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By B. Ferrett

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Abstract

We present two models of the greenfield-FDI, R&D and entry decisions of rival firms in an international oligopoly. Specifically, we develop a blockaded-entry (BE) two-stage game as a benchmark: in the first stage, the two incumbents choose whether to undertake greenfield-FDI or R&D (or both); in the second stage, the firms compete à la Bertrand in two host countries. The potential-entry (PE) game includes the entry decision of a third firm immediately before the market stage. The games are solved backwards so that industrial structure becomes endogenous. Four principal conclusions emerge. First, relationships between industry greenfield-FDI flows and R&D spending, and structural parameters can be non-monotonic. Second, two-way relationships exist between firms' greenfield-FDI and R&D decisions. Third, equilibria in the PE game differ from those under BE because of equilibrium entry-deterrence and -accommodation. Fourth, the incumbents' equilibrium strategies towards entry under PE depend on the sunk costs of greenfield-FDI and R&D.

Outline

Non-Technical Summary

This paper examines the greenfield-FDI ('greenfield investment'), process R&D and entry decisions of rival firms in a concentrated global industry with segmented national product markets ('international oligopoly'). We begin with the claim that there are solid intuitive reasons for expecting those three strategic firm-level decisions to be intimately interrelated. For example, R&D investment affects FDI behaviour via its creation of superior technologies ('ownership advantages' in OLI parlance) that reduce the costs of doing business abroad; conversely, prior FDI may increase the profitability of R&D investment by enlarging the firm's output base, over which cost savings can be spread. We also discuss possible links between incumbents' FDI and R&D decisions, and the entry decisions of outside firms (e.g. FDI and R&D investments may be used pre-emptively to deter entry or may have to be accommodated to certain entry).

To explore these issues, we develop two game-theoretic models of a two-country world. The benchmark blockaded-entry (BE) game has two stages: in stage one, the incumbent firms choose whether to undertake greenfield-FDI or R&D (or both); and in stage two market equilibrium is established in both countries via Bertrand competition. The potential-entry (PE) game includes an extra, intermediate stage: an additional firm's entry decision. Both models are solved backwards so that industrial structure becomes endogenous: in any stage firms take account of the knock-on effects of their choices on the equilibria of subsequent stages.

The equilibria of the BE and PE games have several features in common. The relationships between equilibrium intra-industry greenfield-FDI flows and R&D investment, and structural parameters can be non-monotonic (e.g. the relationship between greenfield-FDI and market size can be U-shaped). Two-way linkages are confirmed between firms' greenfield-FDI and R&D decisions. We also discover that strategic rivalry between firms in the international oligopoly under consideration can take the form of a Prisoner's Dilemma.

In order to gauge the significance of the entry threat in the PE game, we compare the equilibria of the BE and PE games for given parameter values. The broad finding is that, in addition to the equilibria of the BE game, the PE game has both entry-deterring and entry-accommodating equilibria. (Whether entry-deterrence or -accommodation is selected in PE equilibrium depends on the sunk costs of greenfield-FDI and R&D.) In Fudenberg and Tirole's (1984) terminology, when deterring entry the incumbents behave as 'top dogs', undertaking additional sunk investments; but when accommodating entry they behave as 'puppy dogs', undertaking fewer sunk investments because of rent dissipation.

1. Introduction.[1]

This paper examines the relationships between three firm-level decisions in an international oligopoly: (i) whether to serve foreign product markets by exporting from a domestic production base or by undertaking FDI to establish local production facilities (the 'FDI decision'); (ii) whether to undertake R&D investment with the aim of discovering process innovations (the 'R&D decision'); and (iii) whether to diversify production into new industries (the 'entry decision'). It is the fundamental contention of this paper that these three decisions are intimately interrelated, so that all three should be made endogenously in a theoretical model that seeks to explain the equilibrium industrial structure of an international oligopoly. While some authors, whose contributions are reviewed below, have examined the bilateral relationships between two of the three decisions outlined above, none have developed a unified analysis of firms' FDI, R&D and entry decisions.

Our analysis grows out of the game-theoretic models of foreign expansion in an international oligopoly pioneered by Rowthorn (1992) and Horstmann and Markusen (1992). Because of this, we briefly review their common structure. Both Rowthorn and Horstmann/Markusen use a two-firm, two-country modelling structure, where one firm originates from each country and national product markets are perfectly segmented. Furthermore, both use similar two-stage games, which are solved backwards to isolate subgame perfect Nash equilibria: in the first stage the two rival firms simultaneously choose how many plants to establish from a strategy space of {0,1,2}; and in stage two the firms compete à la Cournot to serve both national product markets. (A key trade-off in these models is that, in choosing 2 plants rather than 1, the firm enjoys a fall in its marginal cost abroad – because the trade cost is eliminated – but suffers a doubling of plant-specific fixed costs.) The authors the examine the effects of changes in a variety of parameters on the firms' equilibrium location decisions: Rowthorn focuses on the interplay between 'market size' and trade costs (the 'trade barrier ratio') in creating a 'tariff-jumping' motive for greenfield-FDI; Horstmann and Markusen analyse how the relative sizes of firm- and plant-specific fixed costs affect location decisions.

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[1] For brevity the Appendix material has not been included in this research paper. The Appendix is available from the author on request. This research paper is based on chapter 4 of my Warwick PhD thesis. The full text of the chapter is available from the author on request.

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In terms of our initial taxonomy of firms' decisions, Rowthorn and Horstmann/Markusen provide a rich framework for analysing the FDI decision. However, their models do not incorporate the R&D and entry decisions: both assume a given population of two firms with fixed production technologies. A number of attempts have been made to analyse the three bilateral relationships between the FDI, R&D and entry decisions. On the relationship between FDI and entry decisions, Smith (1987) and Motta (1992) are key contributions. Both present three-stage models of duopolistic rivalry to serve a single host-country product market: in stage one a foreign firm (the potential MNE) chooses between exporting and greenfield-FDI; in stage two a domestic firm chooses whether to enter the market; and in stage three market equilibrium is established either via monopoly pricing (if the domestic firm stays out) or via Cournot competition (if both firms enter). Because decisions in earlier stages of the game become common knowledge, the outcome is a subgame perfect Nash equilibrium. The entrant's stage-two decision can therefore interact with the MNE's decision in two ways. If the entrant's optimal choice is conditional on the MNE's decision, the MNE can use greenfield-FDI strategically to deter entry in stage two. However, if the entrant possesses a dominant strategy, then it is natural to consider how the inclusion of stage two affects the MNE's optimal decision. It can be shown that certain entry reduces the profitability premium for the MNE of FDI over exporting, compared to a situation where entry will certainly *not* occur. This is essentially because entry dissipates the rent earned by the MNE.

An important simplification in the models of Smith and Motta, relative to those of Rowthorn and Horstmann/Markusen, is the assumption that domestic firms in the host country cannot undertake reciprocal FDI in the MNE's home country. This simplifying assumption implies that the Smith and Motta models cannot be used to analyse FDI cross-hauling. However, relative to the Rowthorn and Horstmann/Markusen models, the Smith and Motta models are analytically tractable, and they do succeed in partially endogenising industrial structure (although one firm is constrained to remain 'domestic'). A consideration of the benefits of moving from a one-way (Smith, Motta) model of FDI flows to a two-way one (Rowthorn, Horstmann/Markusen) is in order. Models that permit two-way FDI flows are necessary when firms' equilibrium location strategies vary with those of their rivals; and these connexions are created in general by the presence of fixed costs *other than* those associated solely with greenfield-FDI (e.g. the costs of maintaining head offices and home plants and the costs of financing R&D).

Two brief examples will illustrate these effects. First, consider an international duopoly where firms choose both production locations and process R&D. If a foreign rival undertakes greenfield-FDI in the domestic market (instead of exporting), then ceteris paribus this will increase the domestic firm's incentive to invest in process R&D in search of drastic innovations. In turn, this increased R&D investment may make international production via greenfield-FDI profitable for the domestic firm by reducing its marginal production costs. Second, consider an international duopoly with high firm-specific fixed costs (e.g. for head offices) relative to plant-specific fixed costs, where firms choose production locations. A two-plant firm (MNE) could be forced to exit the industry if the foreign rival undertakes greenfield-FDI in its home market, because this would dissipate its variable profits at home (which were essential to financing its firm-specific fixed costs). These two examples of international duopolies illustrate how firms' equilibrium international location strategies can be interconnected. The models we develop in the following sections have similarities to the first example above (i.e. the focus on endogenous R&D), and therefore we must model all firms' location decisions endogenously in order to derive robust predictions for equilibrium industrial structures.

