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**Strategic Decisions of Multinational Enterprises:
Foreign Direct Investment and Technology**

by

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**A thesis submitted in partial fulfilment of the requirements for the degree of
Doctor of Philosophy (PhD) in Economics**

Department of Economics, University of Warwick

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For Katherine

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My biggest debt is to my partner, Katherine, who could by now (justifiably) be heartily sick of the economics of multinational enterprises. Amazingly, it appears that she is not. Not only has Katherine put up with my long periods of isolation in the study and with my frequent detachment outside the study as the thesis gripped my mind over the last four years, but she has also, and more importantly, given massive amounts of impetus – in almost every conceivable way – to the progress of this project. I honestly believe that this thesis could not have been completed without Katherine, and I just hope that she realises how deeply grateful I am.

Ben Ferrett

Nottingham

September 2003

Declaration

I hereby declare that all of the research contained in this thesis is my own original work. Excluding its current submission for examination for a PhD in economics from Warwick University, none of the work in this volume has been submitted (either previously or simultaneously) for examination for any degree at the University of Warwick or elsewhere. None of the research in this thesis has yet been published.

Ben Ferrett

Nottingham

September 2003

Summary

This thesis consists of three self-contained chapters concerning the determination of 'equilibrium industrial structures' in 'international oligopolies'. In each model presented in the thesis rival oligopolists in the industry concerned choose their 'corporate structures' and then compete to serve the national product markets (either via local production following foreign direct investment (FDI) or via imports). Our analyses are united by the general types of 'corporate structure' choices considered and by the broad features of 'industrial structure' that are endogenously determined in equilibrium. We emphasise the roles played by the following three phenomena in shaping 'equilibrium industrial structures': the distinction between greenfield-FDI ('greenfield investment') and acquisition-FDI (cross-border mergers and acquisitions); R&D investments and technology flows ('technology transfer') both within and between firms; and the potential entry into the industry of 'outside' firms, and incumbent firms' strategic reactions to the entry threat.

The distinction between greenfield-FDI and acquisition-FDI is both empirically and theoretically important: whereas greenfield-FDI adds an extra plant to the host country, acquisition-FDI changes only the ownership pattern of existing plants. Despite this, previous game-theoretic models of equilibrium FDI flows have concentrated exclusively on one type of FDI. Therefore, allowing the *form* of FDI to be endogenously selected as part of the 'equilibrium industrial structure' is both a novel and an interesting feature of our analysis. It also allows us to investigate the differential relationships between the two types of FDI and industry R&D spending (and therefore to test a popular 'failing firm' defence of inward acquisition-FDI: that it fosters 'technological development', the benefits of which outweigh the welfare costs of increased 'concentration'). A further novel feature of our analysis is the potential for (de novo) entry into the industry (at a global level): previous work assumed blockaded entry. We show that a credible entry threat by 'outside' firms has significant consequences for 'equilibrium industrial structure'.

At a general level, the results derived in this thesis provide a perspective on the relationship between MNEs' behaviour and industrial structure in 'globalized' industries that contrasts with that offered by Dunning's 'OLI paradigm'. It is also hoped that this thesis will be viewed as having made a useful contribution to unpicking the aggregation, which frequently occurs in public debate, of greenfield-FDI and acquisition-FDI into a (supposedly homogeneous) flow of 'inward investment'.

Introduction

This thesis consists of three self-contained chapters. The purpose of this brief introduction to the thesis as a whole is to highlight some of the common features of the following chapters. Our analyses all concern the determination of ‘equilibrium industrial structures’ in industries that are often described as ‘international oligopolies’: concentrated global industries that span several (segmented) national product markets (i.e. consumers are perfectly immobile internationally, so each country has a well-defined national market demand curve that is independent of foreign prices). In each model presented in this thesis rival oligopolists in the industry concerned choose their ‘corporate structures’ (from a well-specified set of alternatives) and then compete to serve the national product markets (via either local production or imports). Our chapters are united by the general types of ‘corporate structure’ choices considered and by the broad features of ‘industrial structure’ that are endogenously determined in equilibrium. We emphasise the roles played by the following three phenomena in shaping ‘equilibrium industrial structures’:

- the distinction within foreign direct investment (FDI) flows between *greenfield-FDI* (‘greenfield investment’) and *acquisition-FDI* (cross-border mergers and acquisitions, M&As) as distinct means of establishing local production facilities to serve national product markets;

- investments in *technology* upgrading (i.e. R&D investments), and technology flows ('technology transfer') both within and between ('spillovers') firms;
- the *potential entry* into the industry of 'outside' firms, and incumbent firms' strategic reactions to the entry threat.

The distinction between greenfield-FDI and acquisition-FDI is empirically important (i.e. neither type of FDI flow is empirically trivial): for example, UNCTAD (2000) estimates that the ratio of acquisition-FDI to greenfield-FDI in aggregate global FDI flows was 4:1 in the late 1990s (and since then cross-border M&A flows have collapsed). Furthermore, from an industrial-economic perspective, there are reasons to hypothesize that inflows of greenfield-FDI and acquisition-FDI will generate distinct host-country market structures (at least in the short run) with (possibly) distinct welfare properties: whereas greenfield-FDI adds an extra plant to the host country, acquisition-FDI changes only the ownership pattern of existing plants. Despite these empirical and theoretical observations, previous game-theoretic models of equilibrium FDI flows have concentrated exclusively on one type of FDI (implicitly assuming that it represents the general case?): see, e.g., Horstmann and Markusen (1992) on greenfield-FDI and Horn and Persson (2001b) on acquisition-FDI. Therefore, allowing the *form* of FDI to be endogenously selected as part of the 'equilibrium industrial structure' is both a novel and an interesting feature of our analysis.

It is often suggested (e.g. in Dunning's (1977) 'OLI paradigm') that a positive relationship should exist within an industry (at a global level) between FDI flows and R&D spending. By allowing firms' investment levels in R&D to be endogenously determined, we are able to investigate this hypothesis formally. Furthermore, because both greenfield- and acquisition-FDI flows are modelled, we are able (in chapter 2) to explore the differential relationships between the two types of FDI and industry R&D spending. This last feature allows us to test (an aspect of) the frequently-invoked 'failing firm' defence of acquisition-FDI inflows: that inward investment in the form of acquisition-FDI fosters 'technological development' in the host industry (i.e. increased R&D spending in our context), the benefits of which outweigh the welfare costs of (possibly) increased 'concentration'.

Our recognition of the distinction between greenfield- and acquisition-FDI also allows us to examine additional channels of 'technology transfer' between plants in an industry to those usually highlighted in the theoretical literature. Previous work (e.g. Fosfuri and Motta, 1999; Siotis, 1999) on technology flows between plants in international oligopolies has focussed on the 'spillovers' that can occur between the foreign branch plant of a multinational enterprise (MNE) and indigenous firms in the host country following inward greenfield-FDI. However, inward investment in the form of acquisition-FDI can be associated with 'technology transfer' between plants *within* the (newly-formed) MNE. (For example, if the acquirer's own pre-takeover 'technology stock' is superior to that embodied in the production plant of the purchased firm, the acquirer may upgrade the target plant's technology following the takeover.) We are able (in

chapter 3) to consider both the inter-firm ('spillovers') and intra-firm varieties of 'technology transfer', and to investigate the role of each in shaping national 'productivity distributions' across plants, precisely because we acknowledge the distinction between greenfield- and acquisition-FDI.

The final theme that unifies the three chapters in this thesis is consideration of the impact of potential entry into the industry (at a global level) on 'equilibrium industrial structures'. The canonical models of 'equilibrium industrial structure' in international oligopolies that significantly inform the modelling frameworks used in this thesis (e.g. Horstmann and Markusen, 1992; Rowthorn, 1992) assume that the entry of 'outside' firms at a global level is blockaded. (Of course, incumbent firms can 'enter' foreign markets via greenfield-FDI in those models, but the *number* of firms in equilibrium is assumed to be fixed at two.) However, we show (in chapter 1 especially) that there are often incentives for 'outside' firms to establish plants in the industry at equilibrium, and that the responses of incumbent firms to these credible entry threats have important consequences for 'equilibrium industrial structure' (whether entry is 'accommodated' or 'deterred' in equilibrium). Therefore, the popular assumption of blockaded entry is *not* innocuous and – if it is to be adopted – must be thoroughly justified.

The remainder of the thesis is organised as follows. Chapter 1 ('Entry, Location and R&D Decisions in an International Oligopoly') examines the relationships between rival firms' greenfield-FDI, process R&D and de novo entry decisions in an international oligopoly. The models developed contain two countries, two incumbent firms (which originate from different countries) and one potential

entrant firm. The impact of the entry threat on 'equilibrium industrial structure' is systematically documented and found to be significant. Chapter 2 ('Greenfield Investment versus Acquisition: Alternative Modes of Foreign Expansion') extends the analysis in chapter 1 by introducing the distinction between greenfield- and acquisition-FDI formally. We find that greenfield-FDI and acquisition-FDI are theoretically quite distinct in terms of both the positive and the normative aspects of the industrial structures that they are associated with. Finally, chapter 3 ('Inter- and Intra-Firm Technology Transfer in an International Oligopoly') analyses technology flows both within and between firms in the context of the distinction between greenfield- and acquisition-FDI. We examine the roles of the two types of FDI and of the two types of technology flow in shaping the national 'productivity distribution' across plants within an industry.

At a general level, the results derived in this thesis provide a perspective on the relationship between MNEs' behaviour and industrial structure in 'globalized' industries that contrasts with that offered by Dunning's (1977) 'OLI paradigm'. We explore these contrasts in depth in chapter 3. It is also hoped that this thesis is viewed as having made a useful contribution to unpicking the aggregation, which frequently occurs in public debate, of greenfield-FDI and acquisition-FDI into a (supposedly homogeneous) flow of 'inward investment'.

Chapter 1

Entry, Location and R&D Decisions in an International Oligopoly

1.1. Introduction.

This chapter 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 chapter 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).¹ 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 $\{0,1,2\}$;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 then 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.

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:³ 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.⁴ 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.⁵ 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.⁶ 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).⁷

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.⁸ 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).⁹

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.¹⁰ 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.¹¹

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-detering FDI and (additional) R&D, thus altering the equilibrium FDI/R&D relationship.¹²

The remainder of the chapter is organised as follows. In Section 1.2 the tools necessary for our analysis are developed. In particular, precise meanings are given to terms like market size and R&D, which have (for the sake of brevity) been used rather loosely in this Introduction. We also set out the extensive forms

of the two games that form the core of our analysis. The blockaded-entry (BE) game excludes the possibility of entry and acts as a benchmark case. The BE game assumes the familiar two-country, two-firm world and consists of two stages. In stage one the firms simultaneously and irreversibly choose between four possible 'corporate structures': $(1,N)$, $(1,R)$, $(2,N)$ and $(2,R)$. The first element of a corporate structure refers to the number of plants and the second to whether or not process R&D is undertaken. R&D investment is a binary variable: for a fixed cost of I a firm purchases a probability p that its marginal production cost will fall to 0. (Because the only fixed costs a firm incurs are for greenfield-FDI and R&D, the inactivity strategy of 0 plants can legitimately be ignored.) In stage two of the BE game market equilibrium is established via Bertrand competition (marginal costs are common knowledge and the firms' products are homogeneous). Our second game is the potential-entry (PE) game. We assume that a third firm exists (the 'potential entrant') with access to production facilities in both countries. However, these facilities are initially productively inefficient relative to the incumbents' (their marginal production cost exceeds the monopoly price of an incumbent). For a fixed cost of I the entrant can equip her plants with the best-practice technologies initially possessed by the incumbents. (The entrant can also engage in process R&D on the same basis as the incumbents.) Therefore, our model of entry can be interpreted as one of entry by diversification.¹³ In the PE game an entry stage is inserted between stages one and two in the BE game: it is assumed that the entrant can observe the incumbents' adopted corporate structures (but *not* whether their R&D investments have been successful).

In Section 1.3 we solve the BE and PE games. Both games are solved backwards to isolate subgame perfect Nash equilibria in pure strategies. The equilibrium properties of the BE and PE games are explored. The key findings are: (i) that two-way relationships exist between greenfield-FDI and R&D in international oligopolies; (ii) that equilibria in international oligopolies can exhibit Prisoner's Dilemma characteristics; and (iii) that by making R&D endogenous FDI can be explained in equilibrium in a homogeneous-product international oligopoly under Bertrand competition.¹⁴

In Section 1.4 we investigate the effect of the entry threat by comparing the equilibria of the PE game to those of the BE game. Two broad conclusions emerge. First, the incumbents in the PE game do engage in strategic entry-deterrence, using both greenfield-FDI and R&D. Second, not only does the possibility of strategic entry-deterrence make equilibria involving FDI and R&D 'more likely', it also produces equilibria in the PE game that are qualitatively different from those in the BE game. Therefore, the 'fundamental contention' that firms' FDI, R&D and entry decisions are intimately interrelated, which motivated this chapter's analysis, is validated.

The BE and PE games are built on some very particular assumptions. Therefore, in Section 1.5 we discuss potential modifications of our analysis. We consider the effects of allowing the firms to use mixed strategies when selecting corporate structures; of having the firms select corporate structures sequentially, rather than simultaneously; and of varying our 'information assumptions'. We also consider the effects of assuming differentiated, rather than homogeneous, products and of

substituting Cournot for Bertrand competition.¹⁵ The effects of modifications to our assumptions about entry are explored. Finally, we consider some possible extensions to our analysis.

1.2. The Modelling Structure.

1.2.1. 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 legitimately 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 progress. 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.¹⁶ 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:¹⁷

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

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

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

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

$$Q_j = \mu \cdot (1 - x_j) \quad (1)$$

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; thus, x_j (the market price abroad) does not influence Q_j . μ measures the ‘size’ of either national product market: increases in μ rotate the demand function anticlockwise around $(0,1)$ in (Q_j, x_j) -space, increasing demand at any price equiproportionately. Therefore, μ can be interpreted as an index of the number of homogeneous consumers in each country, all of whom have a reservation price of 1. The specification of demand in (1) is formally identical to that used by Motta (1992), as is the definition of market size. However, our definition of market size differs from Rowthorn’s (1992) ‘idiosyncratic measure of market size’, which measures market size relative to economies of scale in production.

1.2.3. Net Revenue.

Net revenue equals revenue minus variable costs.¹⁸ 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

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

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

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

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' ($(x^M)^{-1}(c_i) > c_j$) 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 $\mu(1 - c_j)$ units.¹⁹ This 'undercutting equilibrium' is shown in the second line of (2). However, if the gap between c_i and c_j is 'large' ($(x^M)^{-1}(c_i) < c_j$) 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. $c_j \equiv \min\{c_1, c_2, \dots, c_{i-1}, c_{i+1}, \dots, c_N\}$).

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 . $R(\cdot)$ is plotted against c_i and c_j in Figures 1.1 and 1.2 below. In Figure 1.1 we assume $c_j > 0.5$ so that $(x^M)^{-1}(c_j) = 2 \cdot c_j - 1 > 0$, and firm i can monopoly-price for low levels of c_i . Reducing c_j would shift the $R(\cdot)$ function leftwards. $R(\cdot)$ has kinks at $c_i = (x^M)^{-1}(c_j)$, where monopoly-pricing and undercutting generate the same net revenue for i , and at $c_i = c_j$, where undercutting generates zero net revenue.

[FIGURES 1.1 AND 1.2 ARE OVERLEAF]

In Figure 1.2 $R(c_i, c_j)$ is plotted against c_j , the behaviour of which can be derived from (2). For $c_j \in (0, c_i]$ and $c_j \in [x^M(c_i), 1)$, $R(\cdot)$ does not vary with c_j : in the former case i is undercut by j in equilibrium, and in the latter case i monopoly-prices. For $c_j \in [c_i, x^M(c_i)]$, i undercuts j in equilibrium and $R(\cdot)$ is strictly concave in c_j . As in Figure 1.1 $R(\cdot)$ has kinks at $c_j = c_i$ and at $c_j = x^M(c_i)$ (i.e. at $c_i = (x^M)^{-1}(c_j)$).

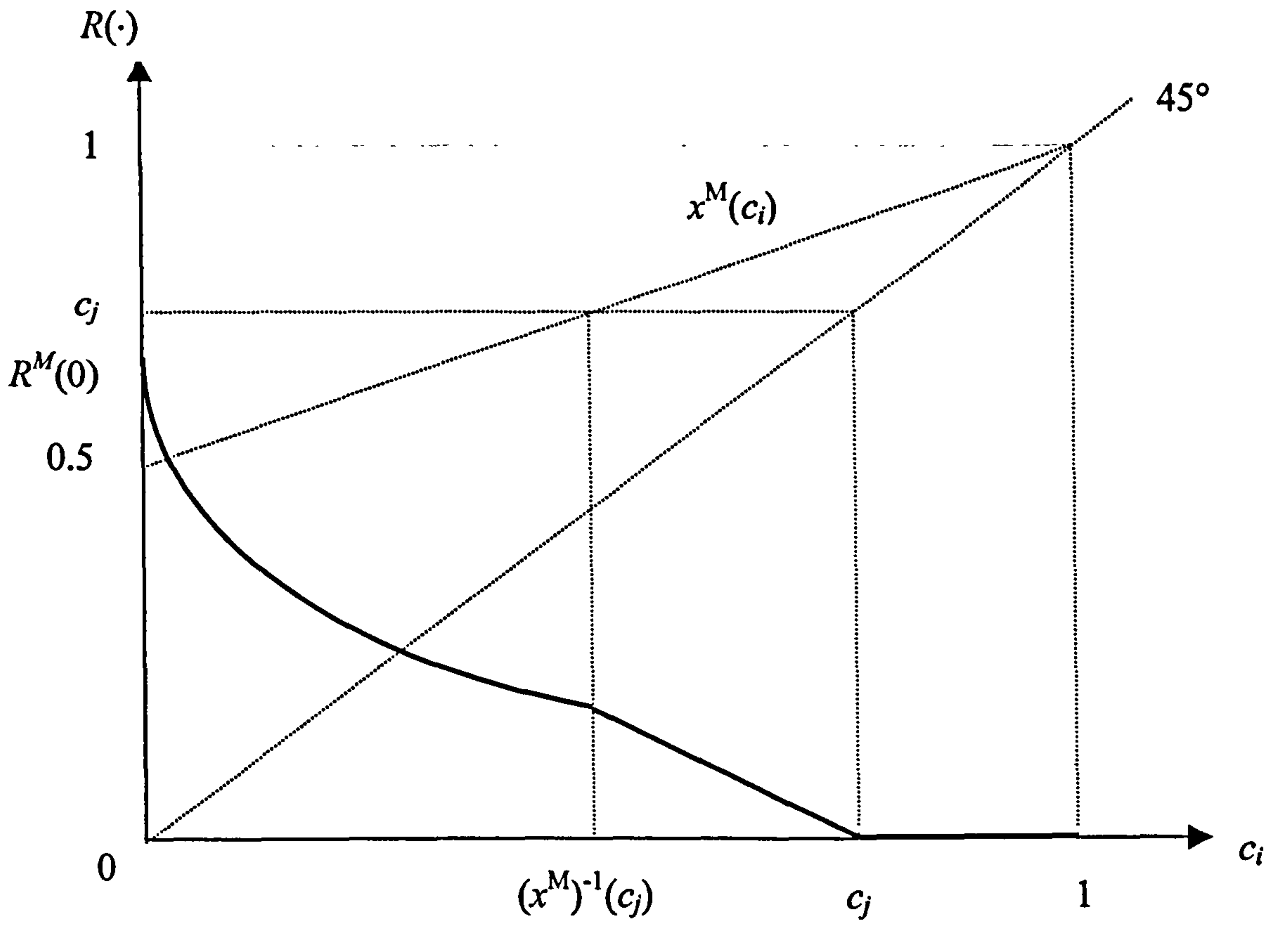


Figure 1.1: $R(c_i, c_j)$ against c_i for $c_j > 0.5$

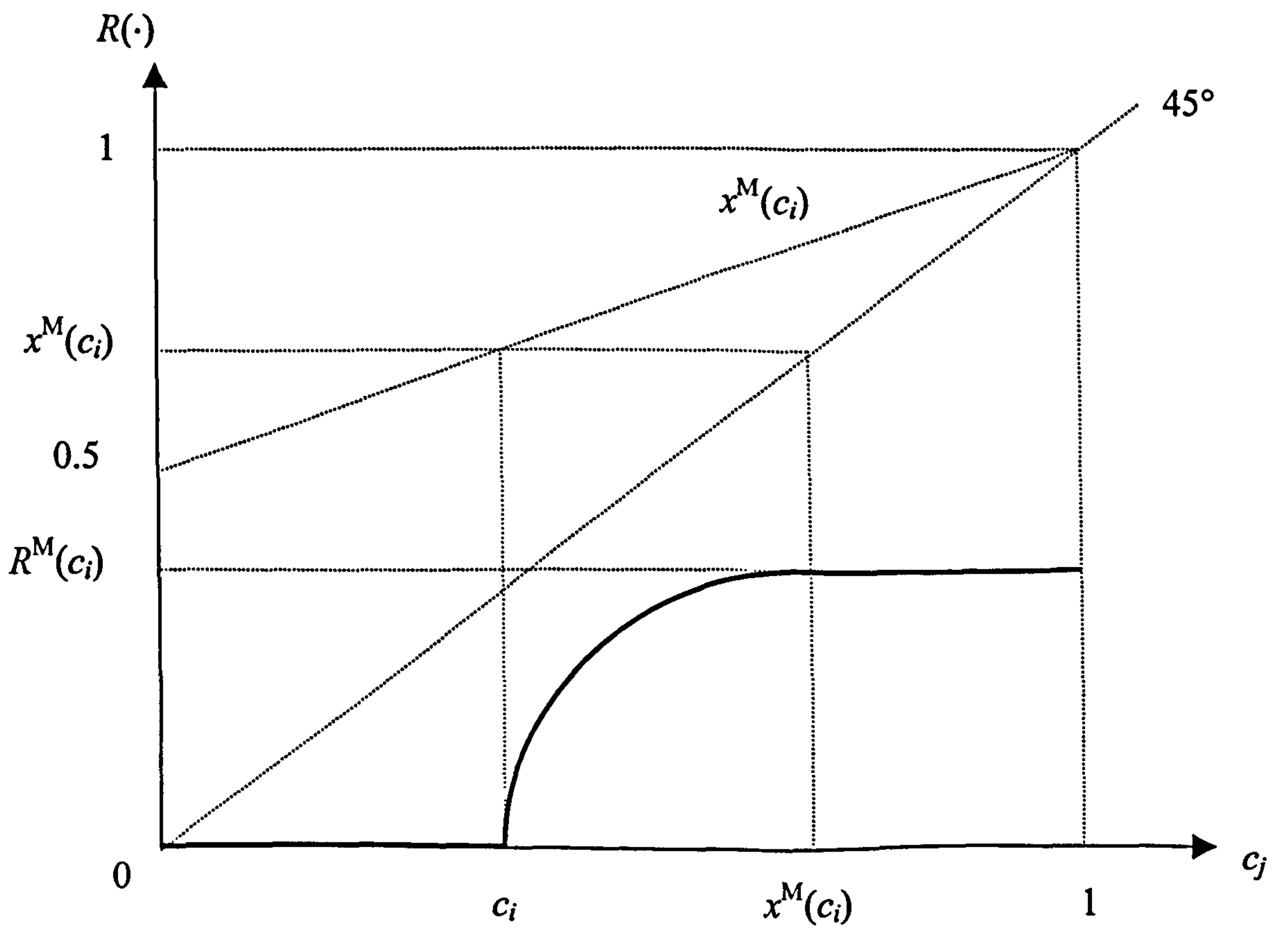


Figure 1.2: $R(c_i, c_j)$ against c_j

There are sixteen distinct realisations of the duopoly net revenue function, because c_i, c_j can take four values (i.e. 0, t , c or $c+t$). In comparing the profitability of different corporate structures (to derive ‘best responses’), it will be necessary to rank the various realisations of the net revenue function.²⁰ The functional form of $R(c_i, c_j)$ creates both advantages and disadvantages for this procedure. 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

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

Likewise, it is possible to rank $R(c_i, c_j)$ for given c_i and different values of c_j . However, 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 . This is the disadvantage created by the badly-behaved functional form of $R(\cdot)$. We return to this problem when solving the BE and PE games below.

From the rankings in (3), qualitative conclusions can be drawn about industrial structure. In the two-country, two-firm world of the BE game, there are two distinct possibilities vis-à-vis industrial structure in each country:²¹

- (i) *Both firms produce locally to serve a product market.* The relevant realisations of the net revenue function for either firm are $R(0, 0)$, $R(0, c)$,

$R(c, 0)$ and $R(c, c)$. A firm will only make strictly positive net revenue if it innovates successfully but its rival does not. The maximum possible market price is c and the minimum is 0.

(ii) *One firm serves the market from abroad (and the other produces locally).*

The net revenues of the local firm are given by $R(0, t)$, $R(0, c+t)$, $R(c, t)$ and $R(c, c+t)$. The net revenues of the foreign firm are described by $R(t, 0)$, $R(t, c)$, $R(c+t, 0)$ and $R(c+t, c)$. Because of the asymmetry between the firms in this case, the possible outcomes are more complex than those in (i). The foreign firm will only be able to earn strictly positive net revenue if it innovates successfully but the local firm does not. For the local firm, the converse is true. The maximum possible market price is $\min\{x^M(c), c+t\}$, which arises when neither firm innovates successfully. The minimum possible market price is $\min\{x^M(0) = 0.5, t\}$, when both firms innovate successfully.

The comparison of industrial structures in (i) and (ii) above suggests two final points. First, outcomes when both firms produce locally are more 'competitive' than when one firm produces abroad, in the sense that both the maximum and the minimum possible market prices are lower. This reflects the fact that the foreign firm becomes a more aggressive competitor for the local firm when it substitutes greenfield-FDI for exporting (because the trade cost is eliminated from its marginal cost). This finding was confirmed by Petit and Sanna-Randaccio (2000); however, note that it assumes that undertaking greenfield-FDI does not alter the form of duopolistic competition in the product market (Bertrand

competition), a point to which we return in Section 5. This assumption was questioned by Hymer (1960), who saw FDI as facilitating collusion.

Second, within our framework of Bertrand competition, cross-hauling of international trade flows will never occur in equilibrium, although FDI cross-hauling may occur. (This contrasts with the predictions of the Rowthorn and Horstmann/Markusen models, which are based on Cournot competition.) Trade cross-hauling could only arise if neither firm undertook greenfield-FDI, and in that case firm i would serve its rival's home market with exports if $c_i + t \leq c_j$. However, note that this condition cannot hold simultaneously with $c_j + t \leq c_i$ (i.e. it is impossible for both firms to possess a marginal cost advantage), so one firm at most will export in equilibrium.²²

1.2.4. Sequence of Moves and Equilibrium Concepts.

The three-stage PE game is shown in Figure 1.3. 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.²³ 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 1.4. The

BE game consists of stages one and three of the PE game and omits the possibility of entry (stage two).

[FIGURE 1.3 IS OVERLEAF]

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 \emptyset .

Proof. (i) Because the two countries' product markets are perfectly segmented, choosing $(2, N)$ rather than $(1, N)$ has no effect on an incumbent's revenues from its home market: it continues to sell at home with a marginal cost of c . Its marginal cost abroad falls from $c+t$ to c , and it sinks G into greenfield-FDI. However, the incumbent's expected net revenues abroad in Bertrand equilibrium remain 0 because its foreign rival has a plant abroad with a marginal cost of c at most. Therefore, choosing $(2, N)$ over $(1, N)$ will reduce an incumbent's expected profits by G , so $(1, N)$ strictly dominates $(2, N)$.

