an exporter**



**Firm 1 is an exporter,  
Firm 2 is multinational**

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