The relationships between firms' FDI and R&D decisions have been analysed by Dunning (1977) and Petit and Sanna-Randaccio (1998, 2000). Dunning's (1977) OLI framework investigates how R&D decisions affect FDI decisions. MNEs producing abroad via FDI incur higher fixed costs than do their local rivals because of the difficulties inherent in co-ordinating business across national boundaries (e.g. created by the necessity of learning the host country's language and legal system). If product markets are generally monopolistically competitive (so the 'representative firm' earns normal profits in equilibrium), then the MNE *must* possess some proprietary 'ownership advantage' to offset its additional fixed cost burden. Dunning argues that R&D investment is key to creating 'ownership advantages': therefore R&D investment enables international expansion via FDI (perhaps by lowering the MNE's marginal production cost).

A common element in the contributions of Petit and Sanna-Randaccio is the argument that two-way relationships can exist between R&D and FDI when market structures generate supernormal profits in equilibrium. Their 1998 paper focuses on a monopolist's choice between FDI and exporting in a two-country world; the monopolist can also invest in process R&D to reduce its marginal production cost. If the costs of international technology transfer are sufficiently low (so that technological knowledge approximates a public good within the firm), then 'there is a two-way relationship between R&D and multinational expansion by the firm, since the presence of R&D activities makes the FDI choice more likely, and the FDI choice produces a higher level of R&D' (Petit and Sanna-Randaccio, 1998, p. 22). R&D promotes FDI via an OLI-type mechanism of enabling the monopolist to finance the fixed costs of an additional plant abroad, and FDI promotes R&D because an MNE's global output is larger than a national firm's (so the value of a given process innovation is greater to the MNE).

In Petit and Sanna-Randaccio (2000) R&D/FDI linkages are explored in the context of an international duopoly, which creates the possibility of 'strategic', as well as 'pure', incentives for R&D and FDI. The model is similar to those of Rowthorn and Horstmann/Markusen with an additional stage, where the firms simultaneously decide how much to invest in process R&D, inserted between the location and output decisions. Unfortunately, the model's complexity makes it impossible for Petit and Sanna-Randaccio to derive analytical solutions via backwards induction; instead, a set of illustrative numerical simulations is presented. However, the results suggest that the intuition on the bilateral relationship between R&D and FDI gained from the (1998) monopoly case does carry over to oligopoly. A key benefit of our modelling structure is that it enables us to derive closed-form solutions.

The third bilateral relationship is between firms' R&D and entry decisions. Of course, this relationship is not specifically connected to MNEs, and it has been extensively analysed in the theoretical literature. Dixit (1980), who develops a model of an incumbent monopolist's investment decision in anticipation of entry and Cournot competition, is particularly relevant to our purpose. (In the one-way FDI models of Smith (1987) and Motta (1992) the FDI/entry relationship is a special case of Dixit's model because FDI is a discrete, rather than a continuous, investment decision.) Dixit's model was generalised and located within a broad taxonomy of incumbents' investment strategies by Fudenberg and Tirole (1984), who confirmed Bain's classic (1956) view that incumbents' equilibrium strategies crucially depend on whether entry is to be deterred or accommodated. While our modelling structure is not exactly analogous to Fudenberg and Tirole's, we shall attempt to relate equilibrium behaviour in anticipation of entry in our model to their 'animal spirits' taxonomy.

Our modelling structure captures formally the relationships between FDI, R&D and entry decisions outlined above. A key contention of our approach is that, because any one of those three decisions is intimately connected to the other two, focussing on one of the three possible bilateral relationships (and thus implicitly holding the third decision fixed) will generate partial results. For example, analysing the relationship between the FDI and R&D decisions without modelling the entry decision excludes a priori a potentially important set of causal linkages: a credible entry threat may prompt incumbents to undertake entry-deterring FDI and (additional) R&D, thus altering the equilibrium FDI/R&D relationship.

The remainder of the paper is organised as follows. In Section 2 the tools necessary for our analysis are developed. In Section 3 we solve the blockaded-entry (BE) and potential-entry (PE) games, which form the core of our analysis. In Section 4 we investigate the effects of the entry threat. Finally, Section 5 concludes.

2. The Modelling Structure.

2.1. Corporate Structure Choices.

We adopt the simplest model necessary to illustrate the implications of an entry threat for incumbents' greenfield-FDI and process R&D decisions. We consider a three-firm, two-country world, where national product markets are of identical 'size' and perfectly segmented and the product is homogeneous. Product markets may be served either by local production or by international trade from a plant abroad, which incurs a per-unit trade cost of t. There are initially four production plants, two in each country. Firms 1 and 2 (the 'incumbents') initially own one plant each, and these plants are located in different countries. (Hence the incumbents 'originate' from different countries.) Firm 3 (the 'potential entrant') initially owns the remaining two plants, which are located in different countries.

Firms can establish additional plants in either country at a sunk cost of G. Plants have constant marginal production costs, which are determined by the firm's stock of technical knowledge. (Technology is assumed to be a public good within the firm, which can costlessly be applied to production in every plant, but a proprietary good between firms. There are no interfirm technological spillovers.) Therefore, there are plant-level economies of scale and no firm will optimally maintain more than one plant in either country.

Initially firms 1 and 2 possess the same level of technology, which sets their marginal production costs at $c \in (0, 1)$. Firm 3's initial marginal production cost is strictly greater than the monopoly price associated with c, which we define below as $x^M(c)$. Technological progress occurs in steps, and each step incurs a sunk cost of I. The technological laggard (firm 3) can purchase the industry's best-practice technology (i.e. a marginal production cost of c) in one step. For firms on the technological frontier (i.e. firms 1 and 2 initially, and firm 3 after sinking an investment of I to catch up) I purchases a process R&D investment with a risky outcome. With probability $p \in (0, 1)$ R&D investment 'succeeds' and the firm's marginal production cost falls to 0; however with probability $(1 - p)$ R&D investment 'fails' and the firm's marginal production cost remains at c.

In the early stages of our model firms choose their 'corporate structures'. A firm's corporate structure choice represents its strategic ('long-term') decisions vis-à-vis the location of production and the level of technology. Given the assumptions on initial conditions and sunk investments outlined above, firms 1 and 2 can both choose between four corporate structure pairs: (1, *N*), (1, *R*), (2, *N*) and (2, *R*). The first component of the pair indicates how many plants the firm will maintain. A choice of 1 plant incurs no sunk cost because the plant is pre-existing; a choice of 2 plants represents a decision to sink G and establish an additional plant abroad. G is the international flow of greenfield-FDI. The second component of an incumbent's corporate structure pair indicates whether the firm undertakes process R&D. Note that loss-making in equilibrium is ruled out by the inclusion of the (1, *N*) strategy, which incurs no sunk costs, and so an 'exit' (or 'inactivity') strategy may legitmately be ignored.

Because firm 3 initially owns one plant in each country and marginal production costs are constant, its corporate structure choice only contains a technological element. This is an extremely useful simplification. Firm 3 chooses between three corporate structures: $\emptyset$, *E* and *R*. $\emptyset$ represents a decision not to invest in technological progess. Despite making no sunk investments under the $\emptyset$ strategy, firm 3 will also earn zero profits in the industry because the step onto the technological frontier represents a drastic innovation. Therefore by choosing $\emptyset$ firm 3 is effectively choosing *not* to 'enter' the industry. *E* and *R* both represent 'entry' by firm 3, potentially with production in both countries. The *E* strategy represents a decision to step onto the technological frontier at a sunk cost of I. Under the *R* strategy firm 3 attempts to take two steps at a sunk cost of $2 \cdot I$: one onto the technological frontier, and an additional step via process R&D.

Clearly, 'entry' by firm 3 via corporate structure choices of *E* or *R* has a rather stylized meaning in our model. Von Weizsäcker (1980) argues that entrants into an industry must pay sunk costs not incurred by incumbents: whether to pay these costs is the essence of the entry decision. By assuming that firm 3 possesses pre-existing but highly (productively) inefficient plants in both countries, our model incorporates a von Weizsäcker-type entry decision for firm 3 *without introducing a location decision*. This restriction on firm 3's strategic choices, implied by the assumptions of pre-existing plants and constant marginal production costs, both simplifies our analysis and generates a significant interest (because the credibility of the entry threat is increased relative to a model where firm 3 must sink an investment of G to establish each plant). However, the question of how to interpret entry by firm 3 remains. A neat interpretation is to view firm 3 as a diversifying MNE entrant (rather than a de novo entrant), whose pre-existing plants produce for a 'related' industry (in terms of production processes) and can be adapted to produce the good under analysis.