(ii) If the entrant chooses E it sinks I to move onto the technological frontier and can produce at both its plants with a marginal cost of c . However, because both countries contain incumbents' pre-existing plants with marginal costs of c , the entrant's expected global net revenues in

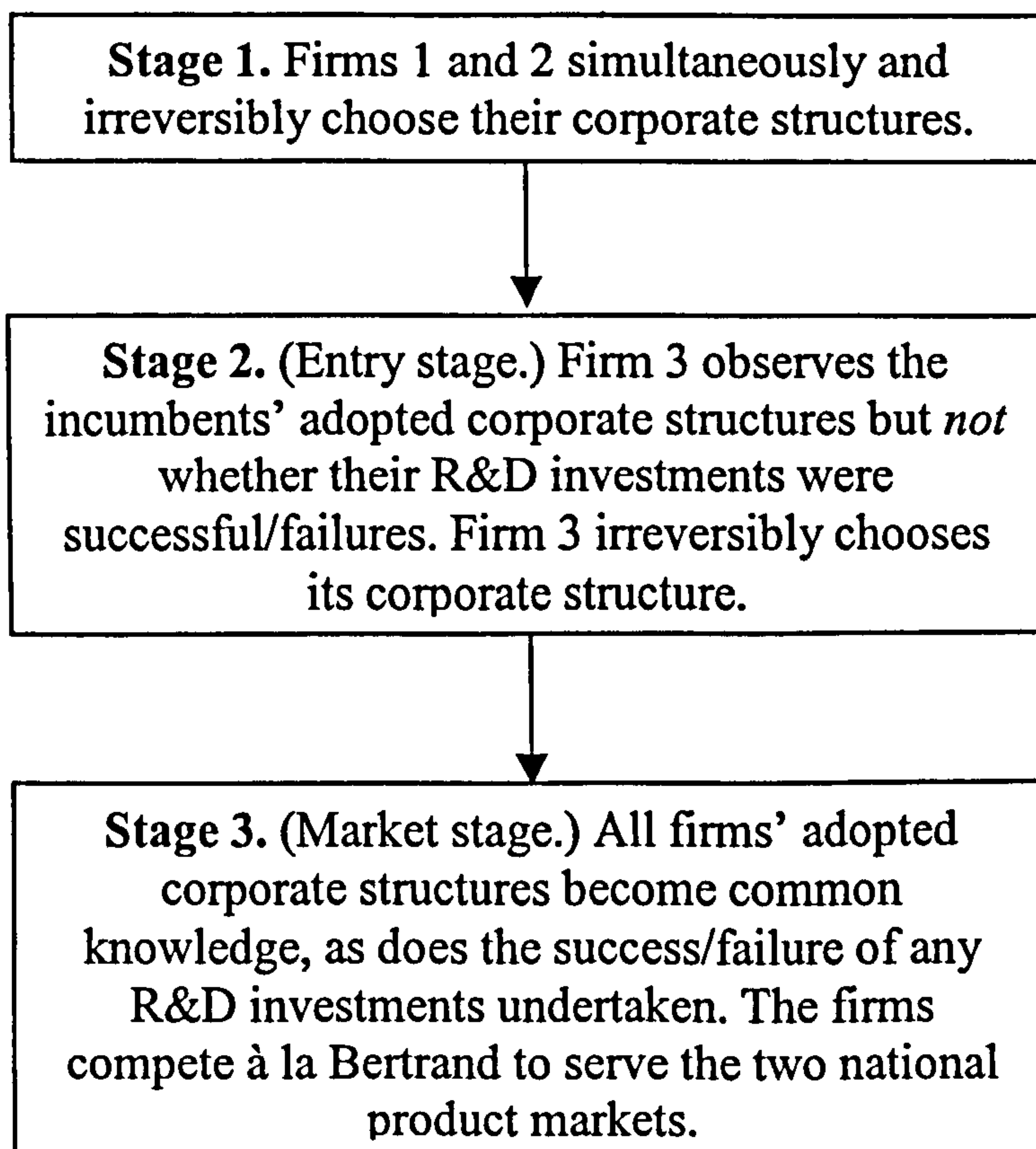


Figure 1.3: Sequence of moves in the PE game

Bertrand equilibrium remain 0. Therefore, choosing E over \emptyset will reduce the entrant's expected profits by I , so \emptyset strictly dominates E . QED.

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 $\{\emptyset, R\}$ 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.

Definitions 1 and 2 formally describe the pure-strategy subgame perfect Nash equilibria of the BE and PE games.

Definition 1. $\{S_1^*, S_2^*; \emptyset\}$ is the *equilibrium industrial structure of the BE game* iff

$$S_1^* = S_1^{BR}(S_2^*) \text{ and } S_2^* = S_2^{BR}(S_1^*)$$

where the $S^{BR}(\cdot)$ functions

$$S_1^{BR}(S_2) \equiv \arg \max_{S_1} E\pi_1(S_1, S_2; \emptyset)$$

$$S_2^{BR}(S_1) \equiv \arg \max_{S_2} E\pi_2(S_1, S_2; \emptyset)$$

for all $S_1, S_2 \in \{(1, N), (1, R), (2, R)\}$

give an incumbent firm's best responses to its rival's corporate structure choice.

Because the incumbents move simultaneously in the BE game, each treats its rival's behaviour as given in equilibrium.

Definition 2. $\{S_1^*, S_2^*; S_3^*\}$ is the *equilibrium industrial structure of the PE game*

iff

$$S_1^* = S_1^{BR}(S_2^*); \quad S_2^* = S_2^{BR}(S_1^*); \quad \text{and} \quad S_3^* = S_3^{BR}(S_1^*, S_2^*)$$

where the $S^{BR}(\cdot)$ functions

$$S_1^{BR}(S_2) \equiv \arg \max_{S_1} E\pi_1(S_1, S_2; S_3^{BR}(S_1, S_2))$$

$$S_2^{BR}(S_1) \equiv \arg \max_{S_2} E\pi_2(S_1, S_2; S_3^{BR}(S_1, S_2))$$

$$S_3^{BR}(S_1, S_2) \equiv \arg \max_{S_3} E\pi_3(S_1, S_2; S_3)$$

for all $S_1, S_2 \in \{(1, N), (1, R), (2, R)\}$ and $S_3 \in \{\emptyset, R\}$

give the firms' best responses to their rivals' corporate structure choices. Because firm 3 is the second-mover in the PE game, it takes the incumbents' corporate structures as given when deriving its best response; therefore, S_3^{BR} depends on S_1, S_2 . However, firms 1 and 2 must take account of the knock-on effects of their own corporate structure choices on firm 3's behaviour; therefore, S_3^{BR} is endogenized within S_1^{BR}, S_2^{BR} . From this formulation of the PE game's

equilibrium it is clear that the incumbents can potentially use their corporate structure choices to influence firm 3's behaviour to their own advantage.

1.3. Analysis.

1.3.1. Expected Profits.

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

BE Game ($S_3 = \emptyset$)

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 $\{(1, R), (1, N); \emptyset\}$, $\{(2, R), (1, N); \emptyset\}$ and $\{(2, R), (1, R); \emptyset\}$ may be derived by straightforward analogy given the underlying symmetric modelling structure.

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

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

Each firm supplies only its home market and influences the equilibrium of the foreign product market only by setting a price ceiling of $c + t$.

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

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

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

If firm 2's R&D investment succeeds, then it alone supplies both countries' product markets, earning $R(0, c + t)$ at home and $R(t, c)$ by exporting to country 1. In this case firm 2's domestic net revenues exceed its net export earnings.²⁴ (We adopt the convention throughout of writing domestic net revenue as the first term in square brackets and foreign net revenue as the second.) If firm 2's R&D investment fails, then market outcomes are identical to those under $\{(1, N), (1, N); \emptyset\}$.

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

$$E\pi_1 = 0$$

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

Regardless of whether firm 2's R&D succeeds, 1's expected profits are zero because by undertaking greenfield-FDI firm 2 can serve country 1's product market with a marginal cost of c *at most*. If firm 2's R&D succeeds, it alone supplies both countries' markets and earns more abroad than under $\{(1, N), (1, R); \emptyset\}$ because undertaking greenfield-FDI eliminates the trade cost. If 2's R&D fails, it earns strictly positive net revenue only at home.

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

$$E\pi_1 = E\pi_2 = p \cdot (1 - p) \cdot [R(0, c + t) + R(t, c)] + p^2 \cdot R(0, t) + (1 - p)^2 \cdot R(c, c + t) - I$$

With probability $p \cdot (1 - p)$ a firm's own R&D succeeds *and* its rival's fails. In this case the successful innovator earns $R(0, c + t)$ at home and $R(t, c)$ abroad, whereas the failing firm is undercut on both markets. If *both* firms' R&D investments either succeed or fail, with probabilities of p^2 and $(1 - p)^2$ respectively, then the firms serve only their home markets.

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

$$E\pi_1 = p \cdot (1 - p) \cdot [R(0, c) + R(t, c)] - I$$

$$E\pi_2 = p \cdot (1 - p) \cdot [R(0, c + t) + R(0, c)] + p^2 \cdot R(0, t) + (1 - p)^2 \cdot R(c, c + t) - G - I$$

Because firm 2 has a local plant in country 1, firm 1 must possess a marginal *production* cost advantage if it is to earn strictly positive net revenue. This occurs with probability $p \cdot (1 - p)$ when 1's R&D investment succeeds but 2's fails. On the other hand, firm 2 can earn strictly positive net revenue *at home* when the firms' marginal production costs are the same because the trade cost insulates its domestic plant from foreign competition.

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

$$E\pi_1 = E\pi_2 = 2 \cdot p \cdot (1 - p) \cdot R(0, c) - G - I$$

Because both firms own two plants, the trade cost is irrelevant to expected profits. When a firm's own R&D succeeds *and* its rival's fails with probability $p \cdot (1 - p)$, then the firm earns net revenue of $R(0, c)$ in both countries.

Lemma 2 uses the following definition to summarise the effects of an incumbent's corporate structure choice on its own and its rival's global net revenues in the BE game.

Definition 3. $R_i(S_1, S_2; S_3)$ is firm i 's, $i \in \{1, 2, 3\}$, global net revenue when the

three firms choose corporate structures of S_1, S_2, S_3 . Global (expected) net revenue is expected profits gross of sunk investment expenditures.

Lemma 2. (i) $R_1((2, R), S_2; \emptyset) > R_1((1, R), S_2; \emptyset) > R_1((1, N), S_2; \emptyset)$ for all S_2 , and likewise (by straightforward analogy) for firm 2. (ii) $R_1(S_1, (1, N); \emptyset) > R_1(S_1, (1, R); \emptyset) > R_1(S_1, (2, R); \emptyset)$ for all S_1 , and likewise (by straightforward analogy) for firm 2. (The result extends directly to $E\pi_1$.)

Proof. By inspection of the expected profit functions and use of the rankings in (3).

Two implications of Lemma 2 are noteworthy. First, if the incumbents chose their corporate structures sequentially, rather than simultaneously as in the BE game, then Lemma 2 suggests that the leader could potentially use sunk investments in greenfield-FDI and R&D to pre-empt similar investments by the follower. (Given the follower's corporate structure, the leader can both increase its own global net revenues – Lemma 2(i) – and decrease its rival's – Lemma 2(ii) – by sinking investments in greenfield-FDI and R&D. In turn, this will make the follower 'less likely' to undertake sunk investments.) We explore this possibility in Section 1.5. The second implication of Lemma 2(i) is purely technical: it allows us to investigate the effects of changes in μ on the relative profitability of different corporate structures in Section 1.3.2.

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 \emptyset or R . Of course, if firm 3 chooses \emptyset , 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 insufficient) 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.

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

$$E\pi_1 = E\pi_2 = 0$$

$$E\pi_3 = 2 \cdot p \cdot R(0, c) - 2 \cdot I$$

The incumbents earn zero expected profits because firm 3 can serve both countries' product markets from local plants at a marginal cost of c *at most*. If its R&D is successful, firm 3 can undercut the incumbents to earn $R(0, c)$ in both countries.

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

$$E\pi_1 = 0$$

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

$$E\pi_3 = 2 \cdot p \cdot (1 - p) \cdot R(0, c) + p^2 \cdot R(0, t) - 2 \cdot I$$

Firm 1 earns zero expected profits for the same reasons as above. Firm 2 requires a marginal production cost advantage over firm 3 to earn strictly positive net

revenue (because firm 3 owns a plant in country 2), which occurs with probability $p \cdot (1 - p)$ when 2's R&D succeeds but 3's fails. Conversely, if 2's R&D fails but 3's succeeds, 3 earns $R(0, c)$ in both countries. If both firms 2 and 3 innovate successfully, 3 earns $R(0, t)$ in country 1.

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

$$E\pi_1 = 0$$

$$E\pi_2 = 2 \cdot p \cdot (1 - p) \cdot R(0, c) - G - I$$

$$E\pi_3 = 2 \cdot p \cdot (1 - p) \cdot R(0, c) - 2 \cdot I$$

Because firms 2 and 3 both own two plants, neither will gain protection from trade costs if the rival's R&D succeeds. To earn strictly positive net revenue both require a marginal production cost advantage.

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

$$E\pi_1 = E\pi_2 = p \cdot (1 - p)^2 \cdot [R(0, c) + R(t, c)] + p^2 \cdot (1 - p) \cdot R(0, t) - I$$

$$E\pi_3 = 2 \cdot p \cdot (1 - p)^2 \cdot R(0, c) + 2 \cdot p^2 \cdot (1 - p) \cdot R(0, t) - 2 \cdot I$$

Because firm 3 owns plants in both countries, the incumbents must innovate successfully to earn strictly positive net revenue. Given R&D success, an incumbent can earn $R(0, c)$ at home and $R(t, c)$ abroad if *both* its rivals' R&D efforts fail with probability $(1 - p)^2$; if the rival incumbent's R&D succeeds but firm 3's fails with probability $p \cdot (1 - p)$ the incumbents both earn $R(0, t)$ at home. Firm 3 earns $R(0, c)$ in both countries if its R&D alone succeeds. If the R&D investments of firm 3 and one incumbent only succeed with probability $2 \cdot p^2 \cdot (1 - p)$, then firm 3 earns $R(0, t)$ in the failing incumbent's home market.

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

$$E\pi_1 = p \cdot (1-p)^2 \cdot [R(0, c) + R(t, c)] - I$$

$$E\pi_2 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) + p^2 \cdot (1-p) \cdot R(0, t) - G - I$$

$$E\pi_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) + p^2 \cdot (1-p) \cdot R(0, t) - 2 \cdot I$$

Firm 1 faces two local rivals and must possess marginal production cost advantages over both with probability $p \cdot (1-p)^2$ to earn $R(0, c)$ at home and $R(t, c)$ abroad. If firm 2 alone innovates successfully, it earns $R(0, c)$ in both countries; additionally, because firm 2 faces only one local rival (firm 3), if both incumbents' R&D investments succeed but 3's fails, then firm 2 earns $R(0, t)$ at home. If firm 3 alone innovates successfully, then it earns $R(0, c)$ in both countries; if only firm 2's R&D fails, then firm 3 earns $R(0, t)$ in country 2.

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

$$E\pi_1 = E\pi_2 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) - G - I$$

$$E\pi_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) - 2 \cdot I$$

All three firms are MNEs with plants in both countries. With probability $p \cdot (1-p)^2$ a firm will gain a marginal production cost advantage over both its rivals and earn $R(0, t)$ in both countries.

Lemma 3 extends the comparisons of global net revenues under different corporate structures in Lemma 2 to the PE game.

Lemma 3. (i) $R_1((2, R), S_2; R) > R_1((1, R), S_2; R) > R_1((1, N), S_2; R) = 0$ for all S_2 , and likewise (by straightforward analogy) for firm 2.

(ii) $R_1(S_1, (1, N); R) \geq R_1(S_1, (1, R); R) \geq R_1(S_1, (2, R); R)$ for all S_1 , and likewise (by straightforward analogy) for firm 2. (The result extends directly to $E\pi_1$.)

(iii) $R_1(S_1, S_2; \emptyset) \geq R_1(S_1, S_2; R)$ for all S_1, S_2 , and likewise (by straightforward analogy) for firm 2. (The result extends directly to $E\pi_1$.)

(iv) $R_3((1, N), S_2; R) > R_3((1, R), S_2; R) > R_3((2, R), S_2; R)$ for all S_2 , and likewise if S_2 is varied while holding S_1 fixed. (The result extends directly to $E\pi_3$.)

Proof. By inspection of the expected profit functions and use of the rankings in (3).

Parts (i) and (ii) of Lemma 3 directly extend Lemma 2 to the PE game. Note that an incumbent choosing $(1, N)$ in the PE game will *always* earn expected profits of zero, so $R_1((1, N), S_2; R) = 0$ for all S_2 , and this accounts for the weak inequalities in part (ii). (For $S_1 \in \{(1, R), (2, R)\}$ the inequalities in part (ii) would be strict.) Therefore, our general conclusion that by sinking investments in greenfield-FDI and R&D an incumbent can both increase its own global net revenues and decrease the rival incumbent's carries over to the PE game. Parts (iii) and (iv) of Lemma 3 relate to the effect of entry by firm 3 (i.e. a choice of R). Entry weakly reduces the incumbents' net revenues; indeed, the inequality in part (iii) holds strictly in all cases except $S_1 = (1, N), S_2 = (2, R)$ when firm 1 earns zero in both the BE and PE games. Furthermore, firm 3's net revenues are reduced when an incumbent undertakes greenfield-FDI or R&D (part (iv)).

Lemma 3(iii) and 3(iv) together illustrate the potential for investments in strategic entry-deterrence by the incumbents in the PE game. From part (iii) it is clear that the incumbents will generally prefer firm 3 to choose \emptyset over R . Part (iv) suggests how the incumbents may induce firm 3 to do this: by undertaking greenfield-FDI and R&D to reduce firm 3's expected profits if it chooses R below the minimum $R_3(S_1, S_2; \emptyset) = 0$ for all S_1, S_2 .

An important implication of Lemma 3(iii) is that it allows us to connect the incumbents' optimal behaviour in the PE game to that in the BE game. The result is given in Lemma 4.

Lemma 4. (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 \emptyset , then S_1^{BR} remains a best response to S_2 in the PE game.

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

Proof. Part (i). Given S_2 , S_1^{BR} is by definition such that $E\pi_1(S_1^{BR}, S_2; \emptyset) \geq E\pi_1(S_1, S_2; \emptyset)$ for all S_1 . Because firm 1's sunk costs are exclusively determined by S_1 , Lemma 3(iii) implies that $E\pi_1(S_1, S_2; \emptyset) \geq E\pi_1(S_1, S_2; R)$. Combining these two relations gives $E\pi_1(S_1^{BR}, S_2; \emptyset) \geq E\pi_1(S_1, S_2; R)$. Therefore $E\pi_1$ in the PE game is maximised under the industrial structure $\{S_1^{BR}, S_2; \emptyset\}$; so if

$S_3^{BR}(S_1^{BR}, S_2) = \emptyset$, which is necessary for $\{S_1^{BR}, S_2; \emptyset\}$ to arise in equilibrium, firm 1 will optimally choose S_1^{BR} in response to S_2 under potential entry. (Of course, the result extends to firm 2 by straightforward analogy.)

Part (ii). Assume that firm 2 plays S_2^* and that $S_3^{BR}(S_1^*, S_2^*) = \emptyset$ where S_1^* is 1's best response to S_2^* in the BE game. Then from (i) above, S_1^* is also 1's best response to S_2^* in the PE game. By symmetry, analogous arguments apply to 2's best responses, and so the equilibrium $\{S_1^*, S_2^*; \emptyset\}$ endures under potential entry. QED.

The results in Lemma 4 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 premised 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.

1.3.2. 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 μ, p, t, c, G, I . Below we define critical μ -values $\mu(p; t, c, G, I)$ which, given the actual μ , allow us to rank the various corporate structures in terms of profitability.

BE Game ($S_3 = \emptyset$)

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

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

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

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

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

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

Because μ enters $R(\cdot)$ multiplicatively, $\frac{1}{\mu} \cdot [\cdot]$ in the RHS of (1BE), (2BE), (3BE)

is independent of μ . Therefore the RHS of each inequality defines a critical μ -value $\mu(p; t, c, G, I)$ such that two corporate structures are equally profitable. In (p, μ) -space RHS(1BE), RHS(2BE) and RHS(3BE) are all rectangular hyperbolas; intuitively, this is because a fall in p can be counterbalanced by a rise in μ , which increases the payoff to *successful* R&D.

In response to (1, R)

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

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

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

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

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

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

RHS(5BE) is a U-shaped parabola in (p, μ) -space, which is symmetric around $p = 0.5$ with asymptotes at $p = 0$ and $p = 1$. Investing in greenfield-FDI only pays off if the firm acquires a marginal production cost advantage over its foreign rival. When both firms undertake R&D this occurs with probability $p \cdot (1 - p)$, which approaches 0 as p approaches 1, so μ must be large to compensate for high p . RHS(4BE) and RHS(6BE) are both strictly convex on $p \in [0, 1]$, possibly with minima on $p \in (0.5, 1]$.²⁵

In response to (2, R)

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

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

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

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

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

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

RHS(7BE) and RHS(8BE) both have the same general shape as RHS(5BE). In particular, note that (5BE) appears twice: it ranks the profitability of $(2, R)$ relative to $(1, R)$ in response to both $(1, R)$ and $(2, R)$. This occurs because in a world of perfectly segmented product markets the choice between one plant and

two depends on ‘competitive conditions’ *abroad*, which are influenced by whether the foreign rival invests in R&D but not greenfield-FDI. In a related vein note that $RHS(5BE) > RHS(2BE)$, which demonstrates that a larger market is necessary to generate greenfield-FDI when the foreign rival undertakes R&D (because the MNE’s probability of acquiring a marginal production cost advantage falls).

Table 1.1 summarises the preceding analysis to give the incumbent’s best responses in the BE game.²⁶

Best response to	is (1, <i>N</i>) iff	is (1, <i>R</i>) iff	is (2, <i>R</i>) iff
(1, <i>N</i>)	(1BE) fails and (3BE) fails	(1BE) holds and (2BE) fails	(2BE) holds and (3BE) holds
(1, <i>R</i>)	(4BE) fails and (6BE) fails	(4BE) holds and (5BE) fails	(5BE) holds and (6BE) holds
(2, <i>R</i>)	(7BE) fails and (8BE) fails	(7BE) holds and (5BE) fails	(5BE) holds and (8BE) holds

Table 1.1. Incumbents’ best responses in the BE (blockaded-entry) game.

Table 1.1 makes the task of deriving equilibrium industrial structures analytically appear complicated because of the sheer number of inequality conditions to consider, each of which contains at least five parameters.²⁷ Lemma 5 provides a simplification by demonstrating that several of the inequality conditions can in general be dropped.

Lemma 5. Let $(1, R) \succ (1, N)$ iff $\mu > \mu_1(p; t, c, G, I)$, which we write as $\mu_1(p)$ for brevity. Similarly, $(2, R) \succ (1, R)$ iff $\mu > \mu_2(p)$ and $(2, R) \succ (1, N)$ iff $\mu > \mu_3(p)$. (i) If $\mu_2(p) > \mu_1(p)$, then $\mu_3(p)$ is irrelevant to determining the best response. (ii) Conversely, if $\mu_1(p) > \mu_2(p)$, then only $\mu_3(p)$ is relevant to determining the best response.

Proof. Part (i). For $\mu \in [0, \mu_1(p))$, $(1, N) \succ (1, R) \succ (2, R)$, so $(1, N)$ is the best response. For $\mu \in (\mu_1(p), \mu_2(p))$, $(1, R) \succ (1, N), (2, R)$, so $(1, R)$ is the best response. For $\mu \in (\mu_2(p), \infty)$, $(2, R) \succ (1, R) \succ (1, N)$, so $(2, R)$ is the best response. Therefore for any μ the best response can be derived without reference to $\mu_3(p)$.

Part (ii). For $\mu \in [0, \mu_2(p))$, $(1, N) \succ (1, R) \succ (2, R)$, so $(1, N)$ is the best response. For $\mu \in (\mu_2(p), \mu_1(p))$, $(1, N), (2, R) \succ (1, R)$, so the best response is either $(1, N)$ or $(2, R)$. For $\mu \in (\mu_1(p), \infty)$, $(2, R) \succ (1, R) \succ (1, N)$, so $(2, R)$ is the best response. Therefore, $(1, R)$ is never optimally chosen and $\mu_3(p)$, which governs the preference relation between $(1, N)$ and $(2, R)$ is sufficient to determine the best response.²⁸ QED.

In the next Section we show that Lemma 5(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 \emptyset , we use 3's expected profit functions from Section 3.1 to derive the following decision rules.

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

$$\mu > \frac{I}{\frac{1}{\mu} \cdot R(0, c) \cdot p} \quad (1PE)$$

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

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

RHS(2PE) is strictly convex on $p \in [0, 1]$ with a minimum on $p \in (0.5, 1]$.

(When $t \geq 0.5$ so $R(0, t) = R(0, c) = R^M(0)$, RHS(2PE) has a minimum at $p = 1$.)

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

$$\mu > \frac{I}{\frac{1}{\mu} \cdot R(0, c) \cdot p \cdot (1-p)} \quad (3PE)$$

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

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

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

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

Both RHS(4PE) and RHS(5PE) are strictly convex on $p \in [0, 1]$ with interior minima.²⁹

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

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

RHS(6PE) is strictly convex on $p \in [0, 1]$ with a minimum at $p = 1/3$.

As in the BE game, the critical μ -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 6 examines how the critical μ -value where firm 3 chooses R over \emptyset changes with the incumbents' selected corporate structures.

Lemma 6. The critical μ -value where firm 3 optimally chooses R over \emptyset increases with the number of sunk investments (in either greenfield-FDI or R&D) undertaken by the incumbents. Specifically, (i) $\text{RHS}(6PE) >$

RHS(5PE) > RHS(4PE); (ii) RHS(4PE) \geq RHS(3PE); (iii) RHS(3PE) > RHS(2PE); and (iv) RHS(2PE) > RHS(1PE).

Proof. By inspection of RHS(1PE) to RHS(6PE). The two relations in (i) and (iii) rely on $R(0, t) > 0$. (ii) holds with strict inequality iff $R(0, c) > R(0, t)$, i.e. iff $t < 0.5$; otherwise $R(0, c) = R(0, t) = R^M(0)$ and RHS(4PE) degenerates into RHS(3PE). (iv) holds iff $2 \cdot R(0, c) > R(0, t)$, which is always satisfied because $R(0, c) \geq R(0, t)$.

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 6 formalizes the intuition from Lemma 4(iv): by undertaking additional sunk investments the incumbents can decrease firm 3's expected profits and thereby increase the critical μ at which entry occurs. Therefore, strategic entry-detering behaviour by the incumbents would imply a larger number of sunk investments (*ceteris paribus*) in the PE equilibrium than in the BE equilibrium.

We derive the equilibrium industrial structure of the PE game in the next Section. By combining the analysis of the incumbents' best responses in the BE game with firm 3's decision rules set out above, we are able to identify cases where the entry threat is not credible and so the equilibrium industrial structure from the BE game prevails (Lemma 4). Whenever firm 3 *does* optimally enter at the BE equilibrium, the incumbents' equilibrium choices may change. Using the intuition gained above on entry-detering and -accommodating strategies, we derive the PE game's equilibrium by conjecturing the incumbents' best responses to a credible entry threat and then checking the result.

1.3.3. Nash Equilibria.

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

Our primary purpose is to investigate the effects of p, μ 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, μ) -space.³⁰

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

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

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 1.4 (although the inter-regional boundaries will shift). *Drastic* variations, on the other hand, alter the form of the plot in Figure 1.4 (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 1.4 illustrates the equilibrium industrial structures of the BE game in (p, μ) -space. (A derivation is given in the Appendix.)