The assumptions on corporate structure choices outlined above imply that an active firm's marginal cost of serving either national product market can take four values:

$$\text{marginal cost} = \begin{cases} 0 \text{ if the firm's R \& D succeeds and it produces locally} \\ t \text{ if the firm's R \& D succeeds and it produces abroad} \\ c \text{ if the firm's R \& D fails and it produces locally} \\ c+t \text{ if the firm's R \& D fails and it produces abroad} \end{cases}$$

Throughout our analysis we maintain the following assumption (which seems intuitively reasonable) on t, c:

(A) $$0 < t < c < 1$$

2.2. Market Size.

There are two countries in the world. Demand conditions in both are identical, and the product is homogeneous. Market demand in either country is

$$Q_j = m \cdot (1 - x_j) \tag{1}$$

Q_j and x_j are demand and price in country j respectively, $j \in \{1, 2\}$. National product markets are assumed to be perfectly segmented, so consumers in country j are constrained to make purchases only on their home market. m measures the 'size' of either national product market and can be interpreted as an index of the number of homogeneous consumers in each country, all of whom have a reservation price of 1.

2.3. Net Revenue.

Net revenue equals revenue minus variable costs. If either national product market is monopolised by firm i with a constant marginal cost of c_i, the monopoly price will be

$$x^M(c_i) = \frac{1}{2} \cdot (1 + c_i)$$

The monopolist's net revenue is

$$R^M(c_i) = \frac{m}{4} \cdot (1 - c_i)^2$$

If a national product market is served by a duopoly, then firm i's net revenue function is $R(c_i, c_j)$, where c_i is firm i's marginal cost and c_j is its rival's marginal cost. (The symmetry across countries – i.e. identical market demand functions – implies that $R^M(c_i)$ and $R(c_i, c_j)$ apply to both countries.) The exact functional form of $R(c_i, c_j)$ depends on the assumed form of duopolistic competition. At Bertrand equilibrium and if marginal costs are common knowledge

$$R(c_i, c_j) = \begin{cases} 0 \ \text{ for } \ c_i \in [c_j, 1) \\ m \cdot (1 - c_j) \cdot (c_j - c_i) \ \text{ for } \ c_i \in [(x^M)^{-1}(c_j), c_j] \\ R^M(c_i) \ \text{ for } \ c_i \in (0, (x^M)^{-1}(c_j)] \end{cases} \tag{2}$$

The results in (2) are standard. (Note that $(x^M)^{-1}(c_j)$ gives the marginal cost that is associated with a monopoly price of c_j.) If $c_i > c_j$ then firm i's rival optimally sets a price below c_i and captures the entire market. If $c_i = c_j$ the Bertrand equilibrium price equals the common level of marginal costs. A conventional assumption is that the market is divided equally between the two firms. If $c_i < c_j$ there are two possibilities. If the gap between c_i and c_j is 'small' ($x^M(c_i) > c_j$) firm i optimally sets a price below c_j, but the gap between the two firms' marginal costs is not large enough to allow firm i to charge its monopoly price. Therefore, i sets a price of $c_j - \varepsilon$, earns net revenue per unit of $c_j - c_i$ and serves the entire market with $m \cdot (1 - c_j)$ units. This 'undercutting equilibrium' is shown in the second line of (2). However, if the gap between c_i and c_j is 'large' ($x^M(c_i) < c_j$) firm i optimally sets its monopoly price, which is still less than c_j. This 'monopoly-pricing equilibrium' is shown in the bottom line of (2). If it is assumed that both firms initially have marginal costs of c_j, then the distinction between 'small' and 'large' levels of $(c_j - c_i)$ can be linked directly to the size of firm i's process innovation (i.e. nondrastic or drastic). Furthermore, net revenues at a Bertrand equilibrium with more than two firms can be straightforwardly described using (2) if c_j is reinterpreted as the minimum of firm i's rivals' marginal costs (i.e. $c_j \equiv \min\{c_1, c_2, ..., c_{i-1}, c_{i+1}, ..., c_N\}$).

The $R(c_i, c_j)$ function is not well-behaved: it is continuous but not smooth. $R(\cdot)$ is decreasing in c_i and increasing in c_j. The functional form of $R(c_i, c_j)$ creates both advantages and disadvantages for our analysis. The advantages are (i) that certain realisations will always be equal to zero; and (ii) that because of the monotonicity of $R(\cdot)$, realisations for given c_j can be ranked using the restrictions in assumption (A) as

$$\left.\begin{array}{l} R(0,0) = R(t,0) = R(c,0) = R(c+t,0) = 0 \\ R^M(0) \geq R(0,t) > 0 \text{ and } R(t,t) = R(c,t) = R(c+t,t) = 0 \\ R^M(0) \geq R(0,c) > R(t,c) > 0 \text{ and } R(c,c) = R(c+t,c) = 0 \\ R^M(0) \geq R(0,c+t) > R(t,c+t) > R(c,c+t) > 0 \text{ and } R(c+t,c+t) = 0 \end{array}\right\} \quad (3)$$

The disadvantage created by the badly-behaved functional form of $R(\cdot)$ is that with only loose restrictions on t, c as in (A), it is impossible to rank $R(\cdot)$ definitively for different values of c_i *and* c_j. We return to this problem when solving the BE and PE games below.

2.4. Sequence of Moves and Equilibrium Concepts.

The PE game has 3 stages. In stage one the incumbents simultaneously and irreversibly choose their corporate structures. Stage two is firm 3's entry decision. Firm 3 can observe the incumbents' chosen corporate structures but *not* whether their R&D investments (if undertaken) succeeded or failed. In stage three the incumbents learn what their rivals' corporate structure choices were, and the success/failure of *all* R&D investments previously undertaken becomes common knowledge. The three firms then compete à la Bertrand to serve both national product markets. For convenience we term this three-stage game the potential-entry (PE) game to distinguish it from the blockaded-entry (BE) game, which acts as a benchmark case in Section 4. The BE game consists of stages one and three of the PE game and omits the possibility of entry (stage two).

The result in Lemma 1 simplifies the analysis of equilibrium behaviour in the PE and BE games.

Lemma 1. (i) In the PE and BE games an incumbent will never optimally choose a corporate structure of (2, N) because it is strictly dominated by one of (1, N). (ii) In the PE game the entrant will never optimally choose a corporate structure of E because it is strictly dominated by one of $\varnothing$.

Proof. See Appendix.

Lemma 1 contains simplifications implied by the assumption of Bertrand competition in the market stage. It allows us without loss of generality to restrict the incumbents' and the entrant's strategy spaces to $\{(1, N), (1, R), (2, R)\}$ and $\{\varnothing, R\}$ respectively. This simplification makes our analysis considerably more tractable; for example, the normal form of the BE game is reduced from four-by-four to three-by-three, which (given the symmetries across incumbents and countries) reduces the number of distinct industrial structures to consider from 10 to 6.

The result in Lemma 1(i) captures the greenfield-FDI/R&D link in OLI models. In order to make greenfield-FDI profitable, the 'ownership advantages' generated by process R&D are *necessary*. However, as is shown below, there also exist 'feedback' linkages from greenfield-FDI to R&D.

The solution concept we adopt for the BE and PE games is a subgame perfect Nash equilibrium in pure strategies.

3. Analysis.

3.1. Expected Profits.

We now define the firms' expected profit functions in the BE and PE games.

BE Game ($S_3 = \varnothing$)

In the BE game there are six distinct industrial structures to consider, three of which are symmetric and three asymmetric. Expected profits in the industrial structures $\{(1,R),(1,N);\varnothing\}$, $\{(2,R),(1,N);\varnothing\}$ and $\{(2,R),(1,R);\varnothing\}$ may be derived by straightforward analogy given the underlying symmetric modelling structure.

$\{(1,N),(1,N);\varnothing\}$

$$E\pi_1 = E\pi_2 = R(c, c+t)$$

$\{(1,N),(1,R);\varnothing\}$

$$E\pi_1 = (1-p)\cdot R(c, c+t)$$

$$E\pi_2 = p\cdot[R(0, c+t) + R(t, c)] + (1-p)\cdot R(c, c+t) - I$$

$\{(1,N),(2,R);\varnothing\}$

$Ep_1 = 0$

$Ep_2 = p\cdot[R(0,c+t)+R(0,c)]+(1-p)\cdot R(c,c+t)-G-I$

$\{(1,R),(1,R);\varnothing\}$

$Ep_1 = Ep_2 = p\cdot(1-p)\cdot[R(0,c+t)+R(t,c)]+p^2\cdot R(0,t)+(1-p)^2\cdot R(c,c+t)-I$

$\{(1,R),(2,R);\varnothing\}$

$Ep_1 = p\cdot(1-p)\cdot[R(0,c)+R(t,c)]-I$

$Ep_2 = p\cdot(1-p)\cdot[R(0,c+t)+R(0,c)]+p^2\cdot R(0,t)+(1-p)^2\cdot R(c,c+t)-G-I$

$\{(2,R),(2,R);\varnothing\}$

$Ep_1 = Ep_2 = 2\cdot p\cdot(1-p)\cdot R(0,c)-G-I$

PE Game with Entry by Firm 3 ($S_3 = R$)

In the PE game there are twelve distinct industrial structures to consider. The incumbents' choices form six distinct pairs (as above), and for each pair firm 3 can choose either $\varnothing$ or R. Of course, if firm 3 chooses $\varnothing$, then expected profits in the PE game are identical to those in the BE game (and 3 earns zero). Therefore, we have six industrial structures to consider; expected profits in the industrial structures $\{(1,R),(1,N);R\}$, $\{(2,R),(1,N);R\}$ and $\{(2,R),(1,R);R\}$ may be derived by straightforward analogy.