[FIGURE 1.4 IS OVERLEAF]

Key to Figure 1.4

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

(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, μ .

Equilibrium Industrial Structures in the PE Game ($S_i \in \{\emptyset, R\}$)

As with the BE game above, we look for a general solution to the PE game in (p, μ) -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

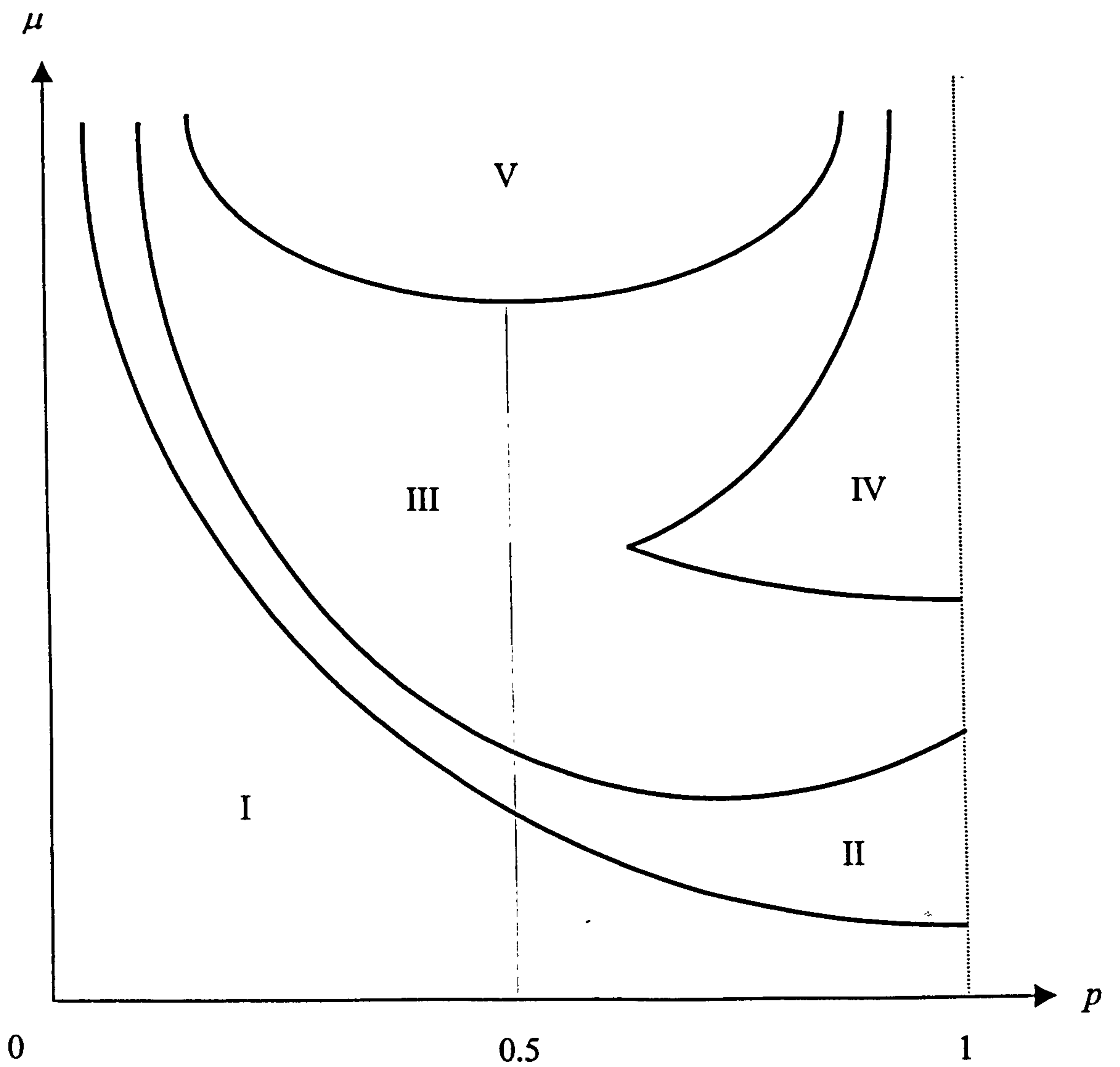


Figure 1.4: Equilibrium industrial structures in the BE game

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).

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

$$(B)' \quad R(0, c+t) - R(c, c+t) + R(t, c) - R(0, c) > 0$$

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 6 we first derive firm 3's optimal choice in each region of Figure 4. If 3 optimally chooses \emptyset at the BE equilibrium, then of course that equilibrium industrial structure is sustained under potential entry (Lemma 4). If 3's optimal response to the BE equilibrium is R , then we conjecture the incumbents' new best responses and check the result.

Figure 1.5 illustrates the equilibrium industrial structures of the PE game.

[FIGURE 1.5 IS OVERLEAF]

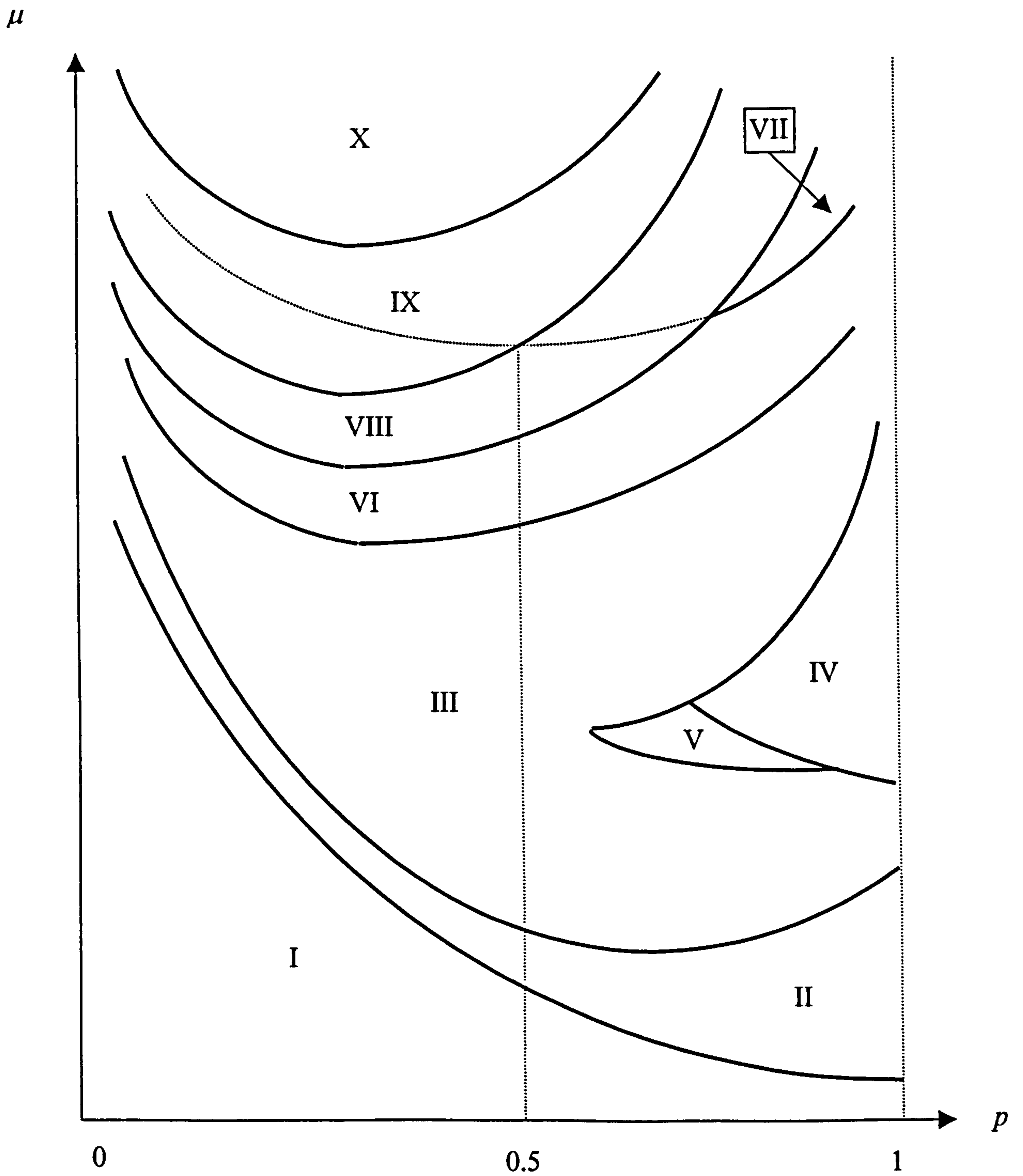


Figure 1.5: Equilibrium industrial structures in the PE game

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).

Key to Figure 1.5³¹

Region	Equilibrium Industrial Structure under PE
I	$\{(1, N), (1, N); \emptyset\}$
II	$\{(1, N), (1, R); \emptyset\}$
III	$\{(1, R), (1, R); \emptyset\}$
IV	$\{(1, R), (1, R); \emptyset\}; \{(1, N), (2, R); \emptyset\}$
V	$\{(1, R), (1, R); \emptyset\}; \{(1, N), (1, N); R\}$ or $\{(1, N), (2, R); \emptyset\}$
VI	$\{(1, R), (1, R); R\}^*$ or $\{(1, R), (2, R); \emptyset\}$
VII	$\{(2, R), (2, R); \emptyset\}^*$
VIII	$\{(1, R), (1, R); R\}; \{(1, R), (1, R); R\}$ or $\{(2, R), (2, R); \emptyset\}$
IX	$\{(1, R), (1, R); R\}$
X	$\{(2, R), (2, R); R\}^*$

(Note: * denotes a dominant strategy equilibrium.)

In the key to Figure 1.5 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 (\emptyset) by the incumbents.

In Section 1.4 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 1.4 and 1.5 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 1.4 and 1.5 of non-drastic variations in the cost parameters.

Comparative statics: the equilibrium effects of varying p, μ

Figures 1.4 and 1.5 provide empirical implications for the relationships between p, μ and equilibrium levels of greenfield-FDI and R&D investment.³² The derived relationships can be quite complex. Consider first the effect of changes in μ . In the BE game increasing μ 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 μ (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 μ 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 μ and equilibrium sunk investments are more complex. Increases in μ 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 μ 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 μ 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 μ .³³ (Similar 'perverse' relationships can be inferred from the PE game in Figure 1.5.)

The effect of changes in p is even less straightforward than that of changes in μ . For brevity, we shall only highlight the most interesting aspects of the relationship between p -values and equilibria.³⁴ As in the case of varying μ , 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 1.5.) 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 1.4 and 1.5.

Proposition 1. *(i) Equilibrium industrial structures in the BE and PE games depend on both p and μ (ii) Equilibrium industry greenfield-FDI flows and R&D investment depend on p and μ 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 μ .*

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 1.4 and 1.5 are either horizontal or vertical. Part (ii) of Proposition 1 highlights two striking non-monotonicities. First, equilibrium sunk expenditures on greenfield-FDI and R&D may be decreasing in p . This is due to our

assumption of Bertrand competition in homogeneous goods. As in Stiglitz's (1987) critique of the 'contestability doctrine', Bertrand competitors in a homogeneous good will only incur sunk costs if they are likely to generate a marginal cost advantage. For example, in our BE game (Figure 1.4) playing $(2, R)$ cannot be a best response to $(2, R)$ for $p \cong 1$ because the most likely outcome is a market price of 0 in both countries and a loss of $G + I$ for both firms. This underlies the switch in equilibrium industrial structure from $\{(2, R), (2, R); \emptyset\}$ to $\{(1, R), (1, R); \emptyset\}$ as we move rightwards from region V to region III in Figure 1.4. The second non-monotonicity is that equilibrium sunk expenditures may be decreasing in μ . For example, as we move upwards from region VII to region VIII in Figure 1.5 (the PE game) an equilibrium of $\{(1, R), (1, R); R\}$ replaces $\{(2, R), (2, R); \emptyset\}$: total greenfield-FDI flows fall from $2 \cdot G$ to 0. This contrasts with the findings of Shaked and Sutton (1987, Corollary to Proposition II) and Sutton (1998, pp. 58-61) that increases in market size are associated with higher spending on fixed costs by incumbents, rather than entry (or 'fragmentation'). A key difference between our analysis and that of Shaked and Sutton (1987) is that the incumbents and the entrant make their corporate structure choices sequentially in our PE game. As we show below (see Section 1.4 and Proposition 8(i)), the incumbents' equilibrium corporate structure choices are highly sensitive to whether entry by firm 3 is to be accommodated (R) or strategically deterred (\emptyset), and a switch from deterrence to accommodation as μ rises can reduce the incumbents' equilibrium sunk expenditures.

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. Part (i) follows directly from Lemma 1(i): given that an incumbent chooses N over R , 1 plant strictly dominates 2 plants. However, incumbents do occasionally choose $(2, R)$ over $(1, R)$ (e.g. whenever $(2, R)$ arises in equilibrium).

Part (ii). Consider firm 1 for concreteness. If committed to 1 plant, firm 1 will undertake R&D iff $R_1((1, R), S_2; \emptyset) - R_1((1, N), S_2; \emptyset) > I$. If committed to 2 plants, firm 1 will undertake R&D iff $R_1((2, R), S_2; \emptyset) - R_1((2, N), S_2; \emptyset) > I$. From Lemma 1(i) we have $R_1((2, N), S_2; \emptyset) = R_1((1, N), S_2; \emptyset)$. Therefore, the second inequality condition is weaker than the first iff $R_1((2, R), S_2; \emptyset) > R_1((1, R), S_2; \emptyset)$, which holds from Lemma 2(i). QED.

The aim of Proposition 2 was to reproduce the two-way relationships between greenfield-FDI and R&D found by Petit and Sanna-Randaccio (1998, 2000).

However, it should be noted that the procedure of examining how an exogenous change to one of the sunk-investment decisions affects the other sunk-investment decision is really an abuse of our modelling structure. Rather than depending on each other, the two sunk-investment decisions should *together* be viewed as depending on the exogenous parameters p, μ, t, c, G, I .

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

Proof. In the Prisoner's Dilemma game a dominant strategy equilibrium (DSE) is Pareto dominated by another (non-equilibrium) set of strategies. From the Appendix we know that 3 symmetric dominant strategy equilibria exist in Figure 1.4. Let us focus on the $\{(2, R), (2, R); \emptyset\}$ DSE in region V. The $\{(2, R), (2, R); \emptyset\}$ DSE is Pareto dominated by an industrial structure of $\{(1, N), (1, N); \emptyset\}$ iff $E\pi_1((1, N), (1, N); \emptyset) > E\pi_1((2, R), (2, R); \emptyset)$, or $G > 2 \cdot p \cdot (1 - p) \cdot R(0, c) - R(0, c + t) - I$. Region V is s.t. $[R(0, c) - R(t, c)] \cdot p \cdot (1 - p) > G$. These two inequalities place bounds on G . They can both be satisfied simultaneously iff $I > [R(0, c) + R(t, c)] \cdot p \cdot (1 - p) - R(0, c + t)$. This lower bound on I is consistent with $G \geq I$ from assumption (C), which underlies Figure 1.4, iff $R(0, c + t) > 2 \cdot R(t, c) \cdot p \cdot (1 - p)$, which holds for all p because $R(0, c + t) > R(t, c)$ and $\max 2 \cdot p \cdot (1 - p) = 0.5$. QED.

Proposition 3 shows that it is possible to choose G, I to make the BE game a Prisoner's Dilemma in region V of Figure 1.4. The Prisoner's Dilemma characteristic of equilibria in the BE game is particularly noteworthy because it confirms our conjecture in the Introduction that strategic interfirm rivalry is a

crucial element in the determination of equilibrium industrial structures. Whenever the BE game is a Prisoner's Dilemma, the two firms would prefer to collude in order to achieve the Pareto dominant outcome; however, such collusion is rendered infeasible in our one-shot modelling structure by dominant free-rider incentives. Therefore, we conclude in line with Horstmann and Markusen (1992, p. 116) 'that we cannot ignore the strategic aspects of market structure and simply infer market structure by comparing profit levels under various strategies'. Of course, the method of 'infer[ring] market structure by comparing profit levels' (and ignoring strategic aspects) is fundamental to the OLI paradigm, which relegates interfirm rivalry by employing a representative-firm framework to determine equilibrium.

Finally, we compare the equilibrium behaviour of the duopolists in the BE game with that of a (global) monopolist. The monopolist is identical to either of the incumbents in the BE game; however, because (by definition) the monopolist does not face a foreign rival its incentives to innovate and locate production abroad are exclusively 'pure'. Therefore we are investigating the effects of the 'strategic' incentives to undertake greenfield-FDI and R&D under arise under duopolistic rivalry by using the monopoly case as a benchmark.³⁵

Lemma 7 prepares the ground for the result in Proposition 4.

Lemma 7. 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 7), (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.

Proposition 4 highlights a key difference between the greenfield-FDI and R&D decisions, which arises when the degree of 'competition' in the industry is varied. For $c \geq x^M(t)$ and $c + t \geq x^M(c)$, greenfield-FDI is 'more likely' under monopoly *but* R&D is 'more likely' under duopoly. The intuition for the greenfield-FDI result is as follows. Establishing a plant abroad increases an incumbent's net revenues in the BE game only if it also acquires a marginal production cost advantage over its foreign rival (via successful R&D). However, for the monopolist greenfield-FDI increases net revenue regardless of whether R&D is successful (via the elimination of trade costs). Therefore, the likelihood of greenfield-FDI in a duopoly is lower than in a monopoly because of the rent-dissipating effect of increases in 'competition'. (The greenfield-FDI result will not hold if $c < x^M(t)$ because in that case an additional incentive for a BE

incumbent to undertake greenfield-FDI will be to 'escape competition'; see below.)

The intuition for the R&D result concerns firms' motives to 'escape competition' by investing in R&D. The incentive to perform R&D depends on the *difference* between the rents of a successful innovator and an unsuccessful one. A global monopolist has a weaker incentive to perform R&D than a duopolist due to Arrow's 'replacement effect': because it is already enjoying monopoly rents without undertaking R&D, its gain from undertaking R&D (difference in expected profit levels) is reduced. (The proof of Proposition 4(ii) places two restrictions on t, c for ease. It can be shown that the area in (c, t) -space that satisfies $c \geq x^M(t)$ and $c + t \geq x^M(c)$ represents 40% of the area defined by assumption (A).)

1.3.4. 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. In Figure 1.6 the solid lines (B) and (B)' trace the loci of points in (c, t) -space where the two constraints bind. (A derivation is given in the Appendix. For the moment, ignore the dashed lines in Figure 1.6.) The area *below* lines (B) and (B)' satisfies the two constraints on t, c . Note that for $t \geq 0.5$ constraints (B) and (B)' are the same: this is because for $t \geq 0.5$, $R(0, t) = R(0, c) = R^M(0)$. However, for $t < 0.5$, where $R^M(0) \geq R(0, c) > R(0, t)$, (B)' is tighter than (B).

[FIGURE 1.6 IS OVERLEAF]

Proposition 5 formally describes the restrictiveness of assumptions (B) and (B)'.

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. From inspection of Figure 1.6.

Proposition 5 is a loose description of Figure 1.6 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 1.4 and 1.5 depict general, rather than special, cases.

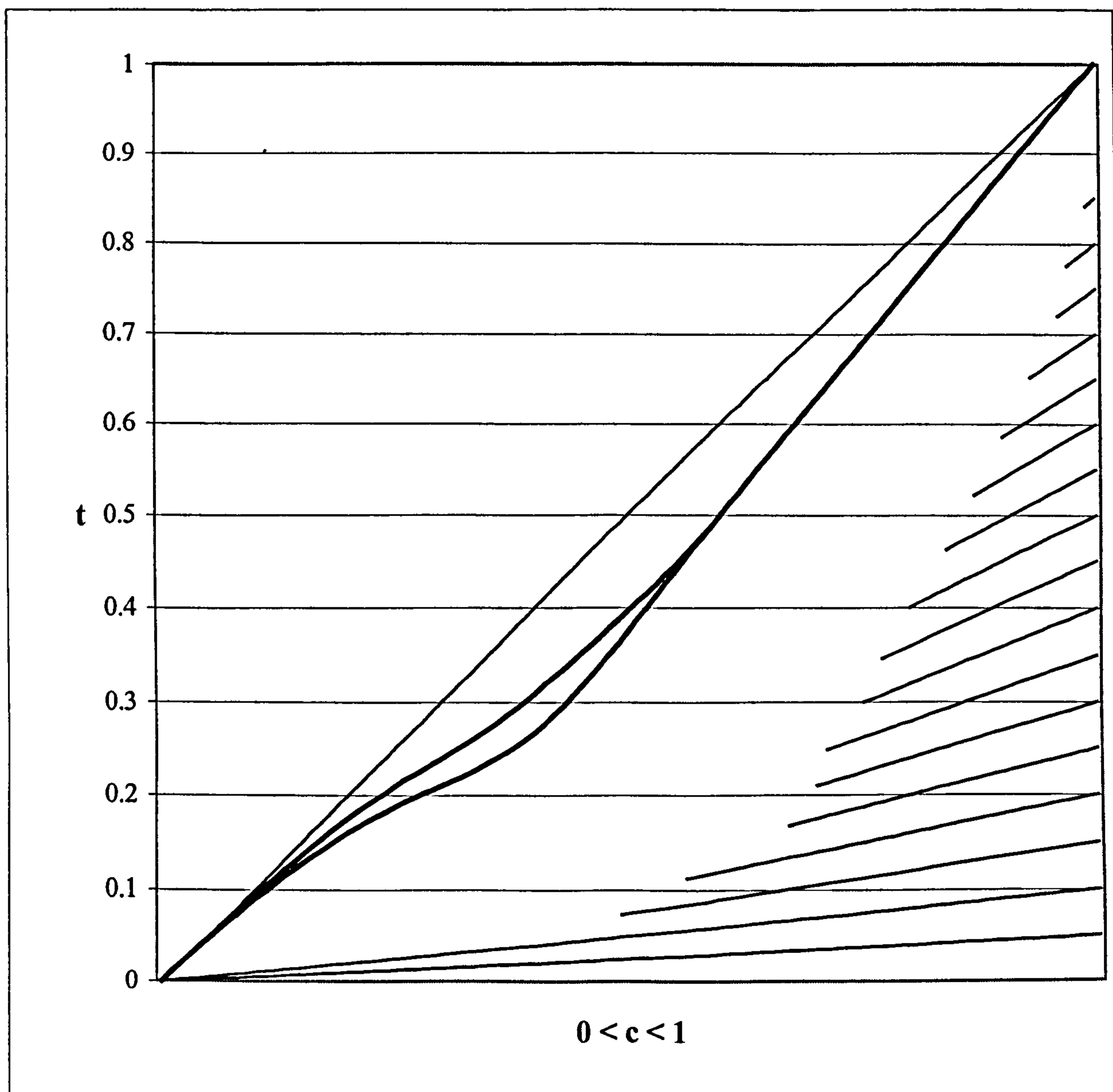


Figure 1.6: Feasible (c, t) -pairs

Notes

c varies between 0 and 1 on the horizontal axis. (c, t) -pairs above the 45° line are ruled out by the maintained assumption (A). The upper (resp. lower) bold line is the locus of (c, t) -pairs where constraint (B) (resp. (B)') binds. The admissible (c, t) -pairs lie *below* the bold lines. The pale lines cover (c, t) -pairs where numerical analysis showed the sufficient condition from Lemma 8 for $\text{LHS}(A10) > 0$ to be *violated*.

Having demonstrated the generality of our solutions, we next consider the effects of changes in the sunk costs G, I . There are two distinct effects to consider. First, changes in G, I may affect the incumbents' choice between accommodating and deterring entry in regions V, VI and VIII of Figure 1.5. We consider these effects in Section 1.4. Second, changes in G, I will shift the inter-regional boundaries in Figures 1.4 and 1.5, thus possibly altering the equilibrium industrial structure associated with a given (p, μ) -pair. We now consider these effects.

We show in the Appendix that the shapes of regions V and VII in Figure 5 depend on whether

$$2 \cdot \frac{I}{G} \cdot [R(0, c) - R(t, c)] - R(0, t) > 0 \quad (\text{A8}) \text{ repeated}$$

is satisfied. (The general shapes of all other regions in Figures 1.4 and 1.5 are robust to changes in G, I , provided that assumption (C) continues to hold.) If (A8) fails, then (i) the bottom boundary of region V, RHS(2PE), will extend to $p = 1$, rather than meeting RHS(2BE) in the interior of Figure 1.5; and (ii) region VII ceases to exist. While (A8) holds when $G = I$, some G, I that satisfy assumption (C) imply $\text{LHS}(\text{A8}) < 0$.³⁶ Intuitively, for $G \square I$ $\text{LHS}(\text{A8}) \cong -R(0, t)$, so (A8) fails.

Given that the initial G, I satisfy assumption (C), increasing G or decreasing I will always be nondrastic cost variations. We consider the effects of these two changes in turn.³⁷ Because G, I enter the expressions for inter-regional boundaries in Figures 1.4 and 1.5 explicitly, the implications of nondrastic variations are immediately clear. We consider only the BE game (Figure 1.4) for brevity, although our conclusions can be applied directly to the lower parts of Figure 1.5

(where entry never occurs) and our techniques can be used throughout Figure 1.5. Increasing G will shift RHS(2BE) and RHS(5BE) upwards but will leave the other three inter-regional boundaries unchanged. This will move region V upwards and will squeeze region IV from below. Decreasing I will shift RHS(1BE), RHS(4BE) and RHS(7BE) downwards, while leaving the other two boundaries unchanged. Therefore, region II will shift downwards and region IV will be squeezed from the left. For some 'marginal' (p, μ) -pairs, these changes in G, I will shift the equilibrium industrial structure. In all the cases just described, the induced changes in equilibria are intuitive.

Gauging the effects of nondrastic variations in t, c on the inter-regional boundaries in Figures 1.4 and 1.5 is complicated by the fact that t, c do not enter the boundary equations explicitly (but only via the net revenue function). The analysis is further complicated because several realisations of the net revenue function typically enter the denominator of any given boundary equation. We briefly consider some of the more straightforward possibilities in Figure 1.4 by focussing on the positions of RHS(2BE), RHS(5BE) and RHS(7BE). A nondrastic rise in t will increase the denominators of RHS(2BE) and RHS(5BE), thereby shifting those inter-regional boundaries downwards. The rise in t will also decrease the denominator of RHS(7BE), shifting that boundary upwards. The combined effect of these changes in Figure 1.4 is to increase the sizes of regions IV and V, where greenfield-FDI arises in equilibrium. The intuition is that an increase in t makes tariff-jumping greenfield-FDI more attractive. A rise in c ³⁸ will (weakly) decrease the denominators of RHS(2BE) and RHS(5BE).³⁹ This will shift RHS(2BE) and RHS(5BE) upwards. The increase in c will

(weakly) increase the denominator of RHS(7BE), pushing the inter-regional boundary downwards. The combined effect of these changes in Figure 1.4 is to decrease the sizes of regions IV and V. The intuition is that, because undertaking greenfield-FDI allows a firm to compete more aggressively in the foreign market, the benefit from undertaking greenfield-FDI falls as the foreign incumbent becomes a 'softer' rival (i.e. c rises).

1.4. 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 1.3). 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 1.5 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-detering equilibria (which are separated by 'or' in the key to Figure 1.5), 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. In the Appendix we derive the following necessary-and-sufficient conditions for the entry-detering PE equilibrium to be selected for all μ in regions V, VI and VIII.