Because firm 3 owns two plants and the incumbents initially own one plant each (in different countries), the smallest possible number of plants in either country when firm 3 chooses R is two. Therefore, a necessary (but insufficent) condition for a firm to earn strictly positive net revenue is that it innovates successfully, because there will always exist a local rival with a marginal cost of c *at most*. For this reason p is a common factor in the net-revenue components of all the expected profit functions below.

$\{(1,N),(1,N);R\}$

$Ep_1 = Ep_2 = 0$

$Ep_3 = 2\cdot p\cdot R(0,c)-2\cdot I$

$\{(1,N),(1,R);R\}$

$Ep_1 = 0$

$Ep_2 = p \cdot (1-p) \cdot [R(0,c) + R(t,c)] - I$

$Ep_3 = 2 \cdot p \cdot (1-p) \cdot R(0,c) + p^2 \cdot R(0,t) - 2 \cdot I$

$\{(1,N),(2,R);R\}$

$Ep_1 = 0$

$Ep_2 = 2 \cdot p \cdot (1-p) \cdot R(0,c) - G - I$

$Ep_3 = 2 \cdot p \cdot (1-p) \cdot R(0,c) - 2 \cdot I$

$\{(1,R),(1,R);R\}$

$Ep_1 = Ep_2 = p \cdot (1-p)^2 \cdot [R(0,c) + R(t,c)] + p^2 \cdot (1-p) \cdot R(0,t) - I$

$Ep_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0,c) + 2 \cdot p^2 \cdot (1-p) \cdot R(0,t) - 2 \cdot I$

$\{(1,R),(2,R);R\}$

$Ep_1 = p \cdot (1-p)^2 \cdot [R(0,c) + R(t,c)] - I$

$Ep_2 = 2 \cdot p \cdot (1-p)^2 \cdot R(0,c) + p^2 \cdot (1-p) \cdot R(0,t) - G - I$

$Ep_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0,c) + p^2 \cdot (1-p) \cdot R(0,t) - 2 \cdot I$

$\{(2,R),(2,R);R\}$

$Ep_1 = Ep_2 = 2 \cdot p \cdot (1-p)^2 \cdot R(0,c) - G - I$

$Ep_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0,c) - 2 \cdot I$

We can connect the incumbents' optimal behaviour in the PE game to that in the BE game. The result is given in Lemma 2.

Lemma 2. (i) Let S_1^{BR} be firm 1's best response to S_2 in the BE game. If firm 3's best response to a choice by the incumbents of the pair $\{S_1^{BR}, S_2\}$ is $\varnothing$, then S_1^{BR} remains a best response to S_2 in the PE game.

(ii) Corollary. Let $\{S_1^*, S_2^*; \varnothing\}$ be the equilibrium industrial structure of the BE game. If firm 3's best response to the pair $\{S_1^*, S_2^*\}$ is $\varnothing$, then $\{S_1^*, S_2^*; \varnothing\}$ is also the equilibrium industrial structure of the PE game.

Proof. See Appendix.

The results in Lemma 2 greatly simplify the analysis of equilibrium industrial structures in the PE game once those in the BE game are known. The general upshot is that firm 3's entry threat can only carry weight when 3 will credibly choose *R* at the equilibrium of the BE game; otherwise, the BE game's equilibrium will endure into the PE game.

It is not immediately obvious what happens when firm 3 optimally chooses *R* at the BE game's equilibrium, i.e. $S_3^{BR}(S_1^*, S_2^*) = R$. Clearly the equilibrium industrial structure of the BE game is undermined because it was premissed on entry *not* occurring. Two possibilities deserve mention. The equilibrium industrial structure of the PE game may involve the incumbents investing more in greenfield-FDI and R&D relative to the BE equilibrium in order *strategically to deter entry* by firm 3. (Recall from Lemma 3(iv) that increasing the incumbents' sunk investments reduces 3's net revenues.) Alternatively, if for example 3 optimally chooses *R regardless* of the incumbents' choices, the incumbents may *accommodate* entry by undertaking fewer sunk investments than in the BE equilibrium. (Recall from Lemma 3(iii) that ceteris paribus entry reduces the incumbents' net revenues, thus making the financing of sunk costs more difficult.) We shall see below that both of these possibilities do indeed arise.

3.2. Best Responses.

The first step in determining equilibrium industrial structures is to isolate the firms' best responses to given corporate structure choices of their rivals, conditional on the six exogenous parameters *m*, *p*, *t*, *c*, *G*, *I*. Below we define critical *m*-values *m*(*p*; *t*, *c*, *G*, *I*) which, given the actual *m*, allow us to rank the various corporate structures in terms of profitability.

BE Game ($S_3 = \varnothing$)

The following results derive from comparisons of the expected profit functions in the BE game.

In response to (1, *N*)

$(1, R) \succ (1, N)$ iff

$$m > \frac{I}{\frac{1}{m}\cdot[R(0,c+t)+R(t,c)-R(c,c+t)]\cdot p} \qquad \text{(1BE)}$$

$(2,R) \succ (1,R)$ iff

$$m > \frac{G}{\frac{1}{m}\cdot[R(0,c) - R(t,c)]\cdot p} \qquad \text{(2BE)}$$

$(2,R) \succ (1,N)$ iff

$$m > \frac{G+I}{\frac{1}{m}\cdot[R(0,c+t) + R(0,c) - R(c,c+t)]\cdot p} \qquad \text{(3BE)}$$

In response to (1, *R*)

$(1,R) \succ (1,N)$ iff

$$m > \frac{I}{\frac{1}{m}\cdot[R(0,c+t) + R(t,c) - R(c,c+t)]\cdot p\cdot(1-p) + \frac{1}{m}\cdot R(0,t)\cdot p^2} \qquad \text{(4BE)}$$

$(2,R) \succ (1,R)$ iff

$$m > \frac{G}{\frac{1}{m}\cdot[R(0,c) - R(t,c)]\cdot p\cdot(1-p)} \qquad \text{(5BE)}$$

$(2,R) \succ (1,N)$ iff

$$m > \frac{G+I}{\frac{1}{m}\cdot[R(0,c+t) + R(0,c) - R(c,c+t)]\cdot p\cdot(1-p) + \frac{1}{m}\cdot R(0,t)\cdot p^2} \qquad \text{(6BE)}$$

In response to (2, *R*)

$(1,R) \succ (1,N)$ iff

$$m > \frac{I}{\frac{1}{m}\cdot[R(0,c) + R(t,c)]\cdot p\cdot(1-p)} \qquad \text{(7BE)}$$

$(2,R) \succ (1,R)$ iff

$$m > \frac{G}{\frac{1}{m}\cdot[R(0,c) - R(t,c)]\cdot p\cdot(1-p)} \qquad \text{(5BE) repeated}$$

$(2,R) \succ (1,N)$ iff

$$m > \frac{G+I}{\frac{2}{m}\cdot R(0,c)\cdot p\cdot(1-p)} \qquad \text{(8BE)}$$

Lemma 3 provides a simplification by demonstrating that several of the inequality conditions (1BE)-(8BE) can in general be dropped.

Lemma 3. Let $(1,R) \succ (1,N)$ iff $m > m_1(p; t, c, G, I)$, which we write as $m_1(p)$ for brevity. Similarly, $(2,R) \succ (1,R)$ iff $m > m_2(p)$ and $(2,R) \succ (1,N)$ iff $m > m_3(p)$. (i) If $m_2(p) > m_1(p)$, then $m_3(p)$ is irrelevant to determining the best response. (ii) Conversely, if $m_1(p) > m_2(p)$, then only $m_3(p)$ is relevant to determining the best response.

Proof. See Appendix.

In the next Section we show that Lemma 3(i) can be invoked under quite general restrictions on *t, c, G, I,* which reduces the set of inequality conditions from eight to five. In turn, this makes the analysis of equilibrium behaviour considerably more tractable.

PE Game with Entry by Firm 3 ($S_3 = R$)

We begin with the penultimate stage of the PE game: firm 3's entry decision. Given that 3's expected profits are zero if it chooses ∅, we use 3's expected profit functions from Section 3.1 to derive the following decision rules.

In response to $\{(1,N),(1,N)\}$ $R \succ \varnothing$ iff

$$m > \frac{I}{\frac{1}{m} \cdot R(0,c) \cdot p} \qquad \text{(1PE)}$$

In response to $\{(1,N),(1,R)\}$ $R \succ \varnothing$ iff

$$m > \frac{2 \cdot I}{\frac{2}{m} \cdot R(0,c) \cdot p \cdot (1-p) + \frac{1}{m} \cdot R(0,t) \cdot p^2} \qquad \text{(2PE)}$$

In response to $\{(1,N),(2,R)\}$ $R \succ \varnothing$ iff

$$m > \frac{I}{\frac{1}{m} \cdot R(0,c) \cdot p \cdot (1-p)} \qquad \text{(3PE)}$$

In response to $\{(1,R),(1,R)\}$ $R \succ \varnothing$ iff

$$m > \frac{I}{\frac{1}{m} \cdot R(0,c) \cdot p \cdot (1-p)^2 + \frac{1}{m} \cdot R(0,t) \cdot p^2 \cdot (1-p)} \qquad \text{(4PE)}$$

In response to $\{(1,R),(2,R)\}$ $R \succ \varnothing$ iff

$$m > \frac{2 \cdot I}{\frac{2}{m} \cdot R(0,c) \cdot p \cdot (1-p)^2 + \frac{1}{m} \cdot R(0,t) \cdot p^2 \cdot (1-p)} \qquad \text{(5PE)}$$

In response to $\{(2,R),(2,R)\}$ $R \succ \varnothing$ iff

$$m > \frac{I}{\frac{1}{m} \cdot R(0,c) \cdot p \cdot (1-p)^2} \qquad \text{(6PE)}$$

As in the BE game, the critical m-values defined above can increase as p approaches 1. The reason for this is the same as in the BE game: a choice of R generally only realises a profit when firm 3 alone innovates successfully, the probability of which approaches 0 as p approaches 1. Lemma 4 examines how the critical m-value where firm 3 chooses R over $\varnothing$ changes with the incumbents' selected corporate structures.

Lemma 4. The critical m-value where firm 3 optimally chooses R over $\varnothing$ increases with the number of sunk investments (in either greenfield-FDI or R&D) undertaken by the incumbents. Specifically, (i) RHS(6PE) > RHS(5PE) > RHS(4PE); (ii) RHS(4PE) ≥ RHS(3PE); (iii) RHS(3PE) > RHS(2PE); and (iv) RHS(2PE) > RHS(1PE).

Proof. By inspection of RHS(1PE) to RHS(6PE).

The *number* of sunk investments undertaken by the incumbents varies from 0 under {(1, *N*), (1, *N*)} to 4 under {(2, *R*), (2, *R*)}. Lemma 4 formalizes the intuition from Lemma 2(iv): by undertaking additional sunk investments the incumbents can decrease firm 3's expected profits and thereby increase the critical m at which entry occurs. Therefore, strategic entry-deterring behaviour by the incumbents would imply a larger number of sunk investments (ceteris paribus) in the PE equilibrium than in the BE equilibrium.

3.3. Nash Equilibria.

Equilibrium Industrial Structures in the BE Game ($S_3 = \emptyset$)

Our primary purpose is to investigate the effects of *p,m* on equilibrium choices. To make this task tractable we place restrictions on the four cost parameters. In the Appendix we show that the following two assumptions on the cost parameters are sufficient uniquely to determine the equilibrium industrial structures of the BE game in (*p*, *m*)-space.

(B) $$R(0, c+t) - R(c, c+t) + R(t, c) - R(0, t) > 0$$

(C) $$G \geq I > 0$$

Assumption (B) on *t,c* is shown below to be only slightly more restrictive than our maintained assumption (A). (In general (B) holds if the gap (*c* – *t*) is sufficiently large.) Given our solution method we can distinguish two types of variation in the cost parameters. *Nondrastic* variations in *t,c,G,I* are consistent with both (B) and (C) continuing to hold: the plot of BE equilibria continues to take the form shown in Figure 1 (although the inter-regional boundaries will shift). *Drastic* variations, on the other hand, alter the form of the plot in Figure 1 (e.g. by causing existing regions to disappear and new ones to emerge). Because we are able to show that (B), (C) continue to hold under wide ranges of variation for the cost parameters, our discussion below on the comparative-statics effects of changes in the cost parameters focusses on nondrastic variations.

Given assumptions (B), (C), Figure 1 illustrates the equilibrium industrial structures of the BE game in (*p*, *m*)-space. (A derivation is given in the Appendix.)

[INSERT FIGURE 1]

Key to Figure 1

Region	Equilibrium Industrial Structure under BE
I	{(1, *N*), (1, *N*); ∅}
II	{(1, *N*), (1, *R*); ∅}
III	{(1, *R*), (1, *R*); ∅}
IV	{(1, *R*), (1, *R*); ∅}; {(1, *N*), (2, *R*); ∅}
V	{(2, *R*), (2, *R*); ∅}*

(Note: * denotes a dominant strategy equilibrium.)

We examine the equilibrium properties of the BE and PE games simultaneously below (because they have several features in common). Before that we solve the PE game for its equilibrium industrial structures given p, m.

Equilibrium Industrial Structures in the PE Game ($S_3 \in \{\varnothing, R\}$)

As with the BE game above, we look for a general solution to the PE game in (p, m)-space that is robust to changes in the cost parameters. Two conditions on the cost parameters are sufficient to generate the plot of equilibrium industrial structures in the PE game that we present below: first, assumption (C) on G,I is maintained; second, we replace assumption (B) on t,c with

(B)′ $$R(0,c+t)-R(c,c+t)+R(t,c)-R(0,c)>0$$

Because $R(0, c) \geq R(0, t)$ (B)′ is (weakly) tighter than (B). In terms of our solution to the PE game assumptions (B)′,(C) define nondrastic variations in costs.

The mechanics of deriving best responses and equilibrium behaviour in the PE game are set out in the Appendix. The solution method operates as follows. Using Lemma 4 we first derive firm 3's optimal choice in each region of Figure 1. If 3 optimally chooses ∅ at the BE equilibrium, then of course that equilibrium industrial structure is sustained under potential entry (Lemma 2). If 3's optimal response to the BE equilibrium is R, then we conjecture the incumbents' new best responses and check the result.

Figure 2 illustrates the equilibrium industrial structures of the PE game.

[INSERT FIGURE 2]

Key to Figure 2

Region	Equilibrium Industrial Structure under PE
I	{(1, N), (1, N); ∅}
II	{(1, N), (1, R); ∅}
III	{(1, R), (1, R); ∅}
IV	{(1, R), (1, R); ∅}; {(1, N), (2, R); ∅}
V	{(1, R), (1, R); ∅}; {(1, N), (1, N); R} or {(1, N), (2, R); ∅}

VI	{(1, *R*), (1, *R*); *R*}* or {(1, *R*), (2, *R*); ∅}
VII	{(2, *R*), (2, *R*); ∅}*
VIII	{(1, *R*), (1, *R*); *R*}; {(1, *R*), (1, *R*); *R*} or {(2, *R*), (2, *R*); ∅}
IX	{(1, *R*), (1, *R*); *R*}
X	{(2, *R*), (2, *R*); *R*}*

(Note: * denotes a dominant strategy equilibrium.)

In the key to Figure 2 multiple equilibria within a region are separated by semicolons. Where PE equilibria are separated by 'or', the relevant equilibrium depends on whether entry by firm 3 is accommodated (*R*) or strategically deterred (∅) by the incumbents.

In Section 4 we examine the related issues of (i) how the incumbents respond to the entry threat (accommodate vs. deter); and (ii) how the entry threat affects equilibrium industrial structures relative to the BE case. In the remainder of this Section we discuss first the similarities between the BE and PE equilibria depicted in Figures 4 and 5 respectively. Focussing on the BE game for concreteness, we next consider how strategic rivalry between the incumbents affects equilibrium behaviour (although our conclusions could be extended to the PE game). Finally we analyse the effects on Figures 4 and 5 of nondrastic variations in the cost parameters.

Comparative statics: the equilibrium effects of varying p,m.