Region V. $\{(1, N), (2, R); \emptyset\}$ is selected over $\{(1, N), (1, N); R\}$ for all μ iff

$$2 \cdot \frac{I}{G} \cdot R(c, c+t) + 2 \cdot \left\{ \frac{I}{G} \cdot [R(0, c+t) - R(c, c+t)] - R(0, c) \right\} \cdot p \\ + \left(\frac{I}{G} + 1 \right) \cdot [2 \cdot R(0, c) - R(0, t)] \cdot p^2 > 0 \quad (\text{A9) repeated}$$

Region VI. $\{(1, R), (2, R); \emptyset\}$ is selected over $\{(1, R), (1, R); R\}$ for all μ iff

$$\frac{I}{G} \cdot R(c, c+t) + \left\{ \frac{I}{G} \cdot [R(0, c+t) - 2 \cdot R(c, c+t) - R(t, c)] - R(0, c) \right\} \cdot p \\ + \left\{ \frac{I}{G} \cdot [R(c, c+t) - R(0, c+t) + R(0, c) + 2 \cdot R(t, c)] + 2 \cdot R(0, c) - R(0, t) \right\} \cdot p^2 \\ + \left\{ \frac{I}{G} \cdot [R(0, t) - R(0, c) - R(t, c)] - R(0, c) + R(0, t) \right\} \cdot p^3 > 0 \quad (\text{A10) repeated}$$

Region VIII. $\{(2, R), (2, R); \emptyset\}$ is selected over $\{(1, R), (1, R); R\}$ as the second PE equilibrium for all μ iff $\mu > \text{RHS}(5\text{BE})$ or

$$4 \cdot \frac{I}{G} \cdot R(0, c) \cdot (1 - p) > \left(\frac{I}{G} + 1 \right) \quad (\text{A11})' \text{ repeated}$$

$$\times \{ 2 \cdot R(0, c) - [4 \cdot R(0, c) - R(0, t)] \cdot p + [2 \cdot R(0, c) - R(0, t)] \cdot p^2 \}$$

and

$$2 \cdot \frac{I}{G} \cdot [R(0, c) - R(t, c)] - 2 \cdot R(0, c) + \left\{ 4 \cdot \frac{I}{G} \cdot R(t, c) + 4 \cdot R(0, c) - R(0, t) \right\} \cdot p$$

$$- \left\{ 2 \cdot \frac{I}{G} \cdot [R(0, c) + R(t, c)] + 2 \cdot R(0, c) - R(0, t) \right\} \cdot p^2 > 0$$

(A12)' repeated

(Note that the case of region VIII is made convoluted because the *number* of PE equilibria is not fixed: there could be a unique entry-accommodating equilibrium of $\{(1, R), (1, R); R\}$, or there might exist both entry-detering and entry-accommodating equilibria. This is not so in regions V and VI, where two PE equilibria will *always* exist.)

We begin by examining whether these conditions hold when $G = I$, which is a (simple) polar case under assumption (C).

Proposition 6. *If $G = I$, then (i) $\{(1, N), (2, R); \emptyset\}$ is selected over $\{(1, N), (1, N); R\}$ for all (p, μ) in region V of Figure 1.5; and (ii) given sufficiently high p , a second equilibrium of $\{(2, R), (2, R); \emptyset\}$ exists for all μ in region VIII of Figure 1.5.*

Proof. Part (i). If $G = I$, (A9) becomes $R(c, c + t) + \{R(0, c + t) - R(c, c + t) - R(0, c)\} \cdot p + \{2 \cdot R(0, c) - R(0, t)\} \cdot p^2 > 0$. Because $2 \cdot R(0, c) > R(0, t)$, LHS is strictly convex in p . Therefore, a sufficient (but unnecessary) condition

for $LHS > 0$ on $p \in [0, 1]$ is that the tangent to LHS at $p = 0$ be ≥ 0 at $p = 1$.

This requires $R(0, c + t) \geq R(0, c)$, which clearly holds.

Part (ii). Condition (A11)': if $G = I$, (A11)' becomes $2 \cdot R(0, c) \cdot (1 - p) > 2 \cdot R(0, c) - [4 \cdot R(0, c) - R(0, t)] \cdot p + [2 \cdot R(0, c) - R(0, t)] \cdot p^2$. Note that $LHS = RHS = 2 \cdot R(0, c)$ at $p = 0$, and $LHS = RHS = 0$ at $p = 1$. Therefore, because LHS is linear in p but RHS is strictly convex in p , we have $LHS > RHS$ on $p \in (0, 1)$.

Condition (A12)': if $G = I$, then (A12)' becomes $-2 \cdot R(t, c) + \{4 \cdot R(0, c) + 4 \cdot R(t, c) - R(0, t)\} \cdot p - \{4 \cdot R(0, c) + 2 \cdot R(t, c) - R(0, t)\} \cdot p^2 > 0$. This condition clearly fails at $p = 0$. Because $LHS = 0$ at $p = 1$, (from Viète's rule on the product of roots) the second root of LHS is $2 \cdot R(t, c) / \{4 \cdot R(0, c) + 2 \cdot R(t, c) - R(0, t)\}$, which is strictly less than 1. Therefore, $p > 2 \cdot R(t, c) / \{4 \cdot R(0, c) + 2 \cdot R(t, c) - R(0, t)\}$ defines 'sufficiently high p '. This p -value is strictly less than that where $RHS(5BE)$ intersects $RHS(5PE)$ when $G = I$, which is $p = 2 \cdot R(t, c) / \{2 \cdot R(0, c) - R(0, t)\}$. QED.

Part (i) of Proposition 6 establishes that the second equilibrium in region V of Figure 1.5 is the entry-detering $\{(1, N), (2, R); \emptyset\}$ when $G = I$. Under assumption (C), we know that two PE equilibria (one entry-accommodating, the other entry-detering) 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 $\{(2, R), (2, R); \emptyset\}$ exists below $RHS(5BE)$ when $G = I$.

Investigating whether entry-deterrence or -accommodation arises in equilibrium in region VI is complicated by the intractable form of condition (A10). LHS(A10) is of the form $\alpha + \beta \cdot p + \gamma \cdot p^2 + \delta \cdot p^3$, where $\alpha, \gamma > 0 > \beta, \delta$ and $\alpha + \beta + \gamma + \delta > 0$ for all G, I under assumption (C).⁴⁰ Furthermore, LHS(A10) has two stationary points on $p > 0$ (the first a local minimum and the second a local maximum), at least the first of which must lie within $p \in (0, 1)$.⁴¹ Ideally, we would like a necessary-and-sufficient condition on t, c for LHS(A10) > 0 on all $p \in [0, 1]$. However, if derived, such a condition would be intractable.⁴² Therefore, we use the sufficient condition for LHS(A10) > 0 on all p set out in Lemma 8. (As we show below, the sufficient condition in Lemma 8 is loose enough to provide valuable insights.⁴³)

Lemma 8. A sufficient condition for LHS(A10) > 0 on $p \in [0, 1]$ is

$$\alpha \cdot \gamma - \frac{3}{8} \cdot \beta^2 > 0, \text{ where } \alpha, \beta, \gamma \text{ are defined from (A10): } \alpha \equiv \frac{I}{G} \cdot R(c, c+t);$$

$$\beta \equiv \frac{I}{G} \cdot [R(0, c+t) - 2 \cdot R(c, c+t) - R(t, c)] - R(0, c); \quad \text{and}$$

$$\gamma \equiv \frac{I}{G} \cdot [R(c, c+t) - R(0, c+t) + R(0, c) + 2 \cdot R(t, c)] + 2 \cdot R(0, c) - R(0, t).$$

Proof. See Appendix.

Despite its seemingly-simple form, the sufficient condition $\alpha \cdot \gamma - \frac{3}{8} \cdot \beta^2 > 0$ is difficult to solve analytically for an explicit relationship between t and c . (The reason is that α, β, γ are potentially all quadratic functions of t and c ; therefore, $\alpha \cdot \gamma$ and β^2 will be fourth-degree polynomials.) Therefore, we investigate

numerically whether the sufficient condition for $\text{LHS}(A10) > 0$ on $p \in [0, 1]$ holds. The adopted procedure is explained in the Appendix. The results of the numerical analysis of $\alpha \cdot \gamma - \frac{3}{8} \cdot \beta^2 > 0$ when $G = I$ are shown in Figure 6, where the areas covered by dashed lines indicate that the sufficient condition does *not* hold. Therefore, where there are no dashed lines, we can be certain that $\{(1, R), (2, R); \emptyset\}$ is selected over $\{(1, R), (1, R); R\}$ for all (p, μ) in region VI of Figure 1.5 when $G = I$. Of course, because our analysis uses a sufficient condition, we cannot conclude that $\{(1, R), (1, R); R\}$ will be selected in areas of dashed lines. However, plots of the cubic $\text{LHS}(A10)$ for given t - and c -values show that $\text{LHS}(A10) < 0$ for some (c, t) -pairs sufficiently inside the dashed region of Figure 1.6; therefore, although our sufficient condition is unnecessary, it does succeed in excluding some inadmissible (c, t) -pairs.

A simple interpretation of the preceding analysis and of Figure 1.6 is that $\{(1, R), (2, R); \emptyset\}$ is ‘more likely’ to be selected over $\{(1, R), (1, R); R\}$ in region VI of Figure 1.5, the higher is t . The intuition for this concerns the conventional tariff-jumping argument for undertaking greenfield-FDI: when t is very low, it is never worth shouldering the sunk cost of establishing an additional plant abroad even if this will deter entry.

The preceding analysis of equilibrium selection in regions V, VI and VIII of Figure 1.5 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-detering PE equilibria (over entry-accommodating PE equilibria) 'less likely' in regions V, VI and VIII of Figure 1.5. 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 1.5; and (ii) in the limit as $G \rightarrow \infty$, entry-deterrence is never selected in equilibrium in regions VI and VIII of Figure 1.5, although entry-deterrence is always selected for some p -values in region V.*

Proof. Part (i). The proof focusses on region V of Figure 1.5; the extension to regions VI and VIII is straightforward. The proof uses the fact that RHS(2PE), RHS(4PE) and RHS(5PE) are all independent of G . From the Appendix $\{(1, N), (2, R); \emptyset\}$ is selected over $\{(1, N), (1, N); R\}$ in region V iff

$$\mu > \mu^* \equiv \frac{G + I}{\frac{1}{\mu} \cdot R(c, c+t) + \frac{1}{\mu} \cdot [R(0, c+t) + R(0, c) - R(c, c+t)] \cdot p}$$

(The necessary-and-sufficient condition (A9) sets $\text{RHS}(2\text{PE}) > \mu^*$.) Clearly $\partial\mu^*/\partial G > 0$, which is intuitive because no greenfield-FDI is undertaken under $\{(1, N), (1, N); R\}$. In terms of the effect of changes in G on the interval of μ -values in region V where $\{(1, N), (1, N); R\}$ is selected, there are two principal cases to consider.

Case 1: $\mu^* < \text{RHS}(2\text{PE})$ or $\mu^* > \min\{\text{RHS}(2\text{BE}), \text{RHS}(7\text{BE})\}$. Marginal changes in G will not affect equilibrium selection (deterrence vs. accommodation) for any (p, μ) -pair in region V. The PE equilibrium will be

either $\{(1, N), (2, R); \emptyset\}$ for all μ (if $\mu^* < \text{RHS}(2\text{PE})$) or $\{(1, N), (1, N); R\}$ for all μ (if $\mu^* > \min\{\text{RHS}(2\text{BE}), \text{RHS}(7\text{BE})\}$).

Case 2: $\mu^* \in (\text{RHS}(2\text{PE}), \min\{\text{RHS}(2\text{BE}), \text{RHS}(7\text{BE})\})$, which is non-empty iff region V exists for given p . Marginal increases (resp. decreases) in G will increase (resp. decrease) the size of the interval of μ -values where $\{(1, N), (1, N); R\}$ is selected, which is $\mu \in (\text{RHS}(2\text{PE}), \mu^*)$.

(When $\mu^* = \text{RHS}(2\text{PE})$ (resp. $= \min\{\text{RHS}(2\text{BE}), \text{RHS}(7\text{BE})\}$), increases (resp. decreases) in G will alter the μ -interval where $\{(1, N), (1, N); R\}$ is selected, but decreases (resp. increases) in G will not.)

Part (ii). Regions VI and VIII. From the Appendix the critical μ -value where entry-deterrence is selected over entry-accommodation depends positively on G but is independent of I . (In the case of region VIII the critical μ -value is defined by two inequality conditions (which must hold simultaneously), one of which is independent of I .) Therefore, for any p the critical μ -value approaches ∞ as $G \rightarrow \infty$. However, the upper boundaries of both region VI and region VIII, $\text{RHS}(5\text{PE})$ and $\text{RHS}(6\text{PE})$, depend on I but not G . Therefore, increases in G shift the critical μ -value upwards *relative* to the inter-regional boundaries.

Region V. The upper boundary of region V is $\min\{\text{RHS}(2\text{BE}), \text{RHS}(7\text{BE})\}$. $\text{RHS}(7\text{BE})$ depends on I but not G , so the arguments above apply. $\text{RHS}(2\text{BE})$ depends on G but not I , and as $G \rightarrow \infty$ $\text{RHS}(2\text{BE}) > \mu^*$ from part (i) iff $R(c, c+t) + [R(0, c+t) - R(c, c+t) + R(t, c)] \cdot p > 0$, which holds for all p . Therefore, for p -values in region V where $\min\{\text{RHS}(2\text{BE}),$

RHS(7BE)} = RHS(2BE), entry-deterrence is *always* selected for some μ in PE equilibrium. QED.

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-detering 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.⁴⁴ In Figure 1.5 the inter-regional boundaries from the BE game (Figure 1.4) 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 1.4 and regions III, V, VI, VIII and IX in Figure 1.5, which together cover the same set of (p, μ) -pairs. In regions III, V, VIII and IX of Figure 1.5 a PE equilibrium where both incumbents choose $(1, R)$ exists for sure, as in region III of Figure 1.4; 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 1.5 (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.⁴⁵

However, there exist additional PE equilibria in the area where $\{(1, R), (1, R); \emptyset\}$ is the BE equilibrium (region III of Figure 1.4). In regions V, VI and VIII of Figure 1.5 an entry-detering 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-detering PE equilibria both, of course, entail two sunk investments.) In particular, note that the entry-detering PE equilibrium of $\{(1, R), (2, R); \emptyset\}$ in region VI is *qualitatively different* from any of the BE equilibria in Figure 1.4 (in terms of the incumbents' behaviour). A final distinction between the 'middle' areas of Figures 1.4 and 1.5 is the possibility of an entry-accommodating PE equilibrium of $\{(1, N), (1, N); R\}$ in region V of Figure 1.5, where the incumbents undertake fewer sunk investments than at the corresponding BE equilibrium.

We now consider the area above $\text{RHS}(5\text{BE})$, where $\{(2, R), (2, R); \emptyset\}$ is the equilibrium industrial structure of the BE game in dominant strategies (region V of Figure 1.4). In regions VIII and IX of Figure 1.5 (both of which lie partially above $\text{RHS}(5\text{BE})$) 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 $\text{RHS}(5\text{BE})$); 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 ($\text{RHS}(A13) > \text{RHS}(5\text{BE})$ for all p);

otherwise the incumbents reduce their expenditures on sunk investments (region IX of Figure 1.5) 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 1.5) but as 'puppy dogs' when accommodating it (in regions V, VIII and IX of Figure 1.5). 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.⁴⁶

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.*

1.5. 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 μ , 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. However, the generality of our results is, of course, limited by the assumptions of our modelling structure. We briefly consider four potential alterations to our modelling structure. First, what would be the effects of having the firms produce differentiated, rather than homogeneous, goods and compete in quantities (Cournot), rather than prices (Bertrand)? The immediate effect of these extensions (differentiated products, Cournot competition, or both) would be to make the determination of equilibrium industrial structures more complex because Lemma 1 could not be invoked to rule out certain corporate structure choices in equilibrium. (Bertrand competition in homogeneous products has the special property that rivals with equal marginal costs earn zero rents in equilibrium.) Intuitively, one would expect equilibrium industrial structures to involve incumbent firms choosing $(2, N)$ when p was low but μ large. Furthermore, the property of the BE game (Figure 1.4) that $(2, R)$ is not a best response to $(2, R)$ for $p \cong 1$ will also be sensitive to the assumption of Bertrand competition in homogeneous goods. (An advantage of considering a differentiated-products oligopoly would be that product R&D could be modelled. However, if for example product R&D shifted the intercept of a linear inverse demand function upwards, we would expect similar equilibria to those under process R&D.)

Second, what would be the effects of having the incumbents move sequentially, rather than simultaneously? Assuming sequential-moves implies the generation of unique equilibrium industrial structures throughout Figures 1.4 and 1.5. For example, we have shown (see n. 33) that only the $\{(1, N), (2, R); \emptyset\}$ equilibrium industrial structure would survive in region IV of Figures 1.4 and 1.5 under sequential-moves, with the leader selecting $(2, R)$, which yields higher expected profits than either $(1, N)$, where the follower chooses $(2, R)$, or $(1, R)$, where the follower chooses $(1, R)$. Imposing sequential-moves is therefore a means of selecting between alternative candidate equilibria. Another is to assume that simultaneously-moving firms co-ordinate on a Pareto dominant equilibrium ('focal point'), if one exists. For example, if G, I are such that the second PE equilibrium in region V of Figure 1.5 is $\{(1, N), (1, N); R\}$, where both incumbents earn zero expected profits, the incumbents may co-ordinate on the alternative (Pareto dominant) equilibrium of $\{(1, R), (1, R); \emptyset\}$.

A third set of modifications to our modelling structure concerns the entry process. The assumption that firm 3 owns two (technologically-inefficient) plants was justified by interpreting 'entry' as entry by diversification, rather than de novo entry. An alternative formulation of (de novo) entry would be for firm 3 initially to own no plants and to choose in stage 2 of the PE game (Figure 3) (i) between 0, 1 or 2 plants (and their locations); and (ii) whether to undertake R&D (on the same terms as the incumbents). This formulation would be complicated relative to our PE game because of the increased number of strategic choices for firm 3 (and hence potential equilibrium industrial structures). (However, there would be a strict-dominance result: if choosing one plant only, firm 3 would

always prefer to site it in the country with less 'local competition'.) In addition to its technical complexity, experimentation with this formulation of the entry process suggested that the entry threat was credible (and hence interesting) far less often than in the PE game we analyse. The reason is that the alternative entry process described above implies that firm 3 must undertake additional sunk investments (relative to the PE game) in order to enter the industry (e.g. to acquire two plants and a marginal production cost of 0 with probability p , firm 3 would have to sink $2 \cdot G + I$, compared to $2 \cdot I$ in the PE game). Given Bertrand competition in homogeneous goods in the market stage, these additional sunk costs act as strong deterrents to entry. Because our modelling structure contains only one potential entrant (firm 3), it could also be argued that analysis should focus on the 'most credible' member of the population of potential entrants, i.e. that with the lowest sunk costs of entry.

Fourth, we consider altering the solution concept from a subgame perfect Nash equilibrium in pure strategies, which defines equilibrium industrial structures in the BE and PE games. Our analysis has ignored possible mixed-strategy equilibria. There are several justifications for not considering mixed strategies in corporate structure choices (stage 1). (i) Pure-strategy equilibria were always found to exist (Figures 1.4 and 1.5). (ii) Parameter values where the pure-strategy were also dominant-strategy equilibria were isolated in the Appendix (e.g. region V of Figure 1.4); in these cases, no mixed-strategy equilibria exist. (iii) The conventional rationale for mixed-strategy equilibria is the desire to keep rivals guessing. This motive has no immediate relevance within our modelling structure. We also assume pure strategies in price setting in the market stage

(stage 3 of Figure 1.3). This use of pure strategies is tied to our assumption that firms' marginal costs of supplying both markets become common knowledge, because we can show that no pure-strategy Bayes-Nash equilibrium in prices exists when marginal costs are private knowledge (as would be the case if the success/failure of R&D were private information).⁴⁷ Therefore, an application of mixed strategies could arise in the market stage if our information assumptions were altered to make the output of R&D investment private knowledge.

A final point on solution concepts concerns our focus on non-collusive equilibria. We have shown (Proposition 3) that the BE game is a Prisoner's Dilemma for certain parameter values. Whenever this occurs, the incumbents would prefer to collude to achieve the Pareto dominant outcome, but such collusion is ruled out in our one-shot modelling structure by dominant free-rider incentives. However, if we allowed for infinitely-repeated product market contact, then collusive equilibria might be supported by trigger strategies to punish defection. In turn, sunk investments in greenfield-FDI and R&D could strengthen these trigger strategies by allow a defector to be punished more severely. Therefore, in a dynamic extension of our modelling structure, collusive equilibria could arise endogenously via non-co-operative play; hence the 'solution concept' becomes endogenous.

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 chapter 2, 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.

1.6 Endnotes.

¹ In part, these models sought to account for the observed international cross-hauling of trade and FDI flows between pairs of countries *within the same industry*. (This stylized empirical fact is often interpreted as being inconsistent with an explanation of international economic specialisation based on differing 'comparative advantages' across countries.) For Rowthorn, this is an explicit aim and therefore he assumes that both firms produce a homogeneous product, whereas Horstmann and Markusen allow for product differentiation.

² 0 plants represents a decision not to enter the industry; 1 plant represents a decision to locate a single plant at home, perhaps serving the foreign market by exporting (which incurs a trade cost); 2 plants represents a decision to undertake greenfield-FDI and maintain plants in both countries. These production location decisions are irreversible and become common knowledge in stage two.

³ Two points of clarification are in order. First, throughout this chapter FDI in general is identified with greenfield-FDI in particular: there is no role for acquisition-FDI. (In this, we follow a widespread convention in game-theoretic analyses of the MNE.) In chapter 2 we nest the modelling structure developed below within a more general framework that allows for acquisition-FDI. That step will allow us systematically to explore the distinction between greenfield- and acquisition-FDI. Second, in the context of an established international oligopoly 'entry' has two distinct meanings. Within a given industry entry into a foreign country via intra-industry FDI is encapsulated in our FDI decision. By contrast, our entry decision refers to additional firms entering the *industry* at a *global* level. Neither Rowthorn nor Horstmann/Markusen analyse 'entry' in the latter (sequential) sense: both assume a given initial population of two firms with no possibility of subsequent entry by extra firms (see Rowthorn, 1989, pp. 3-4). (Horstmann and Markusen (1992, p. 119) do, however, explicitly acknowledge the possibility that certain sets of parameter values may induce entry by additional firms, but they decline to analyse it.)

⁴ See especially Motta (1992, pp. 1564-5).

⁵ Because FDI reduces the MNE's marginal cost relative to exporting, the domestic firm's profits at a Cournot equilibrium following entry *must* fall when the MNE chooses FDI over exporting. Therefore it is impossible for the domestic firm optimally to choose 'enter' against an investing MNE *but* 'stay out' against an exporting one. However, the converse *is* possible, and it creates an incentive for entry-detering (or 'pre-emptive') FDI: see Smith (1987, p. 95, sec. 5.3). Of course, such strategic FDI is a specific example of the entry-detering investments analysed in a general model by Dixit (1980).

⁶ 'Certain entry' means choosing entry is the domestic firm's dominant strategy so the MNE must accommodate it. We are comparing the difference between two levels of monopoly profits with that between two levels of Cournot-duopoly profits. Setting μ (market size) to 1 in Motta's model for simplicity and ignoring the sunk cost parameters, $\alpha \equiv M_H - M_E = (s / 4) \cdot (2 - s)$ is the MNE's gain from FDI if entry is ruled out and $\beta \equiv M_{HH} - M_{EH} = (4 \cdot s / 9) \cdot (1 - s)$ is the MNE's gain from FDI if entry is certain. Clearly $\alpha > \beta$ for all $s > 0$, where s is the per-unit trade cost. Furthermore for $G \in (\beta, \alpha)$, where G is the MNE's sunk cost of greenfield-FDI, the presence of a stage-two domestic entrant with a dominant strategy will affect the MNE's optimal stage-one choice. See also Smith (1987, pp. 94-5, secs. 5.1 and 5.2).

⁷ Linkages between a firm's profits and its rival's behaviour *do not* imply interdependences between the firms' equilibrium strategies: this is the essence of the distinction between Nash equilibria and dominant strategy equilibria. Naylor and Santoni (1999, Lemma 1) provide sufficient conditions for a location game in an international duopoly to be exclusively dominance-solvable. If national product markets are perfectly segmented and fixed costs are incurred *only* for greenfield-FDI, then a firm's export vs. FDI choice will be independent of its rival's behaviour. (The firm will optimally undertake greenfield-FDI if $\pi_{FDI} - \pi_X > G$, where $\pi_{FDI/X}$ is variable profits from abroad when the foreign market is

served by FDI/exporting and G is the sunk cost of greenfield-FDI. Clearly this condition is independent of the foreign firm's export vs. FDI decision: the key assumptions are (i) that only greenfield-FDI incurs a fixed cost, so the foreign firm will always serve its home market; and (ii) that national product markets are perfectly segmented, so a firm's global profits are additively separable in profits earned at home and abroad.) In contrast to Naylor/Santoni, best responses in the Rowthorn and Horstmann/Markusen models are conditional on the rival's behaviour: the presence of plant-specific fixed costs in both models (and of firm-specific fixed costs in Horstmann/Markusen) implies that a 0 plant (inactivity) strategy must be included for both firms to avoid loss-making in equilibrium. Adding the 0 plant strategy considerably complicates the analysis, and *inter alia* it implies that the gain in variable profits from choosing greenfield-FDI over exporting depends on whether the foreign firm is active. (See n. 6 above.)

In our models equilibrium strategies are also interdependent: the analysis of location decisions is identical to Naylor/Santoni; however, by investing in R&D a firm can reduce its marginal cost at home, thus altering its rival's incentive to undertake greenfield-FDI.

⁸ This example is based on Horstmann and Markusen (1992, p. 117)'s Figure 1.

⁹ Recall that, by producing abroad, an MNE 'jumps' the trade cost, which enters a national firm's marginal cost of serving the foreign market.

¹⁰ The problem with investigating equilibria via numerical simulations is that they give no indication of how equilibrium configurations respond to small changes in exogenous parameters in the neighbourhood of the numerical solution; and, more generally, they give no indication of the global 'pattern' of equilibria: there is always a chance that a given simulation may yield highly unrepresentative (fluky) results. (Petit and Sanna-Randaccio perhaps suffer from this latter problem when they admit (2000, p. 356, n. 17): 'Only scenarios leading to a single subgame perfect equilibrium were reported in the paper. However for other parameter values multiple equilibria may be obtained.' But how *likely* are we to obtain multiple, rather than unique, equilibria?)

¹¹ Fudenberg and Tirole modified Dixit's conclusion that an entry threat would generally prompt 'overinvestment' by the incumbent relative to the monopoly benchmark (see Dixit (1980, p. 106): 'the role of an irrevocable commitment of investment in entry-deterrence is to alter the initial conditions of the post-entry game to the advantage of the established firm'). However, they confirmed Dixit's implicit conclusion that credible entry threats *do* affect incumbents' equilibrium strategies.

¹² An analogy from linear algebra may help to make this point. Consider a system of three linear simultaneous equations in three unknowns. By ignoring one of the equations, the remaining two could be solved to express two of the unknowns as functions of the third. However, this procedure would only generate the 'equilibrium' values for the two unknowns if the equilibrium level of the third unknown happened to be inserted into their reduced forms, which would require a fluke.

¹³ This focus on entry by diversification, rather than de novo entry, allows us initially to avoid analysing the entrant's location decision. We assume that the entrant possesses pre-existing plants for another (but 'similar') industry in both countries and that these plants can be used to produce for our industry (albeit highly inefficiently at first). The assumption of entry by diversification can be justified in two ways. First, Geroski (1995, p. 424)'s fifth 'stylized fact about entry' states that 'De novo entry is more common but *less successful* than entry by diversification' (italics added). Therefore, it could be argued that entry by diversification is likely to exert the more significant effect on industrial structure in the long run because a disproportionate number of de novo entrants later exit. Second, it should be recalled that our analysis is concerned with the strategic behaviour of MNEs in concentrated, oligopolistic industries. In part, these oligopolies are sustained by high plant-specific fixed costs (and hence scale economies) relative to 'market size'. In such industries entry by diversification would seem more likely to occur than de novo entry because binding financial constraints would prevent potential de novo entrants from establishing plants

before receiving revenue flows. We discuss possible modifications to the entry decision in Section 1.5.

¹⁴ If the Rowthorn model, which also assumes homogeneous products, were solved using Bertrand competition in stage two, FDI could not occur in equilibrium. Because marginal production costs are constant and equal across firms, an MNE would always make a loss abroad following FDI: price would be driven down to marginal production cost and the MNE's loss would equal the fixed cost of FDI.

¹⁵ In part these modifications are considered as a response to Sutton (1990)'s concern that, because a large range of phenomena can be rationalised by tweaking the assumptions of a given game-theoretic model, game-theoretic models run the risk of 'explaining nothing'.

¹⁶ 'The difference between incumbent firms and entrants is that incumbent firms own plant and equipment specific to this industry and thereby are committed to continue operations in this industry, whereas this is not the case for a potential entrant. It is thus not just simple economies of scale which may cause a barrier to entry, but rather economies of scale in combination with irreversible capital commitments.' (von Weizsäcker, 1980, p. 401).

¹⁷ Note that if firm 3 enters the industry, its marginal cost is restricted to $\{0, c\}$ because firm 3 has two plants by assumption.

¹⁸ Net revenue is sometimes called 'variable profit'.

¹⁹ Firm i 's net revenue if it sets a price of x_i and serves the entire market is $\mu \cdot (1 - x_i) \cdot (x_i - c_i)$ is strictly concave in x_i with a maximum at $x_i = x^M(c_i)$. Therefore, for $x_i < x^M(c_i)$, increases in x_i will increase i 's net revenue; and if i is constrained to set x_i below $x^M(c_i)$, it will optimally set x_i as close to $x^M(c_i)$ as possible. See Vives (1999, p. 123 and p. 368, n. 8 on the 'open set problem').

²⁰ More precisely, being able to rank the various realisations of $R(\cdot)$ ('rankability') is a necessary, but not sufficient, condition for deriving best responses to the rival's corporate structure choices. As is demonstrated below, a sufficient condition is rankability of *linear combinations* of the realisations of $R(\cdot)$, which is more demanding.

²¹ Because the two firms originate from different countries, it is impossible for both firms to regard a given country as 'foreign' (i.e. there must always be a local firm). Therefore, the realisations $R(t, t)$, $R(t, c+t)$, $R(c+t, t)$ and $R(c+t, c+t)$ are ignored.

²² Firm i will export to j 's home market iff $c_j \in [c_i+t, 1)$, and firm j will export to i 's home market iff $c_j \in (0, \bar{c}_i - t]$. For $t > 0$ these two intervals do not overlap.

²³ Note that our information assumptions at each stage of the game are quite exact. Firm 3's stage-two entry decision can be conditional on the incumbents' corporate structure choices. In stage three the marginal costs of each firm in both countries become common knowledge. This assumption underpins the subsequent Bertrand equilibrium. Although our model does not incorporate interfirm technological spillovers, these interfirm information flows could be interpreted as a weak form of spillover.

²⁴ That $R(0, c+t) > R(t, c)$ is intuitively obvious because the firm's price ceiling is lower but its marginal cost is higher in its export market relative to its domestic market. The formal proof comprises two steps. First, from Figure 1.1 $R(0, c) > R(t, c)$. Second, from Figure 1.2 $R(0, c+t) \geq R(0, c)$ where the inequality is strict iff $c < x^M(0) = 0.5$. Because the inequality in step one is strict, combining steps one and two gives $R(0, c+t) > R(t, c)$.

²⁵ Both RHS(4BE) and RHS(6BE) can be written in general as $\mu^{crit} = k/(\alpha \cdot p - \beta \cdot p^2)$; $\alpha, \beta, k > 0$, $\alpha \cdot p - \beta \cdot p^2 > 0$ on $p \in (0, 1]$. (We discuss the β -coefficient in RHS(4BE) in more detail below.) It can be shown that

$d\mu^{crit}/dp = 0$ at $p = \alpha/2 \cdot \beta > 0.5$ and that $\text{sgn}(d\mu^{crit}/dp) \neq \text{sgn}(\alpha - 2 \cdot \beta \cdot p)$.

The sign property implies that μ^{crit} is strictly convex in p .

²⁶ Given that we label an inequality condition as ‘holding’ ($\mu > \mu^{crit}$) or ‘failing’ ($\mu < \mu^{crit}$) on the basis of *strict* inequalities, the case where a condition ‘binds’ ($\mu = \mu^{crit}$) has been glossed over. When an inequality condition exactly binds there will be no unique best response (i.e. a tie), so that multiple equilibria can easily arise. For simplicity we do not explicitly consider these cases because they do not affect our main conclusions. Furthermore, if actual market size is thought of as a continuous random variable (across potential ‘states of nature’), then such ties would not occur with measurable probability.

²⁷ Of course, a widely-used alternative to analytical solutions is numerical simulation. If we assigned numerical values to the six structural parameters, the inequality conditions could easily be tested and equilibrium choices derived. Unfortunately the price of this approach is generality of conclusions.

²⁸ Central to the results in Lemma 5 is the fact that $\mu_1(p)$, $\mu_2(p)$, $\mu_3(p)$ are *not* independent: $\mu_3(p)$ must always lie between $\mu_1(p)$, $\mu_2(p)$. For example, if $\mu_3(p) > \mu_2(p)$ in part (i), then there exists a set of μ -values where $(2, R) \succ (1, R) \succ (1, N) \succ (2, R)$, which is a contradiction.

²⁹ Both RHS(4PE) and RHS(5PE) can be written in general as $\mu^{crit} = k/(\alpha \cdot p - \beta \cdot p^2 + \gamma \cdot p^3)$; $\alpha, \beta, \gamma, k > 0$, $\alpha \cdot p - \beta \cdot p^2 + \gamma \cdot p^3 > 0$ on $p \in (0, 1]$. μ^{crit} can be shown to have the property $\text{sgn}(d\mu^{crit}/dp) \neq \text{sgn}(\alpha - 2 \cdot \beta \cdot p + 3 \cdot \gamma \cdot p^2)$. Because $\alpha - 2 \cdot \beta \cdot p + 3 \cdot \gamma \cdot p^2 = \alpha$ and $-R(0, t)$ at $p = 0$ and 1 respectively, and because $\alpha - 2 \cdot \beta \cdot p + 3 \cdot \gamma \cdot p^2$ is quadratic in p , $d\mu^{crit}/dp$ has only one change of sign (from $-$ to $+$) on $p \in [0, 1]$.

³⁰ Put another way, (B) and (C) are sufficient conditions for the plot of BE equilibria to take a fixed form in (p, μ) -space.

³¹ The underlying symmetries (across both incumbent firms and countries) in the PE game imply that (i) dominant strategy equilibria must be symmetric; and (ii) in asymmetric Nash equilibria the equilibrium corporate structure of a given incumbent is indeterminate.

³² Of course, the problem remains of how to identify our parameters, especially p , in empirical work. Furthermore, our models have no repeated-game structure, so any empirical implications are better thought of as applying to cross-sectional analyses than time-series ones. (We cannot simply assume repeated games with the same per-period equilibria as in Figures 1.4 and 1.5, because the greenfield-FDI and R&D decisions have dynamic implications: they are sunk, rather than fixed, costs.)

³³ There appears no obvious way of selecting between the two equilibria in region IV. One method would be to focus exclusively on symmetric equilibria, but that is ad hoc. A more sophisticated criterion is Pareto dominance: the selected equilibrium (focal point) is (weakly) preferred by both firms to the other candidate equilibrium. Unfortunately, as is clear from the expected profit functions, the two firms have different preferences between the two equilibria. The $(1, N)$ -firm will clearly prefer the $\{(1, R), (1, R)\}$ equilibrium because at the $\{(1, N), (2, R)\}$ equilibrium its profit is zero. However, the $(2, R)$ -firm will prefer the $\{(1, N), (2, R)\}$ equilibrium. To see this, compare its profits at the two equilibria and note that the $(2, R)$ -firm will prefer the asymmetric equilibrium iff $R(0, c) - R(t, c) + R(c, c+t) + [R(0, c+t) - R(c, c+t) + R(t, c) - R(0, t)] \cdot p > G$. From assumption (B) $[\cdot] > 0$, so a sufficient condition for the inequality to hold for high p is $R(0, c) - R(t, c) + R(c, c+t) > G$; i.e. that it holds at $p = 0$. This is a restriction on μ . The lowest μ -value in region IV can be found by noting that when (2BE) binds at $p = 1$, $R(0, c) - R(t, c) = G$; which implies that $R(0, c) - R(t, c) + R(c, c+t) > G$ must hold throughout region IV. An implication of this result is that if the incumbents moved sequentially (rather than simultaneously) in the BE game, then the $\{(1, N), (2, R)\}$ equilibrium would be selected in region IV (with the leader choosing $(2, R)$).

³⁴ For example, there are in fact six distinct sequences of equilibrium industrial structures in the BE game as p varies between 0 and 1, depending on the given μ -value. We list them here for reference; we begin with the lowest range of μ -values and work upwards. (i) $\{(1, N), (1, N)\}$ (region I). (ii) $\{(1, N), (1, N)\}$ (region I); then $\{(1, N), (1, R)\}$ (region II). (iii) $\{(1, N), (1, N)\}$ (region I); then $\{(1, N), (1, R)\}$ (region II); then $\{(1, R), (1, R)\}$ (region III); then $\{(1, N), (1, R)\}$ (region II). The existence of this sequence relies on (4BE) having an interior minimum, which need not always be the case. (iv) $\{(1, N), (1, N)\}$ (region I); then $\{(1, N), (1, R)\}$ (region II); then $\{(1, R), (1, R)\}$ (region III). (v) $\{(1, N), (1, N)\}$ (region I); then $\{(1, N), (1, R)\}$ (region II); then $\{(1, R), (1, R)\}$ (region III); then $\{(1, R), (1, R)\}$ or $\{(1, N), (2, R)\}$ (region IV). (vi) $\{(1, N), (1, N)\}$ (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 $\{(1, R), (1, R)\}$ or $\{(1, N), (2, R)\}$ (region IV).

³⁵ A simpler ‘monopoly case’, not considered in this paper, would be where the two incumbents in the BE game colluded. The monopoly thus created would not undertake greenfield-FDI because the BE game’s incumbents together own plants in both countries. For more discussion of the effects of allowing collusion between the incumbents, see chapter 2 (the ‘Acquisition Subgame’).

³⁶ *Proof.* When $G = I$ (A8) becomes $2 \cdot R(0, c) - 2 \cdot R(t, c) - R(0, t) > 0$. When $t = 0$, LHS = 0. Now consider progressive rises in t from 0 to c . $\partial \text{LHS} / \partial t > 0$ requires $-2 \cdot (\partial R(t, c) / \partial t) > \partial R(0, t) / \partial t$. For $t \leq 0.5$, $R(0, t) = \mu \cdot (1 - t) \cdot t$ and $R(t, c) = \mu \cdot (1 - c) \cdot (c - t)$ for $x^M(t) \geq c$ and $R^M(t)$ for $x^M(t) \leq c$. Given either functional form for $R(t, c)$, $\partial \text{LHS} / \partial t > 0$. (Note that $\partial \text{LHS} / \partial t > 0$ when $R(t, c) = \mu \cdot (1 - c) \cdot (c - t)$ iff $t > c - 0.5$, which is implied by $x^M(t) \geq c$ for $t > 0$.) For $t \geq 0.5$, $R(0, t) = R^M(0)$, so $\partial R(0, t) / \partial t = 0$ and therefore $\partial \text{LHS} / \partial t > 0$.

³⁷ The effects of decreases in G or increases in I will be the opposites of what we catalogue, provided that the changes are not 'too big' (i.e. drastic: assumption (C) must continue to hold).

³⁸ Note from Figure 1.6 that *all* rises in c are nondrastic.

³⁹ For $c > 0.5$ $\partial[R(0, c) - R(t, c)]/\partial c = -\partial R(t, c)/\partial c \leq 0$. The derivative equals 0 if c is very high ($c > x^M(t)$). For $c < 0.5$ $R(0, c) = \mu(1 - c) \cdot c$ and $R(t, c) = \mu(1 - c) \cdot (c - t)$, and $\partial[R(0, c) - R(t, c)]/\partial c < 0$. The derivative cannot be evaluated at $c = 0.5$ because the net revenue function is kinked.

⁴⁰ The sign restrictions on α, δ are straightforward. Those on β, γ follow from (A6), which is proved in the Appendix: $R(c, c + t) - R(0, c + t) + R(0, c) > 0$ for all t, c under assumption (A). $\gamma > 0$ follows directly from (A6). To show $\beta < 0$,

rewrite β as $-\left\{\frac{I}{G} \cdot [R(c, c + t) - R(0, c + t)] + R(0, c)\right\} - \frac{I}{G} \cdot [R(c, c + t) + R(t, c)]$

and note that $\min\{\cdot\} = \text{LHS(A6)}$ when $G = I$.

⁴¹ Because $d\text{LHS(A10)}/dp = \beta + 2 \cdot \gamma \cdot p + 3 \cdot \delta \cdot p^2$, there is a possibility that LHS(A10) is decreasing in p for all $p \geq 0$ (iff $3 \cdot \beta \cdot \delta \geq \gamma^2$). However, this possibility is ruled out because LHS(A10) at $p = 1$ is strictly greater than LHS(A10) at $p = 0$. To see this, note that $\beta + \gamma + \delta > 0$ iff $R(0, t) - R(c, c + t) > 0$. At $t = 0$, LHS = 0. Now consider progressive rises in t towards $t = c$. For $t \leq 0.5$, we have $R(0, t) = \mu(1 - t) \cdot t$ and $R(c, c + t) = \mu(1 - c - t) \cdot t$ or $R^M(c)$. Given either functional form for $R(c, c + t)$, we get $\partial[R(0, t) - R(c, c + t)]/\partial t > 0$. For $t \geq 0.5$, we have $R(0, t) = R^M(0)$ and $R(c, c + t) = R^M(c)$, so the condition becomes $R^M(0) - R^M(c) > 0$, which clearly holds.

Therefore, because $R(0, t) - R(c, c + t) > 0$, LHS(A10) *must* be strictly increasing on some of $p \in [0, 1]$. This implies that the smaller root of $d\text{LHS(A10)}/dp = 0$ must lie on $p \in (0, 1)$.

⁴² The derivation procedure would be: first, solve for the smaller root of $dLHS(A10)/dp = 0$ using the quadratic formula; second, substitute this p -value into condition (A10); third, solve (A10), whose parameters depend implicitly on t, c , for an explicit inequality relation between t and c .

⁴³ Other sufficient conditions that were experimented with (e.g. that the tangent to LHS(A10) at $p = 0$ be ≥ 0 at $p = 1$) proved far too restrictive (unnecessary) to be useful.

⁴⁴ Comparison with the blockaded-entry case is only one (but perhaps the simplest) method of evaluating the effects of an entry threat. For example, Fudenberg and Tirole (1984) compare closed- and open-loop equilibria; in the former the entrant moves after the incumbents (and observes their choices), whereas in the latter all players move simultaneously (or cannot observe preceding moves).

⁴⁵ Perhaps confusingly, a widespread simplification of Bain's classifications of incumbents' strategies given an entry threat (Tirole, 1988, p. 306) suggests that, if both incumbents choose $(1, R)$, entry is 'blockaded' in regions III and V of the PE game (Figure 1.5), whereas it is 'accommodated' in regions VI, VIII and IX. We shall follow Bain's classifications by referring to 'accommodation' and 'deterrence' in Figure 1.5, but for consistency (and to avoid undue confusion) we shall reserve the label of 'blockaded entry' for describing Figure 1.4.

⁴⁶ Fudenberg and Tirole's (1984) analysis of investment behaviour in anticipation of entry is really only tangentially applicable here. Fudenberg/Tirole examined a duopolist's incentives to invest in shifting its best-response function under a variety of assumptions about the nature of competition (strategic complements vs. substitutes) and the effects of investment (which way the best-response function shifts). However, in their model only one firm could vary its level of investment and the investment decision variable was continuous; whereas our analysis has both firms undertaking discrete investment projects. Nevertheless, the investment incentives in our model accord with Fudenberg/Tirole's

conclusions when investment makes the investor 'tough' and competition is in strategic complements.

⁴⁷ Sketch of proof. Let x^H (resp. x^L) be the equilibrium price of a local producer whose R&D investment fails (resp. succeeds) and so has a high (resp. low) marginal cost. (Because marginal costs are private knowledge, firms' equilibrium pricing strategies can only be conditional on their *own* marginal costs.) Set $x^H > x^L$. For all $x^L > 0$, it is a best response by a successful innovator to undercut x^L marginally and earn $\mu(1 - x^L)$: the firm wins the whole market regardless of its rival's type. However, if $x^L = 0$, it is a successful innovator's best response to undercut x^H marginally (and abandon competition with the low-cost type) to earn $(1 - p) \cdot \mu(1 - x^H)$. Therefore, a symmetric Bayes-Nash equilibrium in pure (pricing) strategies does not exist.

1.7 Appendix.

1.7.1. Equilibrium industrial structures in the BE game ($S_3 = \emptyset$).

The solution we derive to the BE game has the following properties:

(i). Lemma 5(i) holds for all S_2 . This requires

RHS(2BE) > RHS(1BE) or

$$R(0, c+t) - R(c, c+t) + R(t, c) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] > 0 \quad (\text{A1})$$

RHS(5BE) > RHS(4BE) or

$$(1-p) \cdot \left\{ R(0, c+t) - R(c, c+t) + R(t, c) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] \right\} + p \cdot R(0, t) > 0 \quad (\text{A2})$$

RHS(5BE) > RHS(7BE) or

$$R(0, c) + R(t, c) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] > 0 \quad (\text{A3})$$

These three conditions together imply that (3BE), (6BE) and (8BE) are irrelevant to determining the incumbents' best responses (and therefore equilibrium behaviour). Furthermore, there will exist for all p a set of μ -values where (1, R) is the best response to any S_2 .

Therefore the five conditions (1BE), (2BE), (4BE), (5BE) and (7BE) are sufficient to determine the BE equilibrium.

(ii). RHS(5BE) > RHS(2BE) > RHS(4BE) > RHS(1BE). This requires RHS(5BE) > RHS(2BE), which holds for all $p \in (0, 1]$; see the discussion in the main text.

RHS(2BE) > RHS(4BE) or

$$(1-p) \cdot [R(0, c+t) + R(t, c) - R(c, c+t)] + p \cdot R(0, t) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] > 0 \quad (\text{A4})$$

RHS(4BE) > RHS(1BE) or

$$[R(0, c+t) + R(t, c) - R(c, c+t) - R(0, t)] \cdot p > 0 \quad (\text{A5})$$

(iii). $\text{RHS}(7\text{BE}) > \text{RHS}(2\text{BE})$ at $p = 1$ and $\text{RHS}(7\text{BE}) < \text{RHS}(1\text{BE})$ for $p \cong 0$.

The first inequality clearly holds because $\lim_{p \rightarrow 1} \text{RHS}(7\text{BE}) = \infty$ whereas

$\text{RHS}(2\text{BE})$ takes a finite value at $p = 1$. The second inequality holds iff

$$R(0, c) - R(0, c+t) + R(c, c+t) > 0 \quad (\text{A6})$$

which ensures that the nonzero p -value where $\text{RHS}(7\text{BE}) = \text{RHS}(1\text{BE})$ is strictly positive.

(iv). A single-crossing result. $\text{RHS}(7\text{BE})$ intersects each of $\text{RHS}(j\text{BE}), j \in \{1, 2, 4\}$, exactly once on $p \in (0, 1)$. This follows directly from (iii) and the fact that the three equations $\text{RHS}(7\text{BE}) = \text{RHS}(j\text{BE})$ all have *unique* solutions in p for $p \neq 0$.

We now show that assumptions (B), (C) are sufficient to ensure that conditions (A1) to (A6) all hold. First, (A2) can be rewritten as $(1-p) \cdot \text{LHS}(A1) + p \cdot R(0, t) > 0$, so (A1) implies (A2) and (A2) can be dropped. Second, for $p \neq 0$ (A5) becomes assumption (B). Third, note that

$$\frac{d\text{LHS}(A4)}{dp} = -\text{LHS}(B) < 0$$

so it is necessary that (A4) hold at $p = 1$:

$$R(0, t) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] > 0 \quad (\text{A4})'$$

We are left with (A1), (A3), (A6), (A4)' and (B). (A1) and (A3) can be eliminated as follows. First, $\text{LHS}(A1) = \text{LHS}(A4)' + \text{LHS}(B)$, so (A4)' and (B) together imply (A1). Second, under assumption (C) $\frac{I}{G} \leq 1$; and because $\frac{I}{G}$ enters (A3) and (A4)' with a negative coefficient, it is sufficient that (A3) and (A4)' hold when $G = I$. In this case, (A3) holds trivially, and (A4)' becomes

$$R(0, t) - R(0, c) + R(t, c) > 0 \quad (\text{A4})''$$

Both (A4)'' and (A6) hold for all t, c under assumption (A). A longhand proof would exhaustively examine whether (A4)'' and (A6) hold for every set of t, c that

uniquely determines the functional form of $R(\cdot)$, i.e. undercutting vs. monopoly-pricing, and is consistent with our maintained assumption (A). Here we present two shorter proofs.

(i). (A4)'' holds for all t, c under (A).

Proof. At $c = t$ LHS(A4)'' = 0. Now consider progressive increases in c above t .

The effect of these increases on LHS(A4)'' is given by

$$\frac{\partial \text{LHS(A4)''}}{\partial c} = \frac{\partial R(t, c)}{\partial c} - \frac{\partial R(0, c)}{\partial c}$$

For $c \geq t$ $R(t, c) = \mu \cdot (1 - c) \cdot (c - t)$ (an undercutting equilibrium), so $\partial R(t, c) / \partial c > 0$; and $R(0, c) = \mu \cdot (1 - c) \cdot c$ or $R^M(0)$ (depending on c), so $\partial R(0, c) / \partial c \geq 0$. Given either expression for $R(0, c)$, $\partial \text{LHS(A4)''} / \partial c > 0$. When $c \leq t$ we get $R(t, c) = R^M(t)$, so $\partial R(t, c) / \partial c = 0$; and therefore $R(0, c) = R^M(0)$, so $\partial R(0, c) / \partial c = 0$. Therefore LHS(A4)'' > 0 and $\partial \text{LHS(A4)''} / \partial c = 0$ for $c \leq t$.

(ii). (A6) holds for all t, c under (A).

Proof. At $t = 0$ LHS(A6) = 0. Now consider progressive increases in t towards c .

The effect of these increases on LHS(A6) is given by

$$\frac{\partial \text{LHS(A6)}}{\partial t} = \frac{\partial R(c, c+t)}{\partial t} - \frac{\partial R(0, c+t)}{\partial t}$$

For $t \geq 0$ $R(c, c+t) = \mu \cdot (1 - c - t) \cdot t$ (an undercutting equilibrium), so $\partial R(c, c+t) / \partial t > 0$; and $R(0, c+t) = \mu \cdot (1 - c - t) \cdot (c+t)$ or $R^M(0)$ (depending on c), so $\partial R(0, c+t) / \partial t \geq 0$. Given either of these expressions for $R(0, c+t)$, $\partial \text{LHS(A6)} / \partial t > 0$. When $t \leq 0$ we get $R(c, c+t) = R^M(c)$, so $\partial R(c, c+t) / \partial t = 0$; and therefore $R(0, c+t) = R^M(0)$, so $\partial R(0, c+t) / \partial t = 0$. Therefore LHS(A6) > 0 and $\partial \text{LHS(A6)} / \partial t = 0$ for $t \leq 0$.

We have reduced the set of constraints (A1) to (A6) to (B) with the aid of (C). Therefore (B) and (C) are sufficient to fix the plot of BE equilibria in a general form in (p, μ) -space. This enables us to draw reasonably general conclusions about the equilibrium properties of the BE game.

Under assumptions (B) and (C), the relative positions of the five conditions (1BE), (2BE), (4BE), (5BE) and (7BE) are fixed in (p, μ) -space. The plot in Figure A1.1 shows that they divide the (p, μ) -space into nine distinct regions, each with a different configuration of best responses (and possibly different equilibria). The equilibrium industrial structure in each region can be inferred from its set of best responses. Figure 1.4 in the main text tidies Figure A1.1 up by grouping together regions of identical equilibria.

[FIGURE A1.1 IS OVERLEAF]

Key to Figure A1.1

Region	Best response to			Nash equilibria (Equilibrium industrial structures)
	(1, N)	(1, R)	(2, R)	
I	(1, N)	(1, N)	(1, N)	$\{(1, N), (1, N); \emptyset\}^*$
II	(1, N)	(1, N)	(1, R)	$\{(1, N), (1, N); \emptyset\}$
III	(1, R)	(1, N)	(1, N)	$\{(1, N), (1, R); \emptyset\}$
IV	(1, R)	(1, N)	(1, R)	$\{(1, N), (1, R); \emptyset\}$
V	(1, R)	(1, R)	(1, N)	$\{(1, R), (1, R); \emptyset\}$
VI	(1, R)	(1, R)	(1, R)	$\{(1, R), (1, R); \emptyset\}^*$
VII	(2, R)	(1, R)	(1, R)	$\{(1, R), (1, R); \emptyset\}$
VIII	(2, R)	(1, R)	(1, N)	$\{(1, R), (1, R); \emptyset\}; \{(1, N), (2, R); \emptyset\}$
IX	(2, R)	(2, R)	(2, R)	$\{(2, R), (2, R); \emptyset\}^*$

(Note: * denotes a dominant strategy equilibrium.)