Figures 4 and 5 provide empirical implications for the relationships between *p*,*m* and equilibrium levels of greenfield-FDI and R&D investment. The derived relationships can be quite complex. Consider first the effect of changes in *m*. In the BE game increasing *m* in low-*p* industries shifts the equilibrium successively from {(1, *N*), (1, *N*)} (region I); to {(1, *N*), (1, *R*)} (region II); to {(1, *R*), (1, *R*)} (region III); to {(2, *R*), (2, *R*)} (region V). A similar sequence can be observed in the PE game if the incumbents accommodate entry. Equilibrium industry spending on both greenfield-FDI and R&D increases with *m* (although not smoothly). (Note, however, that one-way FDI flows are never observed in the BE game: the equilibrium industrial structure jumps from two national (exporting) firms to two MNEs (FDI cross-hauling). Furthermore, if entry is deterred in the PE game, intra-industry greenfield-FDI flows will fall as *m* increases from region VIII to region IX, before returning to $2 \cdot G$ in region X.) These general predictions appear intuitively reasonable: in bigger markets, firms are more easily able to shoulder the sunk costs of greenfield-FDI and R&D.

In high-p industries the relationships between m and equilibrium sunk investments are more complex. Increases in m in the BE game shift the equilibrium industrial structure successively from {(1, *N*), (1, *N*)} (region I); to {(1, *N*), (1, *R*)} (region II); to {(1, *R*), (1, *R*)} (region III); to {(1, *R*), (1, *R*)} or {(1, *N*), (2, *R*)} (region IV); to {(1, *R*), (1, *R*)} (region III); to {(2, *R*), (2, *R*)} (region V). If the {(1, *R*), (1, *R*)} equilibrium is selected in region IV, then there is no difference between low- and high-p industries in terms of the sequence of equilibrium industrial structures as m rises. However, if the asymmetric {(1, *N*), (2, *R*)} equilibrium is selected, then we will observe 're-switching' in terms of both greenfield-FDI and R&D behaviour. The positive relationships between m and both industry greenfield-FDI and industry R&D would be broken by region IV, where the equilibrium switches from both firms investing in R&D to only one and from two national (exporting) firms to one MNE and one exporter, before switching back again when region III is re-entered at higher values of m. (Similar 'perverse' relationships can be inferred from the PE game in Figure 2.)

The effect of changes in p is even less straightforward than that of changes in m. For brevity, we shall only highlight the most interesting aspects of the relationship between p-values and equilibria. As in the case of varying m, it is clear that equilibrium industry spending on greenfield-FDI and R&D need not be increasing in p. In very large markets, increasing p in the BE game will take us successively through the following equilibrium industrial structures: {(1, *N*), (1, *N*)} (region I); then {(1, *N*), (1, *R*)} (region II); then {(1, *R*), (1, *R*)} (region III); then {(2, *R*), (2, *R*)} (region V); then {(1, *R*), (1, *R*)} (region III); then {(1, *N*), (2, *R*)} or {(1, *R*), (1, *R*)} (region IV). If the {(1, *N*), (2, *R*)} equilibrium is selected in region IV, then equilibrium industry R&D spending will be *decreasing* in p for large markets. Furthermore, in large markets greenfield-FDI cross-hauling only occurs for intermediate p-values: for higher p-values the equilibrium industrial structure 're-switches' to one of two national (exporting) firms, before finally one-way greenfield-FDI arises in equilibrium when $p \cong 1$. (Again, similar 'perverse' relationships can be inferred from the PE game in Figure 2.) The intuition for some of these relationships can be seen by considering why (1, *N*) is a best response to (2, *R*) for $p \cong 1$ in the BE game (i.e. how the {(1, *N*), (2, *R*)} equilibrium arises). Facing a foreign rival's choice of (2, *R*), an incumbent will only undertake the sunk investments associated with (1, *R*) or (2, *R*) if it expects to acquire a marginal production cost *advantage* over its rival. The probability of this is $p \cdot (1 - p)$, which tends to 0 as p approaches 1. Therefore, for $p \cong 1$ (1, *N*) must be the best response to (2, *R*) in the BE game.

Proposition 1 summarises the empirical implications of Figures 4 and 5.

Proposition 1. (*i*) *Equilibrium industrial structures in the BE and PE games depend on both* p *and* m. (*ii*) *Equilibrium industry greenfield-FDI flows and R&D investment depend on* p *and* m *in complex ways. In particular, for certain sets of parameter values equilibrium industry spending on greenfield-FDI and R&D may be decreasing in* p *and* m.

Proposition 1 emphasises the complexity of equilibria in the BE and PE games: part (i) draws attention to the fact that none of the inter-regional boundaries in Figures 4 and 5 are either horizontal or vertical. In terms of the existing literature on tariff-jumping FDI, we have seen that when the R&D decision is made endogenous the relationship between (host-country) market size and greenfield-FDI may *not* be increasing. Indeed, larger host-country markets may be associated with *lower* levels of inward FDI, because of the new equilibrium industrial structures they induce.

Strategic rivalry between incumbents in the BE game.

Three types of strategic interaction are noteworthy in the BE game, and we devote a Proposition to each.

Proposition 2. *Two-way relationships exist between greenfield-FDI and R&D* (*à la Petit and Sanna-Randaccio*) *in the BE game.* (*i*) *An incumbent that is committed to investing in R&D is 'more likely' to undertake greenfield-FDI than one that is committed to not investing in R&D.* (*ii*) *An incumbent that is committed to maintaining 2 plants is 'more likely' to undertake R&D than one that is committed to maintaining only its home plant.*

Proof. See Appendix.

Proposition 3. *Equilibrium industrial structures in the BE game can exhibit Prisoner's Dilemma characteristics.*

Proof. See Appendix.

Lemma 5 prepares the ground for the result in Proposition 4.

Lemma 5. Under assumption (C) and for sufficiently high p-values, a global monopolist will (i) never choose a corporate structure of (2, N) in equilibrium; and (ii) choose equilibrium corporate structures in the sequence (1, N), (1, R), (2, R) as μ rises away from 0.

Proof. See Appendix.

Proposition 4. *Under assumption* (*C*) *and for sufficiently high p-values* (*as defined by Lemma 5*), (*i*) *a necessary-and-sufficient condition for greenfield-FDI to be 'more likely' in equilibrium under monopoly than under BE duopoly is* $c \geq x^M(t)$; *and* (*ii*) *sufficient conditions for R&D to be 'more likely' in equilibrium under BE duopoly than under monopoly are* $c \geq x^M(t)$ *and* $c + t \geq x^M(c)$.

Proof. See Appendix.

3.4. Nondrastic Variations in Costs.

In this Section we consider the effects of variations in the four cost parameters t,c,G,I on the equilibrium industrial structures in the BE and PE games. We restrict our attention to nondrastic variations, so assumption (C) on G,I continues to hold; as do assumptions (B) and (B)′ on t,c in the BE and PE games respectively. Our first task is to establish the legitimacy of this focus by showing that assumptions (B), (B)′, (C) are compatible with substantial ranges of variation in the cost parameters. Because assumption (C) is stated explicitly in terms of G,I, the reader can readily assess for herself whether the restriction it contains is reasonable. However, the opposite is true of assumptions (B) and (B)′, which t,c only enter via the net revenue function. Assumptions (B) and (B)′ are analysed in the Appendix and Proposition 5 is established.

Proposition 5. *For all* $c \in (0, 1)$ *assumption* (*B*) *is satisfied on a non-empty open interval of t-values,* $t \in (0, t^*)$ *with* $t^* < c$. *Likewise for assumption* (*B*)′.

Proof. See Appendix.

Proposition 5 is 'loose' in the sense that it gives us no indication of the *size* of the interval of permissible t-values (although it does state that such an interval always exists). A simple indicator of the t-interval's size is that $t^* > 0.5 \cdot c$ for both (B) and (B)′. Therefore, we can conclude that assumptions (B) and (B)′ are consistent with large sets of t- and c-values. Figures 4 and 5 depict general, rather than special, cases.

4. The Effect of the Entry Threat.

Of course, the crucial distinction between the BE and PE games is the presence of an entry threat in the latter (i.e. stage 2 in Figure 3). In this Section we consider two interrelated aspects of the entry threat. First, when will the incumbents select strategies of strategic entry-deterrence over ones of accommodation? Second, for given parameter values how do equilibrium industrial structures in the PE game compare to those in the BE game? (Clearly these two analyses are intimately interrelated because the PE equilibria depend on whether the incumbents choose to deter or accommodate entry.) The second-step analysis will give an indication of whether the inclusion of potential entry is significant within our modelling structure; and it will also test the intuition we provided in the Introduction on the interrelationships between firms' FDI, R&D and entry decisions.

We consider first the incumbents' choice between entry-deterrence and accommodation. From Figure 2 it is clear that PE equilibria where entry is accommodated certainly arise for high μ-values (i.e. regions VIII, IX and X). Conversely, for low μ-values entry is blockaded (i.e. regions I, II, III and IV). For some 'intermediate' μ-values (i.e. regions V, VI and VIII) there potentially exist either entry-accommodating or entry-deterring equilibria (which are separated by 'or' in the key to Figure 2), but assumptions (B)′ and (C) are too loose to allow us to discriminate between them in general. However, we can isolate some of the determinants of whether entry-accommodation or entry-deterrence will arise in equilibrium.