Two significant aspects of the plot in Figure A1.1 are not constrained: the p -value where RHS(4BE) takes its minimum; and the p -value where RHS(7BE) intersects RHS(2BE). These p -values are significant because both are identifiable in Figure 1.4. We make two observations. First, the minimum p -value on RHS(4BE) is greater than 0.5; it will be strictly less than 1 if $LHS(B) > R(0, t)$ which is more demanding than assumption (B). (Therefore RHS(4BE) may be strictly decreasing for all $p \in (0, 1)$.) Second, the minimum p -value on

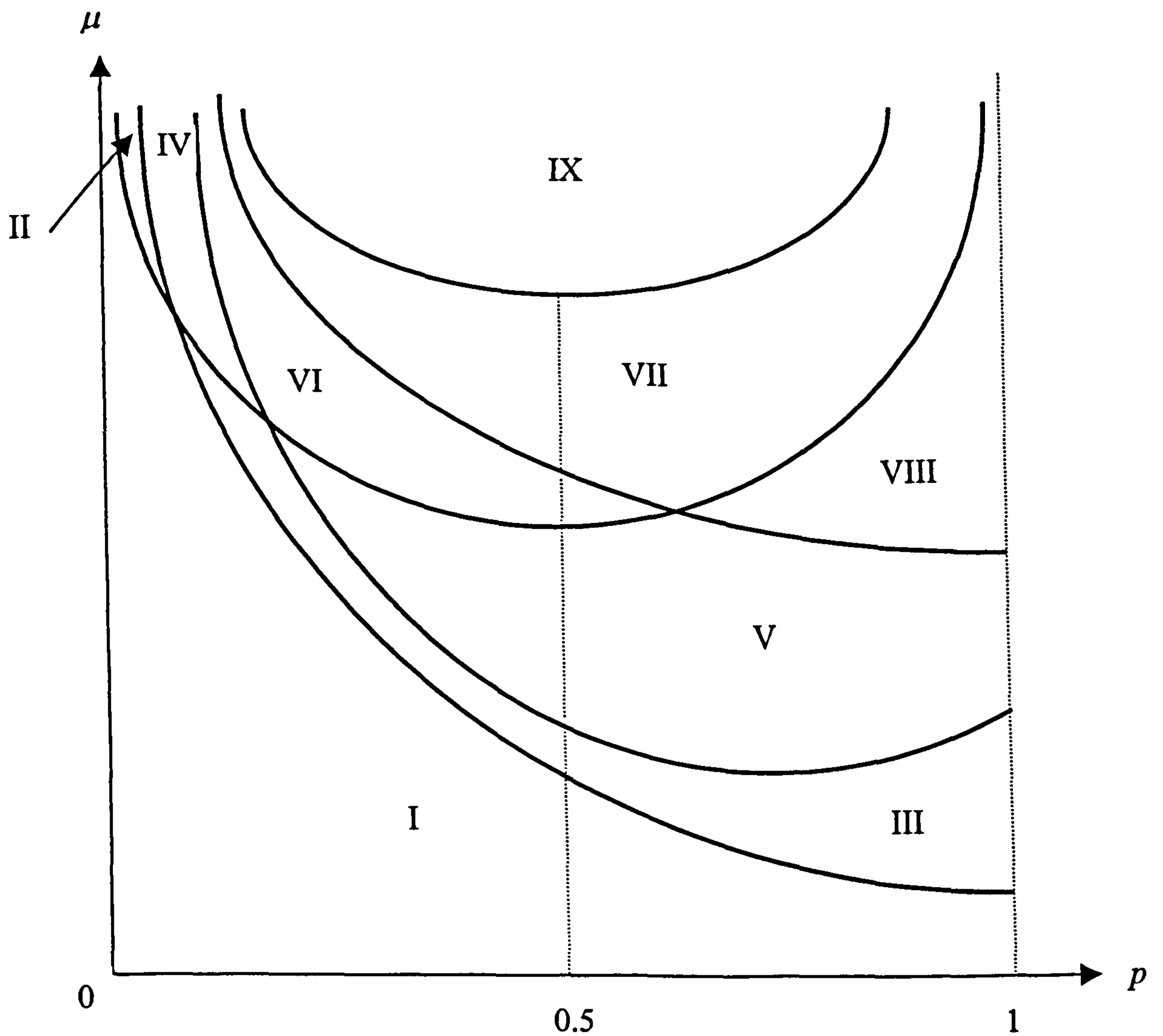


Figure A1.1: Equilibrium industrial structures in the BE game

Inter-regional boundaries. I/II boundary is RHS(7BE); I/III boundary is RHS(1BE); II/IV boundary is RHS(1BE); III/IV boundary is RHS(7BE); III/V boundary is RHS(4BE); IV/VI boundary is RHS(4BE); V/VI boundary is RHS(7BE); V/VIII boundary is RHS(2BE); VI/VII boundary is RHS(2BE); VII/VIII boundary is RHS(7BE); VII/IX boundary is RHS(5BE).

RHS(4BE) will be greater than the p -value where RHS(7BE) and RHS(2BE) intersect iff

$$\frac{I \cdot [R(0, c) - R(t, c)]}{G \cdot [R(0, c) + R(t, c)]} > \frac{R(0, c+t) + R(t, c) - R(c, c+t) - 2 \cdot R(0, t)}{2 \cdot [R(0, c+t) + R(t, c) - R(c, c+t) - R(0, t)]}$$

This condition will certainly hold when (B) almost binds, so the RHS is negative. Alternatively, when $t \cong 0$ we have LHS $\cong 0$ and RHS $\cong 0.5$, so the condition is violated.

1.7.2. Equilibrium industrial structures in the PE game ($S_3 \in \{\emptyset, R\}$).

Our solution to the PE game proceeds in two steps.

Step 1. Lemma 6 ranks RHS(1PE) to RHS(6PE). In step one we position RHS(1PE) to RHS(6PE) on Figure A1.1. The following conditions characterise our solution:

(i). RHS(1PE) > RHS(1BE) for all $p \in [0, 1]$. This inequality is a direct implication of assumption (B)'.

We can show that RHS(1PE) > RHS(1BE) implies that the precise position of RHS(1PE) relative to the inter-regional boundaries in the BE game (Figure A1.1) is irrelevant to solving the PE game; and that therefore condition (1PE) can be discarded. First, note that for $\mu < \text{RHS}(1\text{PE})$ (i.e. when (1PE) is violated) firm 3 will *always* optimally choose \emptyset (Lemma 6). Therefore, when $\mu < \text{RHS}(1\text{PE})$ the PE equilibria are identical to those in the BE game. Second, when $\mu \in (\text{RHS}(1\text{PE}), \text{RHS}(2\text{PE}))$ firm 3 will optimally choose R iff *both* incumbents choose $(1, N)$ (but \emptyset otherwise). From Lemma 4(i), therefore, a necessary condition for the incumbents' best responses to differ between the BE and PE games when $\mu \in (\text{RHS}(1\text{PE}), \text{RHS}(2\text{PE}))$ is that $(1, N)$ be a best response to $(1, N)$ in the BE game when $\mu \in (\text{RHS}(1\text{PE}), \text{RHS}(2\text{PE}))$. (Otherwise the best responses in the BE game will not be disrupted by the entry threat.) However, note from Figure A1.1 that $(1, N)$ is a best response to $(1, N)$ in the BE game *only below* RHS(1BE) (i.e. regions I and II). Therefore, because RHS(1PE) >

RHS(1BE) the entry threat in the PE game cannot change the incumbents' best responses on $\mu \in (\text{RHS}(1\text{PE}), \text{RHS}(2\text{PE}))$ relative to the BE game. *Consequently condition (1PE) can be discarded because for $\mu < \text{RHS}(2\text{PE})$ equilibria in the PE game will be identical to those in the BE game.*

Having discarded (1PE) we now show how assumptions (B)' and (C) position RHS(2PE) to RHS(6PE) on Figure A1.1 to produce Figure A1.2.

[FIGURE A1.2 IS OVERLEAF]

(ii). $\text{RHS}(2\text{PE}) > \text{RHS}(4\text{BE})$ for all $p \in [0, 1]$. In general $\text{RHS}(2\text{PE}) > \text{RHS}(4\text{BE})$ iff

$$2 \cdot [R(0, c+t) + R(t, c) - R(c, c+t) - R(0, c)] \cdot (1-p) + p \cdot R(0, t) > 0$$

Because the LHS of this condition is linear in p , it is sufficient that the inequality hold at $p = 0, 1$ (the end-points). At $p = 0$ the condition is identical to assumption (B)'. At $p = 1$ it becomes $R(0, t) > 0$, which clearly holds.

(iii). $\text{RHS}(2\text{BE}) > \text{RHS}(6\text{PE})$ for low p . In general $\text{RHS}(2\text{BE}) > \text{RHS}(6\text{PE})$ iff

$$R(0, c) \cdot (1-p)^2 > \frac{I}{G} \cdot [R(0, c) - R(t, c)]$$

Because $(1-p)^2$ is strictly decreasing on $p \in [0, 1]$, it is sufficient that the inequality hold at $p = 0$; i.e.

$$R(0, c) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] > 0 \tag{A7}$$

Because the coefficient on $\frac{I}{G}$ is negative and $\frac{I}{G} \leq 1$ under assumption (C), it is sufficient that the inequality hold when $G = I$. In this case, the above inequality holds trivially.

Taken together, (ii) and (iii) imply that *all* of RHS(2PE) to RHS(6PE) lie between RHS(4BE) and RHS(2BE) for low p -values.

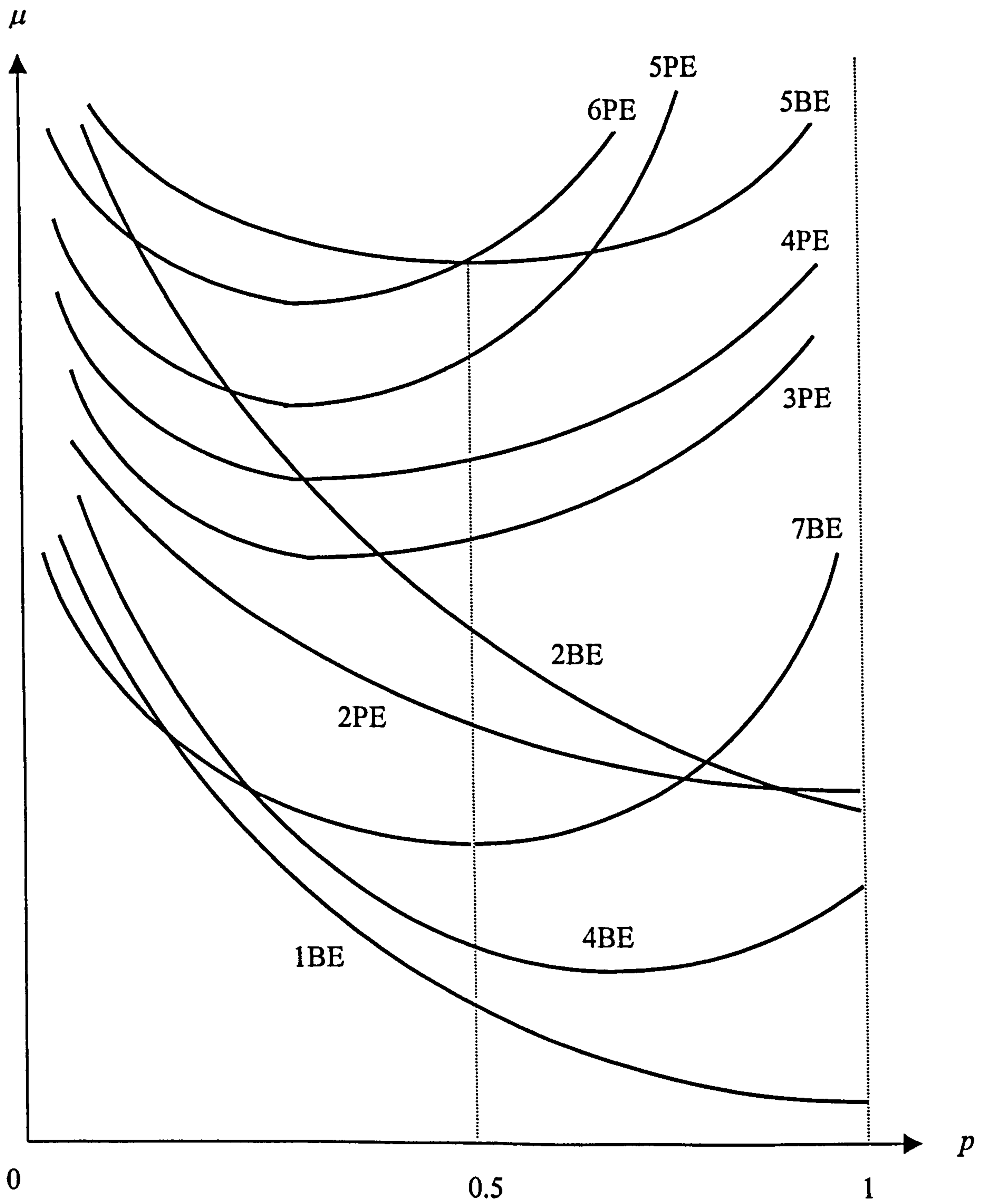


Figure A1.2: Equilibrium industrial structures in the PE game

(iv). $\text{RHS}(5\text{BE}) > \text{RHS}(4\text{PE})$ for all $p \in [0, 1)$. In general $\text{RHS}(5\text{BE}) > \text{RHS}(4\text{PE})$ iff

$$R(0, c) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] - \left\{ 2 \cdot R(0, c) - R(0, t) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] \right\} \cdot p + [R(0, c) - R(0, t)] \cdot p^2 > 0$$

where the LHS is quadratic in p and of the form $\alpha - \beta \cdot p + \gamma \cdot p^2$; $\alpha > 0$ from (A7), $\gamma \geq 0$, $\alpha - \beta + \gamma = 0$. If $\gamma = 0$ the LHS is linear in p and strictly positive on $p \in [0, 1)$ (because both end-points ≥ 0). If $\gamma > 0$ then the LHS is strictly convex in p and it is sufficient for $\text{RHS}(5\text{BE}) > \text{RHS}(4\text{PE})$ on $p \in [0, 1)$ that its second root be strictly greater than 1. From Viète's rule on the product of roots, this requires $\alpha > \gamma$, which reduces to (A4)' (already proven).

(v). $\text{RHS}(6\text{PE}) > \text{RHS}(5\text{BE})$ for high p . For $p \in (0, 1)$ $\text{RHS}(6\text{PE}) > \text{RHS}(5\text{BE})$ iff

$$\frac{I}{G} \cdot [R(0, c) - R(t, c)] > R(0, c) \cdot (1 - p)$$

where the LHS is *strictly* positive for $t > 0$. Therefore by choosing p sufficiently close to 1 the condition can always be met.

An implication of (iv) and (v) is that $\text{RHS}(5\text{BE})$ lies between $\text{RHS}(4\text{PE})$ and $\text{RHS}(6\text{PE})$ for high p . But where does $\text{RHS}(5\text{BE})$ lie in relation to $\text{RHS}(5\text{PE}) \in (\text{RHS}(4\text{PE}), \text{RHS}(6\text{PE}))$ when $p \cong 1$?

(vi). Assumptions (B)' and (C) are consistent with *both* $\text{RHS}(5\text{PE}) > \text{RHS}(5\text{BE})$ and $\text{RHS}(5\text{BE}) > \text{RHS}(5\text{PE})$ for high p . To see this, note that in general $\text{RHS}(5\text{PE}) > \text{RHS}(5\text{BE})$ iff

$$-2 \cdot \left\{ R(0, c) - \frac{I}{G} \cdot [R(0, c) - R(t, c)] \right\} - \left\{ 2 \cdot \frac{I}{G} \cdot [R(0, c) - R(t, c)] - 4 \cdot R(0, c) + R(0, t) \right\} \cdot p - [2 \cdot R(0, c) - R(0, t)] \cdot p^2 > 0$$

where the LHS is of the form $\alpha - \beta \cdot p - \gamma \cdot p^2$; $\alpha < 0$ from (A7), $\gamma > 0$ (so LHS strictly concave in p), $\alpha - \beta - \gamma = 0$. Therefore it is sufficient for $\text{RHS}(5\text{PE}) > \text{RHS}(5\text{BE})$ (resp. $\text{RHS}(5\text{BE}) > \text{RHS}(5\text{PE})$) at high p that the second root of the

LHS be strictly less (resp. greater) than 1. From Viète's rule on the product of roots the second root < 1 iff $\gamma > -\alpha$, or

$$2 \cdot \frac{I}{G} \cdot [R(0, c) - R(t, c)] - R(0, t) > 0 \quad (\text{A8})$$

We show in the main text that assumption (C) is consistent with *both* LHS(A8) > 0 and LHS(A8) < 0 . Whether or not (A8) is satisfied affects equilibrium industrial structures in the PE game for a (small) set of high p - and μ -values. We analyse both possibilities in Section 1.3.4 of the main text.

We finish step one by considering the positions of RHS(2PE) and RHS(3PE) (which from Lemma 6 are the lowest of RHS(2PE) to RHS(6PE) in (p, μ) -space) in relation to the inter-regional boundaries in Figure A1.1.

(vii). RHS(3PE) $>$ RHS(7BE) for all p . This requires $R(t, c) > 0$ and so clearly holds.

(viii). RHS(2PE) $>$ RHS(2BE) for high p iff

$$2 \cdot \frac{I}{G} \cdot [R(0, c) - R(t, c)] - R(0, t) > 0 \quad (\text{A8})$$

which, as we noted in (vi) above, can both hold and fail under assumption (C). In this case whether or not (A8) holds has a minor effect on equilibrium industrial structures in the PE game, which we describe in Section 1.3.4 of the main text.

(ix). The p -value where RHS(7BE) intersects RHS(2PE) is *strictly less* than the p -value where RHS(7BE) intersects RHS(2BE). Comparing RHS(2BE), RHS(7BE) and RHS(2PE), this requires

$$\frac{R(0, c) + R(t, c) - \frac{I}{G} \cdot [R(0, c) - R(t, c)]}{R(0, c) + R(t, c)} > \frac{2 \cdot R(t, c)}{2 \cdot R(t, c) + R(0, t)}$$

It is sufficient for this inequality to hold when the LHS is minimized, which under (C) occurs when $G = I$. Setting $G = I$ and simplifying, the inequality above becomes

$$R(t, c) + R(0, t) - R(0, c) > 0 \quad (\text{A4})''$$

which we have already shown to hold. The significance of this result is that it sets a *lower bound* on the position of RHS(2BE). It implies that a triangle in (p, μ) -space *above* RHS(2PE) whose sides are RHS(2BE), RHS(7BE) and RHS(2PE) *always* exists (see Figure A1.2), where (as we show in step two) equilibrium industrial structures differ between the BE and PE games.

Step 2. In step two we derive the equilibrium industrial structure in each region of Figure A2. The following definition provides a useful shorthand.

Definition A1. Given that $j \in \{\text{BE}, \text{PE}\}$, an incumbent firm's *best response set* in the j game is $\{S_j^{\text{BR}}[(1, N)], S_j^{\text{BR}}[(1, R)], S_j^{\text{BR}}[(2, R)]\}$ where $S_j^{\text{BR}}[S]$ denotes the incumbent's best response to S for all $S \in \{(1, N), (1, R), (2, R)\}$. (By symmetry *both* incumbents must have the same best response set.)

From (i) in step one we know that below RHS(2PE) the PE equilibria are identical to those in the BE game. The area above RHS(2PE) is divided five ways by RHS(3PE) to RHS(6PE). Therefore from the viewpoint of firm 3's best responses there are five distinct regions to consider in Figure A1.2:

(i). $\mu \in (\text{RHS}(2\text{PE}), \text{RHS}(3\text{PE}))$. Firm 3 optimally chooses R in response to $\{(1, N), (1, N)\}$ and $\{(1, N), (1, R)\}$, but \emptyset otherwise. Therefore from Lemma 4(i)

$$\begin{aligned} S_{\text{PE}}^{\text{BR}}[(1, N)] &= S_{\text{BE}}^{\text{BR}}[(1, N)] = (2, R) \text{ for } \mu > \text{RHS}(2\text{BE}) \\ S_{\text{PE}}^{\text{BR}}[(1, R)] &= S_{\text{BE}}^{\text{BR}}[(1, R)] = (1, R) \\ S_{\text{PE}}^{\text{BR}}[(2, R)] &= S_{\text{BE}}^{\text{BR}}[(2, R)] = \begin{cases} (1, N) & \text{for } \mu < \text{RHS}(7\text{BE}) \\ (1, R) & \text{for } \mu > \text{RHS}(7\text{BE}) \end{cases} \end{aligned}$$

$S_{\text{PE}}^{\text{BR}}[(2, R)] = S_{\text{BE}}^{\text{BR}}[(2, R)]$ because firm 3 will never enter if at least one incumbent chooses $(2, R)$. $S_{\text{PE}}^{\text{BR}}[(1, R)] = S_{\text{BE}}^{\text{BR}}[(1, R)]$ and $S_{\text{PE}}^{\text{BR}}[(1, N)] = S_{\text{BE}}^{\text{BR}}[(1, N)]$ for $\mu > \text{RHS}(2\text{BE})$ because neither $\{(1, R), (1, R)\}$ nor $\{(1, N), (2, R)\}$ provokes entry.

RHS(2BE) and RHS(7BE) divide the area between RHS(2PE) and RHS(3PE) into four parts. For $\mu > \text{RHS}(2\text{BE})$, RHS(7BE) an incumbent's best response set

under PE is $\{(2, R), (1, R), (1, R)\}$, so the PE equilibrium is $\{(1, R), (1, R); \emptyset\}$ (as under BE). For $\mu \in (\text{RHS}(2\text{BE}), \text{RHS}(7\text{BE}))$ an incumbent's best response set under PE is $\{(2, R), (1, R), (1, N)\}$, so the PE equilibrium is $\{(1, R), (1, R); \emptyset\}$ or $\{(1, N), (2, R); \emptyset\}$ (as under BE). For $\mu < \text{RHS}(2\text{BE})$ $S_{\text{BE}}^{\text{BR}}[(1, N)] = (1, R)$, which could be disrupted by potential entry. From Lemma A1 below, an incumbent's best response set under PE for $\mu \in (\text{RHS}(7\text{BE}), \text{RHS}(2\text{BE}))$ is $\{(1, R)$ or $(2, R), (1, R), (1, R)\}$, which yields a PE equilibrium of $\{(1, R), (1, R); \emptyset\}$ (as in the BE game, but possibly no longer a dominant-strategy equilibrium). For $\mu < \text{RHS}(2\text{BE}), \text{RHS}(7\text{BE})$ an incumbent's best response set under PE is $\{(1, N)$ or $(2, R), (1, R), (1, N)\}$, which always yields two PE equilibria: $\{(1, R), (1, R); \emptyset\}$ for sure and *either* $\{(1, N), (1, N); R\}$ (if $(1, N) \succ (2, R)$ in response to $(1, N)$) *or* $\{(1, N), (2, R); \emptyset\}$ (if $(2, R) \succ (1, N)$ in response to $(1, N)$), where the identity of the second equilibrium depends (inter alia) on $\frac{I}{G}$.

In the final case above, when $\mu < \text{RHS}(2\text{BE}), \text{RHS}(7\text{BE})$, the identity of the second equilibrium depends on an incumbent's preference between $(1, N)$ and $(2, R)$ in response to $(1, N)$. In general, given that $\{(1, N), (1, N)\}$ provokes entry but $\{(1, N), (2, R)\}$ does not, $(2, R) \succ (1, N)$ in response to $(1, N)$ iff

$$\mu > \frac{G+I}{\frac{1}{\mu} \cdot R(c, c+t) + \frac{1}{\mu} \cdot [R(0, c+t) + R(0, c) - R(c, c+t)] \cdot p}$$

which holds for all $\mu > \text{RHS}(2\text{PE})$ iff

$$\begin{aligned} & 2 \cdot \frac{I}{G} \cdot R(c, c+t) + 2 \cdot \left\{ \frac{I}{G} \cdot [R(0, c+t) - R(c, c+t)] - R(0, c) \right\} \cdot p \\ & + \left(\frac{I}{G} + 1 \right) \cdot [2 \cdot R(0, c) - R(0, t)] \cdot p^2 > 0 \end{aligned} \tag{A9}$$

We examine the properties of (A9) in the main text.

Lemma A1. If firm 3 optimally chooses R in response to both $\{(1, N), (1, N)\}$ and $\{(1, N), (1, R)\}$, then an incumbent has $(1, R) \succ$ (resp. \prec) $(1, N)$ in response to $(1, N)$ as $\mu >$ (resp. $<$) $\text{RHS}(7\text{BE})$.

Proof. By comparing expected profit functions from the main text.

This result is not a coincidence. Given that firm 3 will *certainly* choose R , the foreign rival's choice of $(1, N)$ makes it irrelevant to the incumbent's decision (because firm 3 is always a 'tougher competitor' than the foreign rival). Therefore, it is *as if* the incumbent is responding to a choice of \emptyset by firm 3 and $(2, R)$ by its foreign rival.

(ii). $\mu \in (\text{RHS}(3\text{PE}), \text{RHS}(4\text{PE}))$. Firm 3 optimally chooses R in response to *any* corporate structure pair where at least one incumbent chooses $(1, N)$, but \emptyset otherwise. Therefore from Lemma 4(i)

$$\begin{aligned} S_{\text{PE}}^{\text{BR}}[(1, R)] &= S_{\text{BE}}^{\text{BR}}[(1, R)] = (1, R) \\ S_{\text{PE}}^{\text{BR}}[(2, R)] &= S_{\text{BE}}^{\text{BR}}[(2, R)] = (1, R) \end{aligned}$$

Under BE an incumbent's best response to $(1, N)$ would be $(1, R)$ below $\text{RHS}(2\text{BE})$ and $(2, R)$ above it. However, in the PE game for $\mu > \text{RHS}(3\text{PE})$ entry by firm 3 must be accommodated if an incumbent's rival chooses $(1, N)$. Lemma A2 below shows that for $\mu \in (\text{RHS}(3\text{PE}), \text{RHS}(4\text{PE}))$ $S_{\text{PE}}^{\text{BR}}[(1, N)] = (1, R)$. Therefore, $\{(1, R), (1, R); \emptyset\}$ is the equilibrium industrial structure (in dominant strategies) in the PE game.

Lemma A2. If firm 3 optimally chooses R in response to both $\{(1, N), (1, R)\}$ and $\{(1, N), (2, R)\}$, then an incumbent has $(2, R) \succ$ (resp. \prec) $(1, R)$ in response to $(1, N)$ as $\mu >$ (resp. $<$) $\text{RHS}(5\text{BE})$.

Proof. By comparing expected profit functions from the main text.

For reasons analogous to those for Lemma A1, this result is not a coincidence. Together Lemma A1 and Lemma A2 imply that $S_{\text{PE}}^{\text{BR}}[(1, N)] = (1, R)$ for $\mu \in (\text{RHS}(7\text{BE}), \text{RHS}(5\text{BE}))$ and that $S_{\text{PE}}^{\text{BR}}[(1, N)] = (2, R)$ for $\mu > \text{RHS}(5\text{BE})$.

(iii). $\mu \in (\text{RHS}(4\text{PE}), \text{RHS}(5\text{PE}))$. Firm 3 optimally chooses R *unless* the incumbents select $\{(1, R), (2, R)\}$ or $\{(2, R), (2, R)\}$. We have

$$S_{\text{PE}}^{\text{BR}}[(1, N)] = \begin{cases} (1, R) & \text{for } \mu < \text{RHS}(5\text{BE}) \\ (2, R) & \text{for } \mu > \text{RHS}(5\text{BE}) \end{cases}$$

from Lemma A1 and Lemma A2, and

$$S_{PE}^{BR}[(1, R)] = (2, R) \text{ for } \mu > \text{RHS}(5BE)$$

$$S_{PE}^{BR}[(2, R)] = \begin{cases} (1, R) & \text{for } \mu < \text{RHS}(5BE) \\ (2, R) & \text{for } \mu > \text{RHS}(5BE) \end{cases}$$

from Lemma 4(i).

For $\mu > \text{RHS}(5BE)$ the equilibrium industrial structure of the PE game (in dominant strategies) is $\{(2, R), (2, R); \emptyset\}$. For $\mu < \text{RHS}(5BE)$ $S_{BE}^{BR}[(1, R)] = (1, R)$, which would induce entry. Using Lemma A3 below, an incumbent's best response set under PE for $\mu < \text{RHS}(5BE)$ is $\{(1, R), (1, R) \text{ or } (2, R), (1, R)\}$, which yields a PE equilibrium of either $\{(1, R), (1, R); R\}$ in dominant strategies (if $(1, R) \succ (2, R)$ in response to $(1, R)$) or $\{(1, R), (2, R); \emptyset\}$ (if $(2, R) \succ (1, R)$ in response to $(1, R)$). Therefore, to tie the PE equilibrium down, we need to derive an incumbent's preference relation between $(1, R)$ and $(2, R)$ in response to $(1, R)$. In general, given that $\{(1, R), (1, R)\}$ provokes entry but $\{(1, R), (2, R)\}$ does not, $(2, R) \succ (1, R)$ in response to $(1, R)$ iff

$$\mu > \frac{G}{\frac{1}{\mu} \cdot R(c, c+t) + \frac{1}{\mu} \cdot [R(0, c+t) - 2 \cdot R(c, c+t) - R(t, c)] \cdot p + \frac{1}{\mu} \cdot [R(c, c+t) - R(0, c+t) + R(0, c) + 2 \cdot R(t, c)] \cdot p^2 + \frac{1}{\mu} \cdot [R(0, t) - R(0, c) - R(t, c)] \cdot p^3}$$

which holds for all $\mu > \text{RHS}(4PE)$ iff

$$\frac{I}{G} \cdot R(c, c+t) + \left\{ \frac{I}{G} \cdot [R(0, c+t) - 2 \cdot R(c, c+t) - R(t, c)] - R(0, c) \right\} \cdot p + \left\{ \frac{I}{G} \cdot [R(c, c+t) - R(0, c+t) + R(0, c) + 2 \cdot R(t, c)] + 2 \cdot R(0, c) - R(0, t) \right\} \cdot p^2 + \left\{ \frac{I}{G} \cdot [R(0, t) - R(0, c) - R(t, c)] - R(0, c) + R(0, t) \right\} \cdot p^3 > 0$$

(A10)

We examine the properties of (A10) in the main text.

Lemma A3. If firm 3 optimally chooses R in response to both $\{(1, N), (1, R)\}$ and $\{(1, R), (1, R)\}$, then an incumbent has $(1, R) \succ (1, N)$ in response to $(1, R)$ for all $p \in [0, 1)$ when $\mu > \text{RHS}(4\text{PE})$.

Proof. Comparing expected profit functions in the main text, we find that in general $(1, R) \succ (1, N)$ in response to $(1, R)$ (given that both choices provoke entry) iff

$$\mu > \frac{I}{\frac{1}{\mu} \cdot [R(0, c) + R(t, c)] \cdot p - \frac{1}{\mu} \cdot [2 \cdot R(0, c) + 2 \cdot R(t, c) - R(0, t)] \cdot p^2 + \frac{1}{\mu} \cdot [R(0, c) + R(t, c) - R(0, t)] \cdot p^3}$$

This holds for all $\mu > \text{RHS}(4\text{PE})$ iff

$$R(t, c) \cdot (1 - p)^2 > 0$$

which trivially holds on $p \in [0, 1)$. QED.

(iv). $\mu \in (\text{RHS}(5\text{PE}), \text{RHS}(6\text{PE}))$. Firm 3 optimally chooses R unless both incumbents choose $(2, R)$. We have

$$S_{\text{PE}}^{\text{BR}}[(1, N)] = \begin{cases} (1, R) & \text{for } \mu < \text{RHS}(5\text{BE}) \\ (2, R) & \text{for } \mu > \text{RHS}(5\text{BE}) \end{cases}$$

from Lemma A1 and Lemma A2, and

$$S_{\text{PE}}^{\text{BR}}[(2, R)] = (2, R) \text{ for } \mu > \text{RHS}(5\text{BE})$$

from Lemma 4(i).

Because 3 optimally chooses R in response to *any* industrial structure involving $(1, R)$, $S_{\text{PE}}^{\text{BR}}[(1, R)]$ cannot automatically be related to $S_{\text{BE}}^{\text{BR}}[(1, R)]$. We show in Lemma A4 below that $S_{\text{PE}}^{\text{BR}}[(1, R)] = (1, R)$ for all $\mu \in (\text{RHS}(5\text{PE}), \text{RHS}(6\text{PE}))$. Therefore for $\mu > \text{RHS}(5\text{BE})$ an incumbent's best response set under PE is $\{(2, R), (1, R), (2, R)\}$, which yields PE equilibria of $\{(1, R), (1, R); R\}$ and $\{(2, R), (2, R); \emptyset\}$. For $\mu < \text{RHS}(5\text{BE})$ $S_{\text{PE}}^{\text{BR}}[(2, R)]$ must be derived. The immediate difficulty is that under assumption (C) on G, I it is impossible to derive any pairwise preference rankings between $(1, N)$, $(1, R)$ and $(2, R)$ that are valid for all $\mu \in (\text{RHS}(5\text{PE}), \text{RHS}(6\text{PE}))$ (which would enable us to discount one

corporate structure as a best response, as in Lemma A1 to Lemma A3). Therefore, for $\mu < \text{RHS}(5\text{BE})$ $S_{\text{PE}}^{\text{BR}}[(2, R)] \in \{(1, N), (1, R), (2, R)\}$ and an incumbent's best response set under PE is $\{(1, R), (1, R), S_{\text{PE}}^{\text{BR}}[(2, R)]\}$. If $S_{\text{PE}}^{\text{BR}}[(2, R)] = (1, N)$ or $(1, R)$, then there is a unique equilibrium industrial structure of $\{(1, R), (1, R); R\}$, possibly in dominant strategies. If $S_{\text{PE}}^{\text{BR}}[(2, R)] = (2, R)$, then there is an additional equilibrium industrial structure of $\{(2, R), (2, R); \emptyset\}$. Therefore, given our focus on equilibria, the crucial determinant is whether $(2, R)$ is an incumbent's best response to $(2, R)$ under PE. In general, given that only $\{(2, R), (2, R)\}$ deters entry, we have $(2, R) \succ (1, N)$ in response to $(2, R)$ iff

$$\mu > \frac{G+I}{\frac{2}{\mu} \cdot R(0, c) \cdot p \cdot (1-p)} \quad (\text{A11})$$

and $(2, R) \succ (1, R)$ in response to $(2, R)$ iff

$$\mu > \frac{G}{\frac{1}{\mu} \cdot [R(0, c) - R(t, c)] \cdot p + \frac{2}{\mu} \cdot R(t, c) \cdot p^2 - \frac{1}{\mu} \cdot [R(0, c) + R(t, c)] \cdot p^3} \quad (\text{A12})$$

Conditions (A11) and (A12) hold for all $\mu > \text{RHS}(5\text{PE})$ iff

$$4 \cdot \frac{I}{G} \cdot R(0, c) \cdot (1-p) > \left(\frac{I}{G} + 1 \right) \times \{2 \cdot R(0, c) - [4 \cdot R(0, c) - R(0, t)] \cdot p + [2 \cdot R(0, c) - R(0, t)] \cdot p^2\} \quad (\text{A11}'$$

and

$$2 \cdot \frac{I}{G} \cdot [R(0, c) - R(t, c)] - 2 \cdot R(0, c) + \left\{ 4 \cdot \frac{I}{G} \cdot R(t, c) + 4 \cdot R(0, c) - R(0, t) \right\} \cdot p - \left\{ 2 \cdot \frac{I}{G} \cdot [R(0, c) + R(t, c)] + 2 \cdot R(0, c) - R(0, t) \right\} \cdot p^2 > 0 \quad (\text{A12}'$$

We examine the properties of (A11)' and (A12)' in the main text.

Lemma A4. $S_{\text{PE}}^{\text{BR}}[(1, R)] = (1, R)$ for all $\mu \in (\text{RHS}(5\text{PE}), \text{RHS}(6\text{PE}))$.

Proof. (i). Given that both choices provoke entry, $(1, R) \succ (1, N)$ in response to $(1, R)$ iff

$$\mu > \frac{I}{\frac{1}{\mu} \cdot [R(0,c) + R(t,c)] \cdot p - \frac{1}{\mu} \cdot [2 \cdot R(0,c) + 2 \cdot R(t,c) - R(0,t)] \cdot p^2 + \frac{1}{\mu} \cdot [R(0,c) + R(t,c) - R(0,t)] \cdot p^3}$$

(using expected profit functions from the main text). For $p \neq 0$ this holds for all $\mu > \text{RHS}(5\text{PE})$ iff

$$2 \cdot R(t,c) \cdot (1-p)^2 > R(0,t) \cdot p \cdot (p-1)$$

which clearly holds for all $p \in (0, 1)$, where $\text{LHS} > 0 > \text{RHS}$.

(ii). Given that both choices provoke entry, $(1, R) \succ (2, R)$ in response to $(1, R)$ iff

$$\mu < \frac{G}{\frac{1}{\mu} \cdot [R(0,c) - R(t,c)] \cdot p \cdot (1-p)^2}$$

(using expected profit functions from the main text). For $p \neq 0, 1$ this holds for all $\mu < \text{RHS}(6\text{PE})$ iff

$$R(0,c) - \frac{I}{G} \cdot [R(0,c) - R(t,c)] > 0 \quad (\text{A7}) \text{ repeated}$$

which was shown above to hold under assumption (C). QED.

(v). $\mu > \text{RHS}(6\text{PE})$. Firm 3 optimally chooses R *regardless* of what the incumbents choose. We have

$$S_{\text{PE}}^{\text{BR}}[(1, N)] = \begin{cases} (1, R) & \text{for } \mu < \text{RHS}(5\text{BE}) \\ (2, R) & \text{for } \mu > \text{RHS}(5\text{BE}) \end{cases}$$

from Lemma A1 and Lemma A2. We show in Lemma A5 below that $S_{\text{PE}}^{\text{BR}}[(1, R)] \neq (1, N)$ and that $S_{\text{PE}}^{\text{BR}}[(2, R)] \neq (1, N)$. Indeed, in response to *both* $(1, R)$ and $(2, R)$ an incumbent has $(2, R) \succ$ (resp. \prec) $(1, R)$ as

$$\mu > \text{ (resp. } < \text{) } \frac{G}{\frac{1}{\mu} \cdot [R(0,c) - R(t,c)] \cdot p \cdot (1-p)^2} \quad (\text{A13})$$

where $\text{RHS}(\text{A13}) > \text{RHS}(5\text{BE}), \text{RHS}(6\text{PE})$. (Note that $\text{RHS}(\text{A13}) > \text{RHS}(6\text{PE})$ relies on condition (A7), which holds under assumption (C).) It is significant that (A13) governs an incumbent's preference between $(1, R)$ and $(2, R)$ in response to both $(1, R)$ and $(2, R)$. The reason is analogous to that for the 'double appearance' of condition (5BE) when we examined the incumbents' best

responses under BE in the main text. Given that national product markets are perfectly segmented, the choice of an R&D-undertaking incumbent between 1 plant and 2 depends on ‘competitive conditions’ abroad, which are influenced by the foreign incumbent’s investment in R&D but not by its investment in greenfield-FDI.

From the viewpoint of the incumbents’ best response sets, the area where $\mu > \text{RHS}(6\text{PE})$ is split three ways. For $\mu < \text{RHS}(5\text{BE})$ the equilibrium industrial structure under PE (in dominant strategies) is $\{(1, R), (1, R); R\}$. For $\mu \in (\text{RHS}(5\text{BE}), \text{RHS}(A13))$ the PE equilibrium remains $\{(1, R), (1, R); R\}$ (but not in dominant strategies). For $\mu > \text{RHS}(A13)$ the PE equilibrium (in dominant strategies) is $\{(2, R), (2, R); R\}$.

Lemma A5. (i) In response to $(1, R)$ an incumbent has $(1, R) \succ (1, N)$ for all $\mu > \text{RHS}(6\text{PE})$ and $p \in (0, 1)$ in the PE game. (ii) In response to $(2, R)$ an incumbent has $(1, R) \succ (1, N)$ for all $\mu > \text{RHS}(6\text{PE})$ and $p \in (0, 1)$ in the PE game.

Proof. (i) follows directly from Lemma A4(i).

(ii). Given that both choices provoke entry, $(1, R) \succ (1, N)$ in response to $(2, R)$ iff

$$\mu > \frac{I}{\frac{1}{\mu} \cdot [R(0, c) + R(t, c)] \cdot p \cdot (1 - p)^2}$$

which trivially holds for all $\mu > \text{RHS}(6\text{PE})$, $p \neq 0, 1$ because $R(t, c) > 0$. QED.

Figure 5 in the main text summarises the results of step two. Figure 5 tidies Figure A2 up by grouping together regions of identical equilibria.

1.7.3. Monopoly case.

Monopolist's expected profits

$$E\pi^M(1, N) = R^M(c) + R^M(c+t)$$

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

$$E\pi^M(2, N) = 2 \cdot R^M(c) - G$$

$$E\pi^M(2, R) = 2 \cdot p \cdot R^M(0) + 2 \cdot (1-p) \cdot R^M(c) - G - I$$

Note that, relative to the duopoly case, the monopoly case is complicated because Lemma 1(i) cannot be invoked to rule out (2, N). (Indeed, intuitively one would expect (2, N) to be the monopolist's equilibrium choice for sufficiently high μ -values when p is low.)

Proof of Lemma 7

Part (i). Comparing expected profit functions, we get (1, R) \succ (2, N) iff

$$R^M(c+t) - R^M(c) + [R^M(0) + R^M(t) - R^M(c) - R^M(c+t)] \cdot p > I - G$$

Under assumption (C), RHS ≤ 0 . LHS is linear in p ; at $p = 0$ LHS < 0 , and at $p = 1$ LHS > 0 . LHS > 0 is sufficient for the inequality condition to hold, and this occurs when

$$p > \frac{R^M(c) - R^M(c+t)}{R^M(0) + R^M(t) - R^M(c) - R^M(c+t)} \equiv p_1$$

QED.

Part (ii). Ignoring (2, N) and comparing expected profit functions, we get (1, R) \succ (1, N) iff

$$\mu > \frac{I}{\frac{1}{\mu} \cdot [R^M(0) + R^M(t) - R^M(c) - R^M(c+t)] \cdot p} \quad (\text{A14})$$

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

$$\mu > \frac{G}{\frac{1}{\mu} \cdot [R^M(c) - R^M(c+t)] + \frac{1}{\mu} \cdot [R^M(0) - R^M(t) - R^M(c) + R^M(c+t)] \cdot p} \quad (\text{A15})$$

From Lemma 5(i) in the main text, if $\text{RHS(A15)} > \text{RHS(A14)}$ then (A14) and (A15) are sufficient to determine the monopoly equilibrium. Furthermore, the monopolist will optimally choose $(1, N)$, $(1, R)$ and $(2, R)$ in sequence as μ rises away from 0. Under assumption (C), a sufficient condition for $\text{RHS(A15)} > \text{RHS(A14)}$ is $\text{denom(A14)} > \text{denom(A15)}$, or

$$p > \frac{R^M(c) - R^M(c+t)}{2 \cdot [R^M(t) - R^M(c+t)]} \equiv p_2$$

It is straightforward to show that $p_2 \in (0, 0.5)$ for $c > t$. Furthermore, $p_2 > p_1$ iff $R^M(0) - R^M(t) - R^M(c) + R^M(c+t) > 0$, which *must* hold. (Proof: for $t = 0$, LHS = 0; and $\partial \text{LHS} / \partial t = \partial R^M(c+t) / \partial t - \partial R^M(t) / \partial t > 0$ given that $\partial R^M(t) / \partial t < \partial R^M(c+t) / \partial t < 0$.) Therefore in both parts of Lemma 7 ‘sufficiently high p ’ can be interpreted as $p > p_2$; and the results in the Lemma apply to all $p \in (p_2, 1)$. QED.

Proof of Proposition 4

Part (i). From Lemma 7(ii) greenfield-FDI occurs in monopoly equilibrium iff (A15) holds. For sufficiently high p , greenfield-FDI occurs in BE equilibrium iff (2BE) from the main text holds. Greenfield-FDI is ‘more likely’ in monopoly equilibrium iff $\text{RHS(2BE)} > \text{RHS(A15)}$, or iff

$$R^M(c) - R^M(c+t) + [R^M(0) - R^M(t) - R^M(c) + R^M(c+t)] \cdot p > [R(0, c) - R(t, c)] \cdot p$$

At $p = 0$ this condition certainly holds. Because both LHS and RHS are linear in p , the condition will hold on $p \in [0, 1)$ iff

$$R^M(0) - R(0, c) \geq R^M(t) - R(t, c)$$

(i.e. LHS \geq RHS at $p = 1$). If $R(t, c) = R^M(t)$, then RHS = 0 while LHS ≥ 0 . At $t = 0$, LHS = RHS. Therefore, it is sufficient for the condition to hold for all t, c under assumption (A) that $\partial \text{RHS} / \partial t \leq 0$ when $R(t, c) = \mu \cdot (1 - c) \cdot (c - t)$, which in turn requires $c \geq x^M(t)$; a contradiction because $R(t, c) = \mu \cdot (1 - c) \cdot (c - t)$ implies $c \leq x^M(t)$. Therefore, a necessary-and-sufficient condition for greenfield-FDI to be ‘more likely’ in monopoly than BE equilibrium on $p \in [0, 1)$ is $c \geq x^M(t)$. QED.

Part (ii). From Lemma 7(ii) R&D occurs in monopoly equilibrium iff (A14) holds. R&D occurs in BE equilibrium iff (1BE) from the main text holds. R&D is 'more likely' in BE equilibrium iff $\text{RHS}(A14) > \text{RHS}(1BE)$, or (for $p \neq 0$) iff

$$R(0, c+t) + R(t, c) - R(c, c+t) > R^M(0) + R^M(t) - R^M(c) - R^M(c+t)$$

Imposing $c \geq x^M(t)$, which implies that $R(t, c) = R^M(t)$, and $c + t \geq x^M(c)$, which implies that $R(c, c+t) = R^M(c)$ and thus also that $R(0, c+t) = R^M(0)$, is sufficient to ensure that the condition holds because $R^M(c+t) > 0$. QED.

1.7.4. Plotting constraints (B) and (B)' in (c, t) -space.

An immediate problem is the fact that t, c do not enter assumptions (B) and (B)' explicitly. Moreover, each of the five nonzero realisations of $R(\cdot)$ takes one of two possible functional forms, depending on whether the Bertrand equilibrium involves undercutting or monopoly-pricing. Therefore

$$R(0, t) = \begin{cases} \mu \cdot (1-t) \cdot t & \text{for } t \leq 0.5 \\ R^M(0) & \text{for } t \geq 0.5 \end{cases}$$

$$R(0, c) = \begin{cases} \mu \cdot (1-c) \cdot c & \text{for } c \leq 0.5 \\ R^M(0) & \text{for } c \geq 0.5 \end{cases}$$

$$R(0, c+t) = \begin{cases} \mu \cdot (1-c-t) \cdot (c+t) & \text{for } c+t \leq 0.5 \\ R^M(0) & \text{for } c+t \geq 0.5 \end{cases}$$

$$R(t, c) = \begin{cases} \mu \cdot (1-c) \cdot (c-t) & \text{for } c \leq x^M(t) \\ R^M(t) & \text{for } c \geq x^M(t) \end{cases}$$

$$R(c, c+t) = \begin{cases} \mu \cdot (1-c-t) \cdot t & \text{for } c+t \leq x^M(c) \\ R^M(c) & \text{for } c+t \geq x^M(c) \end{cases}$$

Figure A1.3 divides (c, t) -space below the 45° line (recall that assumption (A) is maintained throughout) up into 9 distinct regions. In each region the functional form of $R(\cdot)$ is fixed, so constraints (B) and (B)' can be written explicitly in terms of t, c .

[FIGURE A1.3 IS OVERLEAF]

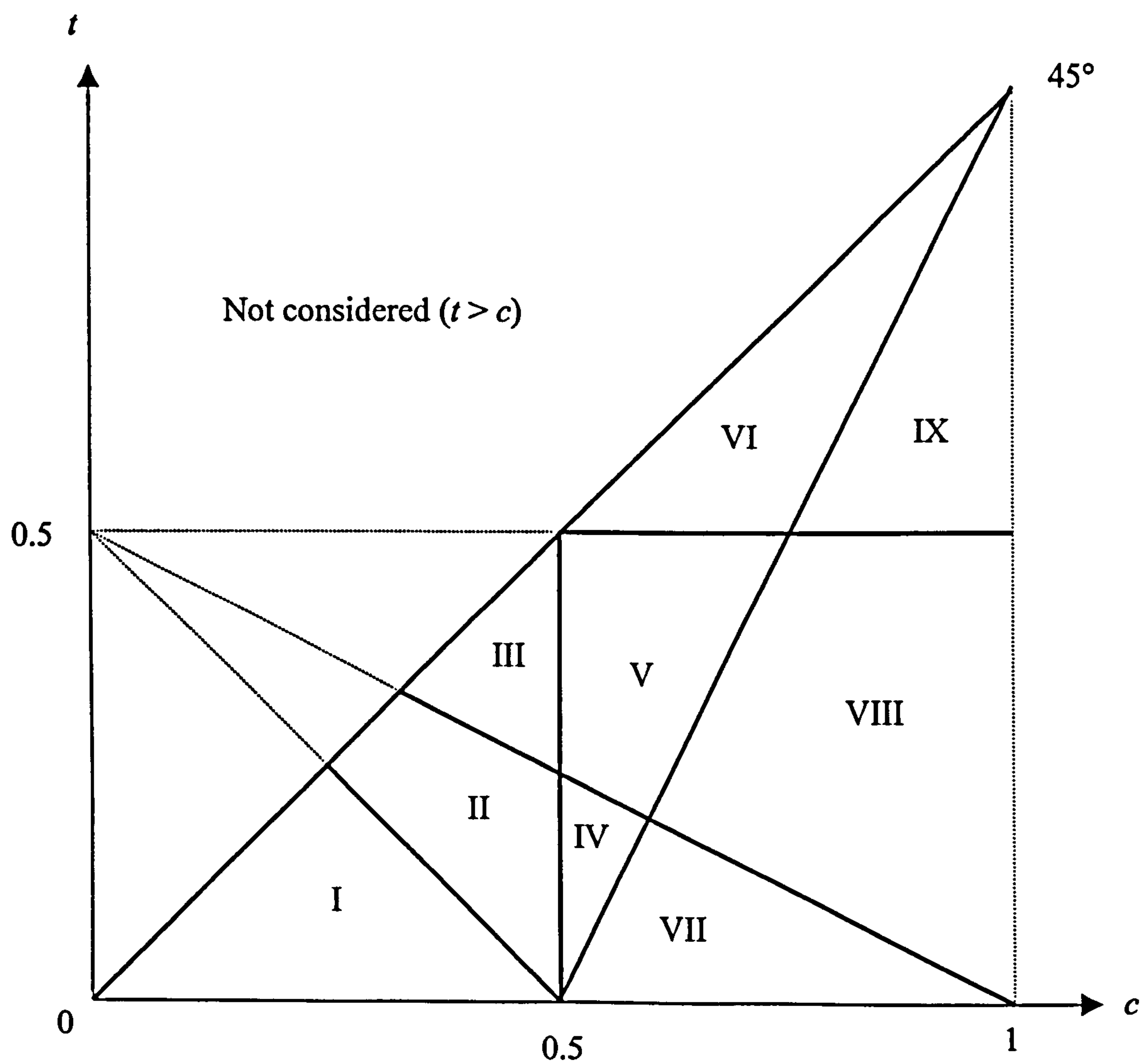


Figure A1.3: Feasible set of c - and t -values

Inter-regional boundaries: I/II boundary is $c + t = x^M(0) = 0.5$; II/III, IV/V and VII/VIII boundaries are $c + t = x^M(c)$; IV/VII, V/VIII and VI/IX boundaries are $c = x^M(t)$.

Key to Figure A1.3

Region	Form of $R(\cdot)$ (N.B. U = 'undercutting', M = 'monopoly-pricing')				
	$R(0, t)$	$R(0, c)$	$R(0, c+t)$	$R(t, c)$	$R(c, c+t)$
I	U	U	U	U	U
II	U	U	M	U	U
III	U	U	M	U	M
IV	U	M	M	U	U
V	U	M	M	U	M
VI	M	M	M	U	M
VII	U	M	M	M	U
VIII	U	M	M	M	M
IX	M	M	M	M	M

Using the specific functional forms of $R(\cdot)$, we can derive the sets of t - and c -values where assumptions (B) and (B)' hold for each region of Figure A1.3.

Region	Assumption (B) holds iff	Assumption (B)' holds iff
I	$t < 1 - \sqrt{1 - 2 \cdot c + 2 \cdot c^2}$	$t < c \cdot (1 - c)$
II	$t < \frac{3 - 2 \cdot c - \sqrt{(6 \cdot c - 7) \cdot (2 \cdot c - 1)}}{4}$	$t < \frac{2 \cdot (1 - c) - \sqrt{4 \cdot (1 - c)^2 - 1}}{2}$
III	$t < \frac{2 - c - \sqrt{(6 \cdot c - 4) \cdot (c - 1)}}{2}$	$t < \frac{c \cdot (2 - c)}{4 \cdot (1 - c)}$
IV	Holds throughout	Holds throughout
V	$t < \frac{2 - c - \sqrt{(6 \cdot c - 4) \cdot (c - 1)}}{2}$	$t < \frac{1}{4} \cdot (5 \cdot c - 1)$
VI	$t < \frac{1}{4} \cdot (5 \cdot c - 1)$	$t < \frac{1}{4} \cdot (5 \cdot c - 1)$
VII	Holds throughout	Holds throughout
VIII	Holds throughout	Holds throughout
IX	Holds throughout	Holds throughout

Given that (c, t) are such that constraints (B) and (B)' bind (i.e. on the bold lines in Figure 6 in the main text), the extreme c -values in each region are calculated (using *Maple*) as:

Constraint (B)

Region I: $\min c = 0$; $\max c = 0.275$

Region II: $\min c = 0.275$; $\max c = 0.392$

Regions III/V: $\min c = 0.392$; $\max c = 0.6$

Region VI: $\min c = 0.6$; $\max c = 1$

Constraint (B)'

Region I: $\min c = 0$; $\max c = 0.293$

Region II: $\min c = 0.293$; $\max c = 0.423$

Region III: $\min c = 0.423$; $\max c = 0.5$

Regions V/VI: $\min c = 0.5$; $\max c = 1$

1.7.5. Proof of Lemma 8 (and description of numerical analysis technique).

Proof of Lemma 8

Define $p_{\text{INF}} \equiv -\frac{\gamma}{3 \cdot \delta} > 0$ as the p -value where LHS(A10) has a point of inflection. For $p <$ (resp. $>$) p_{INF} , LHS(A10) is strictly convex (resp. concave) in p . The proof now proceeds in two steps.

Step (i). Note that if $\text{LHS(A10)} > 0$ at p_{INF} , then $\text{LHS(A10)} > 0$ on all $[p_{\text{INF}}, 1]$. This follows because $\alpha + \beta + \gamma + \delta > 0$ and because a chord between two points on a concave function always lies beneath the function. Therefore a sufficient condition for $\text{LHS(A10)} > 0$ on $p \in [0, 1]$ is $\text{LHS(A10)} > 0$ on $p \in [0, p_{\text{INF}}]$ (when $p_{\text{INF}} \leq 1$, this condition is also necessary).

Step (ii). To test $\text{LHS(A10)} > 0$ on $p \in [0, p_{\text{INF}}]$, we replace LHS(A10) with a quadratic in p . $\text{LHS(A10)} = \alpha + (\beta + \gamma \cdot p + \delta \cdot p^2) \cdot p$, and we replace (\cdot) with

$\beta + \frac{2}{3} \cdot \gamma \cdot p$, where $\beta + \frac{2}{3} \cdot \gamma \cdot p$ is the chord between $p = 0$ and $p = p_{\text{INF}}$ on $\beta + \gamma \cdot p + \delta \cdot p^2$. Compared to $(\beta + \gamma \cdot p + \delta \cdot p^2) \cdot p$, $\left(\beta + \frac{2}{3} \cdot \gamma \cdot p\right) \cdot p$ has two noteworthy features. First, $\left(\beta + \frac{2}{3} \cdot \gamma \cdot p\right) \cdot p \leq (\beta + \gamma \cdot p + \delta \cdot p^2) \cdot p$ for all $p \in [0, p_{\text{INF}}]$, so $\alpha + \left(\beta + \frac{2}{3} \cdot \gamma \cdot p\right) \cdot p > 0$ is a sufficient condition for $\text{LHS(A10)} > 0$ on $p \in [0, p_{\text{INF}}]$. Second, the global minimum of $\left(\beta + \frac{2}{3} \cdot \gamma \cdot p\right) \cdot p$ must lie on $[0, p_{\text{INF}}]$ because for $p > p_{\text{INF}}$ and $p < 0$ $\left(\beta + \frac{2}{3} \cdot \gamma \cdot p\right) \cdot p > 0$ whereas for some p in $[0, p_{\text{INF}}]$ $\left(\beta + \frac{2}{3} \cdot \gamma \cdot p\right) \cdot p < 0$. Therefore a sufficient condition for $\text{LHS(A10)} > 0$ on $p \in [0, p_{\text{INF}}]$ is $\alpha + \beta \cdot p + \frac{2}{3} \cdot \gamma \cdot p^2 > 0$ for all p . $\alpha + \beta \cdot p + \frac{2}{3} \cdot \gamma \cdot p^2$ has a global minimum (because $\gamma > 0$) at $p = -\frac{3 \cdot \beta}{4 \cdot \gamma} > 0$ where its value is $\alpha - \frac{3 \cdot \beta^2}{8 \cdot \gamma}$. Therefore $\alpha \cdot \gamma - \frac{3}{8} \cdot \beta^2 > 0$ provides our sufficient condition. QED.