Proposition 6. *If $G = I$, then* (*i*) {(1, *N*), (2, *R*); ∅} *is selected over* {(1, *N*), (1, *N*); *R*} *for all* (*p*, m) *in region V of Figure 2; and* (*ii*) *given sufficiently high p, a second equilibrium of* {(2, *R*), (2, *R*); ∅} *exists for all* m *in region VIII of Figure 2.*

Proof. See Appendix.

Part (i) of Proposition 6 establishes that the second equilibrium in region V of Figure 2 is the entry-deterring {(1, *N*), (2, *R*); ∅} when $G = I$. Under assumption (C), we know that two PE equilibria (one entry-accommodating, the other entry-deterring) will always exist in region VIII above RHS(5BE). However, below RHS(5BE) only the entry-accommodating equilibrium may survive. Part (ii) of Proposition 6 establishes that a *second* equilibrium of {(2, *R*), (2, *R*); ∅} exists below RHS(5BE) when $G = I$.

In the Appendix we show that entry-deterrence arises in equilibrium in region VI when $G = I$ if t is 'sufficiently large'.

The preceding analysis of equilibrium selection in regions V, VI and VIII of Figure 2 set $G = I$. Proposition 7 covers cases where $G > I$, which are also compatible with assumption (C).

Proposition 7. *For all G,I under assumption* (*C*)*, rises in G relative to I make the selection of entry-deterring PE equilibria* (*over entry-accommodating PE equilibria*) *'less likely' in regions V, VI and VIII of Figure 2. Specifically,* (*i*) *rises in G ceteris paribus weakly increase the size of the* μ*-interval where entry-accommodation is selected in equilibrium in regions V, VI and VIII of Figure 2; and* (*ii*) *in the limit as* $G \to \infty$*, entry-deterrence is never selected in equilibrium in regions VI and VIII of Figure 2, although entry-deterrence is always selected for some p-values in region V.*

Proof. See Appendix.

The intuitive justification for the results in Proposition 7 is that, whereas firm 3 must undertake R&D but not greenfield-FDI to enter the industry, the incumbents' entry-deterring strategies always entail greenfield-FDI. Therefore the result stems directly from our modelling structure. (Because firm 3 initially owns 2 plants, the cost of additional plants, G, is irrelevant to its entry decision. However, the incumbents must invest in greenfield-FDI to deter entry.)

We now turn to the second-step analysis of the effects of the entry threat in the PE game on equilibrium industrial structures. We use equilibrium industrial structures in the BE game as benchmarks. In Figure 2 the inter-regional boundaries from the BE game (Figure 1) are plotted: four of them are also inter-regional boundaries in the PE game, and the remainder of RHS(5BE) (apart from the lower boundary of region VII) is shown as a dashed line. An interesting comparison is between region III in Figure 1 and regions III, V, VI, VIII and IX in Figure 2, which together cover the same set of (p, μ)-pairs. In regions III, V, VIII and IX of Figure 2 a PE equilibrium where both incumbents choose (1, R) exists for sure, as in region III of Figure 1; such a PE equilibrium also exists in region VI if G is sufficiently close to I (Propositions 6 and 7). In the lower regions of Figure 2 (III and V) entry does not occur when both incumbents choose (1, R) in PE equilibrium, whereas in the upper regions (VI, VIII and IX) it does.

However, there exist additional PE equilibria in the area where {(1, R), (1, R); $\varnothing$} is the BE equilibrium (region III of Figure 1). In regions V, VI and VIII of Figure 2 an entry-deterring PE equilibrium where the incumbents undertake more sunk investments than at the corresponding BE equilibrium exists if G is sufficiently close to I (Propositions 6 and 7). (In the case of region V the two entry-deterring PE equilibria both, of course, entail two sunk investments.) In particular, note that the entry-deterring PE equilibrium of $\{(1, R), (2, R); \emptyset\}$ in region VI is *qualitatively different* from any of the BE equilibria in Figure 1 (in terms of the incumbents' behaviour). A final distinction between the 'middle' areas of Figures 4 and 5 is the possibility of an entry-accommodating PE equilibrium of $\{(1, N), (1, N); R\}$ in region V of Figure 2, where the incumbents undertake fewer sunk investments than at the corresponding BE equilibrium.

We now consider the area above RHS(5BE), where $\{(2, R), (2, R); \emptyset\}$ is the equilibrium industrial structure of the BE game in dominant strategies (region V of Figure 1). In regions VIII and IX of Figure 2 (both of which lie partially above RHS(5BE)) entry-accommodating PE equilibria of $\{(1, R), (1, R); R\}$ exist for sure, where the incumbents undertake fewer sunk investments than at the BE equilibrium. PE equilibria where both incumbents choose $(2, R)$ exist (i) in regions VII and VIII (above RHS(5BE)); and (ii) in region X. In case (i) firm 3 does not enter the industry in the resulting equilibrium industrial structure of the PE game, whereas in case (ii) it does. Therefore, when entry must be accommodated, larger markets are necessary in the PE game to induce the incumbents to make sunk investments (RHS(A13) > RHS(5BE) for all p); otherwise the incumbents reduce their expenditures on sunk investments (region IX of Figure 2) relative to the BE case.

In terms of Fudenberg and Tirole's (1984) taxonomy of investment strategies, the incumbents therefore behave as 'top dogs' when deterring entry (in regions VI and VIII of Figure 2) but as 'puppy dogs' when accommodating it (in regions V, VIII and IX of Figure 2). The 'top dog' invests in 'strength' (by undertaking extra sunk investments) to look tough and ward off rivals, whereas the 'puppy dog' conspicuously avoids looking 'strong' (by reducing spending on sunk investments) to appear inoffensive and avert aggressive reactions from rivals.

Proposition 8 sums up the comparisons between equilibrium industrial structures in the BE and PE games.

Proposition 8. (*i*) *For given parameter values, the incumbents in the PE game tend to adopt 'tough'* (*resp. 'soft'*) *strategies when entry is deterred* (*resp. accommodated*) *in equilibrium by undertaking more* (*resp. fewer*) *sunk investments than at the corresponding BE equilibrium.* (*ii*) *The entry threat in the PE game can induce the incumbents to choose* *qualitatively different configurations of corporate structures in equilibrium to any observed in the BE game.*

5. Concluding Comments.

We have analysed the equilibrium corporate structure choices of rival international duopolists both without (BE game) and with (PE game) the threat of entry. This modelling structure permits investigation of the interrelationships between firms' (greenfield-)FDI, (process) R&D and entry decisions. Our principal findings are

(i) Equilibrium industry spending on greenfield-FDI and R&D in the BE game depends non-monotonically on p, the probability of R&D success, and m, market size. (Proposition 1.)

(ii) Two-way relationships exist between the incumbents' greenfield-FDI and R&D decisions in the BE game, and the resulting equilibrium industrial structures can exhibit Prisoner's Dilemma characteristics. (Propositions 2 and 3.)

(iii) Compared to the BE game, additional equilibrium industrial structures arise in the PE game. When entry is deterred (resp. accommodated) in PE equilibrium, equilibrium spending on sunk investments by the incumbents tends to be higher (resp. lower) than in the BE game. (Proposition 8.)

(iv) Whether the incumbents in the PE game choose strategies of entry-deterrence or -accommodation depends on the sunk costs of greenfield-FDI and R&D. The higher is G, the cost of greenfield-FDI, relative to I, the cost of R&D, the 'more likely' is it that entry-accommodation will arise in PE equilibrium. (Propositions 6 and 7.)

Therefore, our analysis has uncovered significant interrelationships between firms' FDI, R&D and entry decisions in the international oligopoly under consideration.

Finally, we consider two applications of our modelling structure. Note that our BE and PE games can be generally applied to firm expansion across segmented product markets, rather than solely across national borders that coincide with segmented markets. (In this sense, there is nothing 'special' about MNEs, although their various markets are probably more completely segmented than those faced by exclusively national firms.) The first application is to policy games between national governments. For example, rival governments may non-co-operatively set tariffs or FDI policies. If tariffs were determined endogenously, the model would be similar to those in 'strategic trade theory', although production locations would become endogenous. (Horstmann and Markusen (1992) discuss the jumps in equilibrium industrial structures that can arise if t is marginally adjusted, which would characterise these models.) Alternatively, suppose that national governments set their FDI policies endogenously, choosing between free-FDI, where inward flows of greenfield-FDI are unregulated, and no-FDI, where inward greenfield-FDI is banned. (Governments have no power over outward FDI flows.) Equilibrium policies would depend on the government's objective function, and there will be a conflict between the interests of domestic consumers (who will favour free-FDI and intense competition) and domestic firms (who would prefer the protection afforded by no-FDI). Our modelling structure provides a framework within which to investigate these issues.

The second application, which is the subject of ongoing research, is to the distinction between greenfield-FDI, the form of FDI modelled in the BE and PE games, and acquisition-FDI, whereby a firm establishes production facilities abroad by purchasing a local rival. Given that acquisition-FDI is a dominant component of empirical FDI flows but has received little theoretical attention, models where different *forms* of FDI arise endogenously would fill a significant gap. They will allow us inter alia to develop a more rounded picture of the welfare effects of international flows of FDI.

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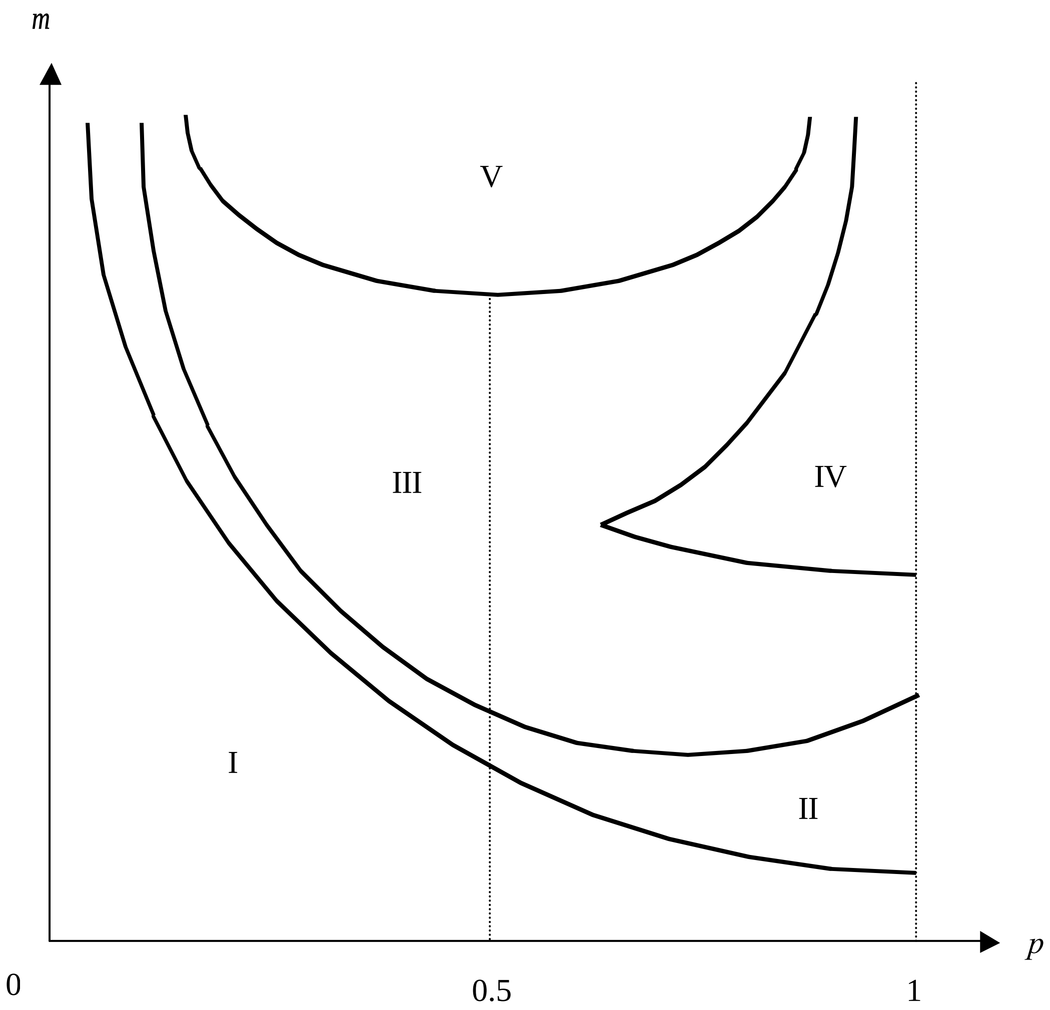

Figure 1: Equilibrium industrial structures in the BE game

Inter-regional boundaries: I/II boundary is RHS(1BE); II/III boundary is RHS(4BE); III/IV lower boundary is RHS(2BE); III/IV upper boundary is RHS(7BE); III/V boundary is RHS(5BE).

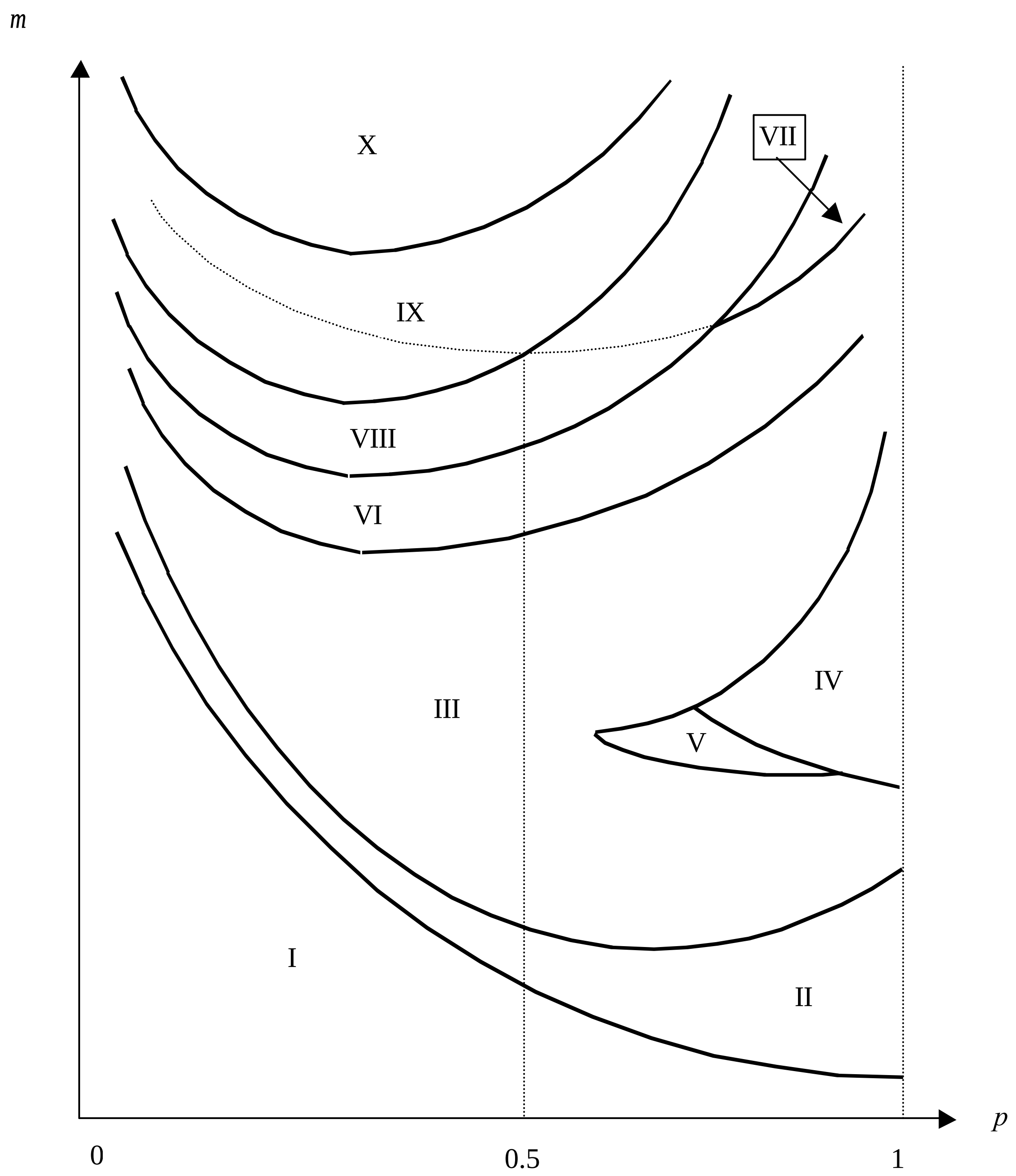

Figure 2: Equilibrium industrial structures in the PE game

Inter-regional boundaries: I/II boundary is RHS(1BE); II/III boundary is RHS(4BE); III/IV lower boundary and IV/V boundary is RHS(2BE); III/IV upper boundary and III/V upper boundary is RHS(7BE); III/V lower boundary is RHS(2PE); III/VI boundary is RHS(4PE); VI/VII boundary is RHS(5BE); VI/VIII boundary and VII/VIII boundary is RHS(5PE); VIII/IX boundary is RHS(6PE); IX/X boundary is RHS(A13).