Description of numerical analysis technique behind Figure 6

We set $t = \lambda \cdot c$, $\lambda \in \{0.05, 0.1, 0.15, \dots, 0.95\}$, and substituted this t -value into the sufficient condition for $\text{LHS(A10)} > 0$ on $p \in [0, 1]$ from Lemma 8. The sufficient condition could therefore be written in terms of c alone. Taking account of how the functional forms of α , β and γ vary between regions in Figure A1.3, we then calculated, for each λ , the set of c -values where the sufficient condition from Lemma 8 was satisfied. The numerical results are given in the table overleaf (and are plotted in Figure 1.6 in the main text).

λ	Interval of c -values where the sufficient condition for $LHS(A10) > 0$ on $p \in [0, 1]$ from Lemma 8 is satisfied.
0.05	None
0.1	None
0.15	[0, 0.48]
0.2	[0, 0.56]
0.25	[0, 0.67]
0.3	[0, 0.69]
0.35	[0, 0.71]
0.4	[0, 0.74]
0.45	[0, 0.76]
0.5	[0, 0.79]
0.55	[0, 0.83]
0.6	[0, 0.86]
0.65	[0, 0.89]
0.7	[0, 0.92]
0.75	[0, 0.95]
0.8	[0, 0.96]
0.85	[0, 0.98]
0.9	[0, 0.99]
0.95	[0, 0.99]

Table A1.1: Numerical analysis of the sufficient condition in Lemma 8.

Chapter 2

Greenfield Investment versus Acquisition: Alternative Modes of Foreign Expansion

2.1. Introduction.

In reality foreign direct investment (FDI) is a heterogeneous flow of funds, composed of both greenfield-FDI ('greenfield investment'), which represents a net addition to the host country's capital stock, and acquisition-FDI, which represents a change in the ownership of pre-existing production facilities in the host country.¹ The current chapter is primarily concerned with two questions, which are provoked by this observation. First, what determines the form of FDI that arises in equilibrium? Second, what are the comparative welfare properties of equilibria associated with the alternative forms of FDI? (The positive analysis of Section 2.3 tackles the first question, and the normative analysis of Section 2.4 addresses the second.)

To explore these questions, we model the equilibrium industrial structures of a concentrated global industry that spans two (perfectly segmented) national product markets (i.e. an 'international oligopoly'). Firms' FDI decisions (i.e.

whether to produce abroad and what form of FDI to choose) and process R&D decisions are made endogenously. A key contribution of this chapter is its incorporation of acquisition-FDI into a model of equilibrium industrial structures in an international oligopoly: precursor models in this tradition (e.g. Horstmann and Markusen, 1992; Rowthorn, 1992; Petit and Sanna-Randaccio, 2000; chapter 1 above) identified FDI in general with greenfield-FDI in particular. This contribution is potentially significant because, empirically, acquisition-FDI is the dominant form of FDI: UNCTAD (2000, pp. 14-18) reports that '[o]ver the past decade, most of the growth in international production has been via cross-border M&As [mergers and acquisitions]... rather than greenfield investment: the value of completed cross-border M&As rose from less than \$100 billion in 1987 to \$720 billion in 1999... *[when t]he ratio of the value of cross-border M&As to world FDI flows reached over 80 per cent*' (italics added).

A number of contributions have analysed equilibrium acquisition-FDI (e.g. Barros and Cabral, 1994; Falvey, 1998; Horn and Persson, 2001a, 2001b). All employ a decision rule for equilibrium selection pioneered by Salant, Switzer and Reynolds (1983): for a given cross-border acquisition to arise in equilibrium, the equilibrium profits of the resulting multinational enterprise (MNE) must exceed the combined profits of the predator and target firms in product market equilibrium if the proposed cross-border acquisition does not occur.² The equilibrium in the absence of acquisition provides a 'threat point', and therefore the decision rule selects acquisition iff an acquisition price exists that will make *both* the predator *and* the target firms better off (see Section 2.2). However, none of the analyses of equilibrium acquisition-FDI include greenfield-FDI as an

alternative to acquisition-FDI: a firm's only alternative means of serving the foreign product market is to export from its domestic production base. This omission has two consequences. First, existing models of equilibrium acquisition-FDI cannot provide comparisons between greenfield- and acquisition-FDI: such comparisons require the development of a modelling structure where the *form* of FDI is endogenously selected.³ The current paper attempts to fill this gap. Second, the exclusion of greenfield-FDI as an alternative to acquisition-FDI implies that firms' profits at the threat point (i.e. their 'disagreement profits' if no acquisition occurs) may be incorrectly represented. In turn, this will of course affect the validity of predictions concerning the emergence of acquisition-FDI in equilibrium (via the decision rule outlined above). (It should be noted that the exclusion of greenfield-FDI *does not* imply that disagreement profits will be 'too low'. If rival firms non-co-operatively choose between exporting and greenfield-FDI as means of serving the foreign product market when acquisition-FDI is ruled out, then greenfield-FDI can arise in (Prisoner's Dilemma) equilibria where both firms would prefer exporting: see Proposition 3 of chapter 1.)

The modelling structure we develop in Section 2.2 captures the choice between greenfield- and acquisition-FDI formally; it also includes endogenous process R&D decisions. It is instructive to consider why these two innovations might be expected to produce interesting results. First, the greenfield/acquisition distinction is significant because FDI is likely to have different welfare effects depending on its form: insofar as foreign market entry via acquisition-FDI, rather than greenfield-FDI, results in a more concentrated market structure, acquisition-

FDI will be associated with lower consumer welfare (i.e. higher prices) than greenfield-FDI.⁴ However, despite the fact that acquisition-FDI leaves the number of firms in the host country unchanged (i.e. it merely produces a change in ownership), it is wrong to conclude that host-country consumer welfare is the same under entering firm strategies of acquisition-FDI and no-FDI. Assume that the host country initially contains one indigenous firm, and a foreign firm is contemplating serving its product market via exporting, greenfield-FDI or acquisition-FDI; both firms have identical production costs, and the product is homogeneous.⁵ Greenfield entry will produce a symmetric duopoly in the host country, and entry via acquisition will produce a monopoly. However, in the absence of entry via either form of FDI, the indigenous firm may be constrained from monopolistic behaviour by the foreign firm's exporting option; most obviously, if the foreign firm chooses to export and Bertrand competition prevails, then the indigenous firm cannot (in equilibrium) set a price higher than the common marginal cost plus the trade cost, which might be beneath its monopoly price.⁶ Therefore, in consumer welfare terms, the best entry strategy is greenfield-FDI and the worst acquisition-FDI, with exporting lying between the two. The key point is that equilibrium outcomes if the foreign firm does not undertake FDI (but chooses instead to export to the host country) are not necessarily identical to those under entry via acquisition: the possibility of facing imports places a constraint on the indigenous firm's behaviour under the no-FDI (exporting) strategy, which is removed by acquisition.

Second, process R&D investments are determined endogenously within our modelling structure because the relationships between R&D and the two forms of

FDI may be different, although it is unclear a priori whether acquiring firms or greenfield investors will have a greater propensity to undertake R&D. Investigating these relationships will allow us to test a hypothesis that frequently motivates public policy: an oft-cited benefit of inward investment in the form of acquisition-FDI is its ability to foster 'technological development', both via the ability of firms in a more concentrated market to bear the sunk costs of R&D and via the injection of superior technologies into the moribund target firm (a 'failing firm' defence).⁷ However, a simple theoretical example shows the issue is far from closed. Assume a Bertrand duopoly in a homogeneous-good market, where both firms initially have marginal costs of $c > 0$ and both have access to the same process innovation. The innovation is drastic and, at a sunk cost of I , will reduce the innovator's marginal cost to 0.⁸ The duopolists play a two-stage (non-cooperative) game, first choosing whether to invest in R&D and then competing in prices. There are two distinct pure-strategy equilibria. If $R^M(0) - I < 0$,⁹ there is a dominant strategy equilibrium where neither firm does R&D. However, if $R^M(0) - I > 0$, there are two asymmetric Nash equilibria where one firm only does R&D.¹⁰ If the two firms combine to form a monopoly, R&D will be undertaken iff $R^M(0) - I > R^M(c)$. It is clear that the 'incentive' to undertake R&D is greater for either duopolist than for the monopolist, in the sense that the critical level of I where R&D is abandoned is greater in the duopoly.¹¹

The remainder of the paper is organised as follows. In Section 2.2 the tools necessary for our analysis are developed. We set out the extensive form of the game that forms the core of our analysis, and we provide several idiosyncratic definitions. We assume that the world comprises two identical countries and that

consumers are immobile internationally so that national product markets are perfectly segmented. There initially exist four plants to produce the homogeneous product, two in each country. There are three firms, two of which (the 'incumbents') own one plant each in different countries; the third firm (the 'potential entrant') owns one plant in each country. The potential entrant's plants are initially (drastically) productively inefficient relative to the incumbents' (their marginal production cost exceeds the monopoly price of an incumbent). By undertaking process R&D the potential entrant can lower her marginal production cost and sell strictly positive output in product market equilibrium. Therefore, 'entry' in our model occurs via R&D investment rather than via sunk investments in new plants (although process R&D investments do, of course, alter the *productivity* of existing plants), as in (e.g.) Gilbert and Newbery (1982). I have argued in chapter 1 that this characterisation of the entry decision is consistent with entry by diversification.

The game has four stages. In stage one, one of the incumbents may purchase the rival incumbent, thereby generating an international flow of acquisition-FDI. If an acquisition occurs, we then enter the Acquisition (A) subgame: in stage two the integrated incumbent (which owns a plant in each country) chooses how much to invest in process R&D. If no acquisition occurs in stage one, we enter the Greenfield (G) subgame, which is formally identical to the potential entry (PE) game set out in chapter 1: in stage two the incumbents non-co-operatively choose (i) whether to undertake (tariff-jumping) greenfield-FDI and (ii) how much to invest in process R&D. Stages three and four are identical in both the A and the G subgames. In stage three the potential entrant decides whether to enter

the industry by undertaking process R&D. In stage four market equilibrium in both countries is established via Bertrand competition (marginal costs are common knowledge).

Two features of our modelling structure generate significant interest. First, the inclusion of endogenous R&D investment decisions implies that consumer welfare need not necessarily be lower in more concentrated market equilibria because the (logical) possibility exists that equilibrium R&D investment may increase with concentration. Second, the inclusion of a third firm's entry decision (stage three) implies that the stage-one choice between the two subgames is not a (trivial) comparison of monopoly and duopoly profits. It also allows us to compare 'entry decisions' in the two subgames.

In Section 2.3 we derive equilibrium industrial structures, conditional on the game's exogenous parameters. The A and G subgames are solved backwards to isolate subgame perfect Nash equilibria in pure strategies. In both subgames firms behave non-co-operatively. The stage-one choice of which subgame to play is determined by a co-operative decision rule: the A subgame is selected iff the integrated monopolist's profits are strictly greater than the combined profits of the incumbents in the G subgame.¹² Therefore, the G-equilibrium represents a threat point if take-over negotiations break down. A sufficient condition for co-operative equilibria to be stable is that players can make binding commitments to each other. In the context of a cross-border acquisition it is reasonable to assume that binding commitments can be made because after a take-over control over the target firm is ceded to the acquirer. (Furthermore, it should be noted that the use

of co-operative decision rules for mergers is widespread in the theoretical literature.) The key findings are that acquisition-FDI certainly arises in medium-sized markets and that greenfield-FDI arises in large markets if the sunk costs of greenfield-FDI and R&D are not 'too large'.

In Section 2.4 we compare the welfare properties of the A- and G-equilibria. We focus on global social welfare (GSW), which comprises consumer surplus across countries and the sum of profits across firms, because the symmetry across countries in our model implies that, if market equilibria differ in the two countries, any assignment of equilibrium roles would be arbitrary. We find that consumers generally (but not always) prefer the G-equilibrium to the A-equilibrium because 'competition' is more intense. However, *global* profits (across both incumbents *and* the potential entrant) are higher in the A-equilibrium. (Note, however, that this does *not* imply that the equilibrium industrial structure will always involve acquisition-FDI because rent-dissipating entry is 'more likely' in A-equilibrium.) Therefore, the welfare comparison of G- and A-equilibria generally involves a Williamson (1968) trade-off between profits and consumer surplus. Despite this general result, we do find (limited) circumstances where the A-equilibrium is socially Pareto dominant because acquisition-FDI increases consumer welfare: in small markets acquisition-FDI can be associated with equilibrium R&D that would not occur at the G-equilibrium, thus lowering market prices in spite of monopolization. In this special case the advocacy of acquisition-FDI in public policy is unambiguously justified.

Finally, Section 2.5 offers some concluding comments. We consider some of the limitations of our analysis and some potential extensions.

2.2. The Modelling Structure.

2.2.1. Sequence of Moves and Corporate Structure Choices.

Figure 2.1 illustrates the extensive form of our four-stage game. (As we show below, Figure 2.1 incorporates the simplification of firms' strategic choices given in Lemma 1.) The stage-one choice between the two subgames is determined by the co-operative greenfield/acquisition decision rule (GADR), which is set out formally in Section 2.2.3. In stages two and three the incumbents and the potential entrant, respectively, choose their 'corporate structures'. In stage four market equilibrium is established in both countries via Bertrand competition. Firms will be seen to have 'symmetric information' (Rasmusen, 2001, p. 49) and thus maximize their expected profits.

A firm's corporate structure choice represents its strategic ('long-term') decisions vis-à-vis the location of production and the level of technology. The incumbents initially own one plant each, located in different countries, both of which can produce the homogeneous good at a constant marginal cost of $c \in (0, 1)$; they can serve the local product market at their marginal production cost but must pay a per-unit premium of t (the trade cost) if selling abroad via exporting rather than FDI. The potential entrant initially owns two plants, one in each country, whose marginal production costs are strictly greater than $x^M(c)$, the

monopoly price associated with c (see Section 2.2.2). Firms can establish additional plants in either country at a sunk cost of G . Therefore, there are plant-level economies of scale, and (i) neither the potential entrant nor the acquirer will optimally establish additional plants (note that via take-over the acquirer gains the rival incumbent's 'home' plant); (ii) each incumbent will optimally establish at most one additional plant abroad in the G subgame.

[FIGURE 2.1 IS OVERLEAF]

Technological progress occurs via process R&D investments in steps, and each step incurs a sunk cost of I . The technological laggard (the potential entrant) 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. the incumbents initially, and the potential entrant 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 . The probability of success p is identical and independent across firms.

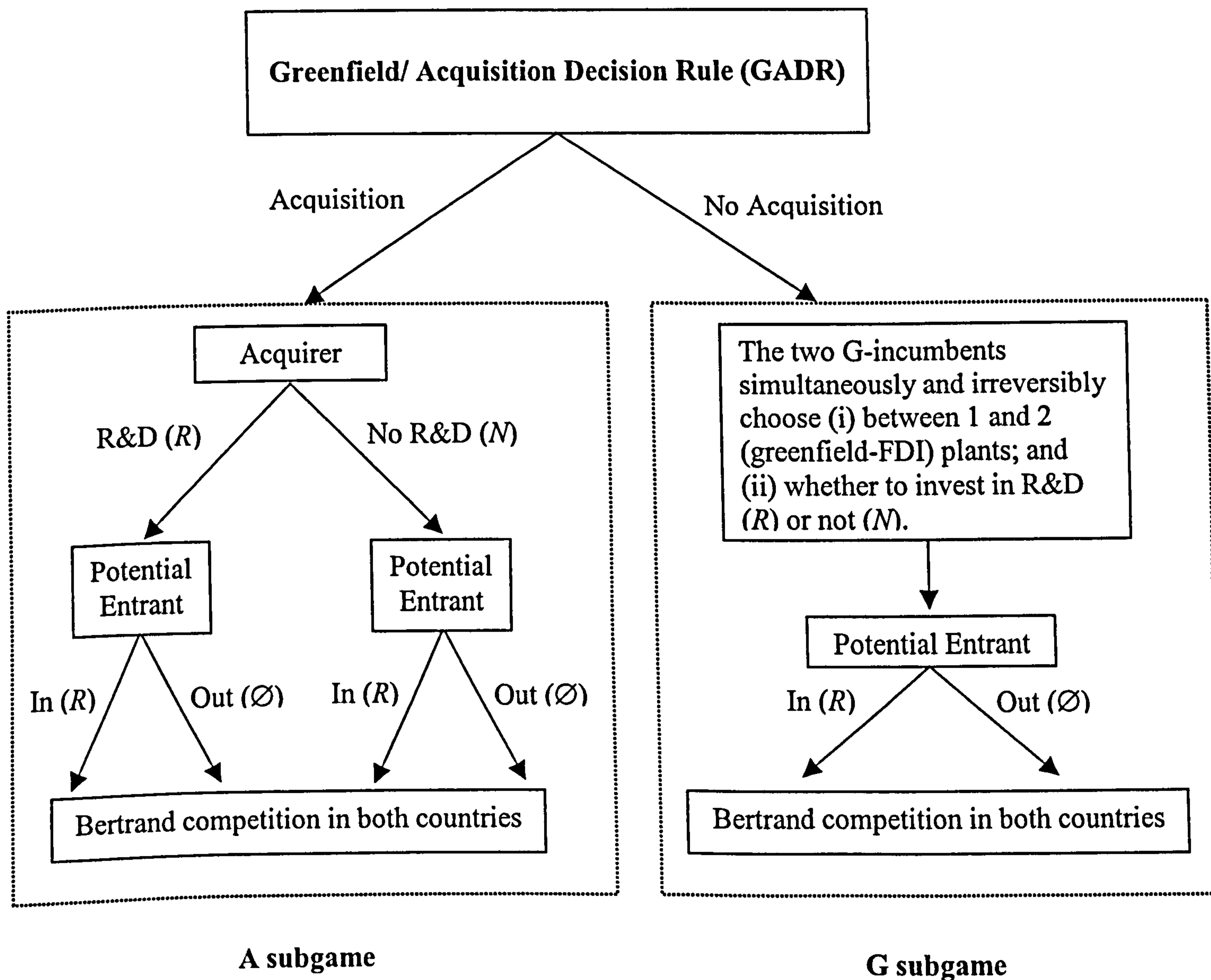


Figure 2.1: Game Tree

Several aspects of the order of moves in Figure 2.1 require justification. First, Bertrand competition is modelled as the final stage after firms have taken production location and R&D investment decisions because decisions involving sunk investments entail more commitment than pricing decisions, which can be altered rapidly and at relatively little cost. It is thus natural (and conventional) to treat pricing policies as contingent on prior sunk investment decisions. Second, we assume that the incumbents (whether or not an acquisition occurs) make sunk investments before the potential entrant to capture the frequently-cited first-mover advantage of incumbency (e.g. Dixit, 1980): historical presence in the industry affords the incumbents earlier knowledge of, and ability to exploit, profitable investment opportunities created by the opening up of national markets to cross-border trade and investment flows. Third, the incumbents' merger decision (leading potentially to a flow of acquisition-FDI) occurs before their process R&D and greenfield-FDI decisions. We make this assumption to add significant interest to our investigation of the second motivating question set out in the Introduction ('What are the comparative welfare properties of equilibria associated with the alternative forms of FDI?'). By making R&D investments conditional on whether a merger has occurred, we are able to explore additional possible welfare consequences of merger to the 'pricing effects' that have traditionally dominated the literature. Moreover, Petit and Sanna-Randaccio (2000, p. 341) cite several recent empirical studies which find that 'to an ever greater degree, firms are concerned with how their international strategy will influence their innovative activity'. This implies that firms' FDI decisions precede their R&D decisions (contrary to the 'traditional' view of, e.g., Caves,

1971) perhaps – as Petit and Sanna-Randaccio suggest – because the FDI decision involves a longer term commitment than the R&D decision.

Given these characteristics of the firms' strategic choices, we can limit the strategy spaces of the acquirer and the potential entrant in the A subgame to $\{N, R\}$ and $\{\emptyset, E, R\}$ respectively. (The latter is also the potential entrant's strategy space in the G subgame.) N and \emptyset both represent decisions not to invest in any process R&D, although they are taken from different marginal production costs (c for the acquirer and $> x^M(c)$ for the potential entrant). A choice of \emptyset by the potential entrant is equivalent to a decision *not* to enter the industry. A choice of E by the potential entrant costs I and reduces its marginal production cost to c . A choice of R (investment in 'new' R&D from a social viewpoint, rather than just 'catching up') produces a marginal production cost of either 0 ('success') or c ('failure'), and it costs the acquirer I but the potential entrant $2 \cdot I$. We show in Lemma 1 below that the potential entrant's strategy space can be simplified to $\{\emptyset, R\}$ because E is strictly dominated by \emptyset . Therefore, a choice of R by the potential entrant represents a decision to enter the industry.¹³

The incumbents' stage-two strategy space in the G subgame is $\{(1, N), (1, R), (2, N), (2, R)\}$. (The G subgame is identical to the potential-entry (PE) game in chapter 1, where the purpose was to examine the effects of an entry threat on equilibrium industrial structures.) The first component of a corporate structure pair indicates how many plants the incumbent will maintain (a choice of 2 costs G); the second component indicates whether (R) or not (N) the incumbent invests in process R&D at a sunk cost of I . 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 legitimately be ignored. Lemma 1 shows that $(2, N)$ may be dropped from the incumbents' strategy spaces because it is strictly dominated by $(1, N)$.

Lemma 1. (Chapter 1) (i) In the A and G subgames the potential entrant will never optimally choose a corporate structure of E because it is strictly dominated by one of \emptyset . (ii) In the G subgame an incumbent will never optimally choose a corporate structure of $(2, N)$ because it is strictly dominated by one of $(1, N)$.

Proof. (i) If the potential entrant chooses E it sinks I to move onto the technological frontier and can produce at both its plants with a marginal cost of c . However, because both countries contain rivals' pre-existing plants with marginal costs of c , the potential entrant's expected global net revenues in Bertrand equilibrium remain 0. Therefore, choosing E over \emptyset will reduce the entrant's expected profits by I , so \emptyset strictly dominates E .

(ii) Because the two countries' product markets are perfectly segmented, choosing $(2, N)$ rather than $(1, N)$ has no effect on an incumbent's revenues from its home market: it continues to sell at home with a marginal cost of c . Its marginal cost abroad falls from $c+t$ to c , and it sinks G into greenfield-FDI. However, the incumbent's expected net revenues abroad in Bertrand equilibrium remain 0 because its foreign rival has a plant abroad with a marginal cost of c at most. Therefore, choosing $(2, N)$ over $(1, N)$ will reduce an incumbent's expected profits by G , so $(1, N)$ strictly dominates $(2, N)$. QED.

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:¹⁴

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

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

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

2.2.2. Market Size and Net Revenue.¹⁵

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

$$Q_j = \mu \cdot (1 - x_j) \quad (1)$$

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; thus, x_j (the market price abroad) does not influence Q_j . μ measures the 'size' of either

national product market, and it can be interpreted as an index of the number of homogeneous consumers in each country, all of whom have a reservation price of 1.

Net revenue equals revenue minus variable costs.¹⁶ 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

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

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

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

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 $\mu(1 - c_j)$ units.¹⁷ 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. $c_j \equiv \min\{c_1, c_2, \dots, c_{i-1}, c_{i+1}, \dots, c_N\}$).

The $R(c_i, c_j)$ function is not well-behaved: it is continuous but not smooth (with kinks as we move between lines in (2)). $R(\cdot)$ is decreasing in c_i and increasing in c_j . The weak monotonicity of $R(\cdot)$ implies that realisations for given c_j can be ranked using the restrictions in assumption (A) as

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

Likewise, it is possible to rank $R(c_i, c_j)$ for given c_i and different values of c_j . However, 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 . This is a disadvantage created by the badly-behaved functional form of $R(\cdot)$. We return to this problem when deriving equilibrium solutions in Section 2.3 below.

To provide a feel for the implications of Bertrand competition and assumption (A) taken together, we make three final observations on the characteristics of market equilibria. First, if two firms produce locally to serve a product market (and entry does not occur in stage three), then either will only make strictly positive net revenue if it innovates successfully but its rival doesn't. Second, in the asymmetric industrial structure where one firm produces locally but its rival produces abroad (and serves the market by exporting) the local firm will make strictly positive net revenue *unless* its own R&D fails but its rival's succeeds; conversely, the exporting firm will *only* make strictly positive net revenue if its own R&D succeeds but the local firm's fails. Third, cross-hauling of international trade flows will never occur in equilibrium, although greenfield-FDI cross-hauling (in the G subgame) may occur. (To see this, note that a necessary condition for trade cross-hauling is that neither firm undertake greenfield-FDI. Given that, firm i will export to j 's home market iff $c_j \in [c_i+t, 1)$, and firm j will export to i 's home market iff $c_j \in (0, c_i-t]$, where c_i is i 's marginal production cost. For $t > 0$ these two intervals do not overlap.)

2.2.3. Equilibrium Concepts.

Definitions 1 and 2 formally characterise the pure-strategy (subgame perfect) Nash equilibria of the A and G subgames. Definition 3 then sets out the greenfield/acquisition decision rule (GADR) that selects between the A- and G-equilibria to determine the equilibrium industrial structure of the overall game. We label the incumbents in the G subgame firms 1 and 2, the potential entrant in stage three firm 3, and the acquirer (integrated firm) in the A subgame firm A.

Definition 1. $\{S_A^*; S_3^*\}$ is the *equilibrium of the A subgame* iff

$$S_A^* = \arg \max_{S_A} E\pi_A(S_A; S_3^{\text{BR}}(S_A)) \text{ and } S_3^* = S_3^{\text{BR}}(S_A^*)$$

where

$$S_3^{\text{BR}}(S_A) \equiv \arg \max_{S_3} E\pi_3(S_A; S_3)$$

for all $S_A \in \{N, R\}$ and $S_3 \in \{\emptyset, R\}$

$S_3^{\text{BR}}(S_A)$ gives the potential entrant's best response to any choice of S_A by the acquirer. Because the acquirer is the first-mover (and its corporate structure choice is observed by the potential entrant at the start of stage three), S_3^{BR} is endogenous when S_A^* is determined: the acquirer must take account of the knock-on effects of its own corporate structure choice on the potential entrant's behaviour. From this formulation of the A subgame's equilibrium it is clear that the acquirer can potentially use its corporate structure choice to influence the potential entrant's behaviour to its own advantage.

Definition 2.¹⁸ $\{S_1^*, S_2^*; S_3^*\}$ is the *equilibrium of the G subgame* iff

$$S_1^* = S_1^{\text{BR}}(S_2^*); \quad S_2^* = S_2^{\text{BR}}(S_1^*); \quad \text{and} \quad S_3^* = S_3^{\text{BR}}(S_1^*, S_2^*)$$

where the $S^{\text{BR}}(\cdot)$ functions

$$S_1^{\text{BR}}(S_2) \equiv \arg \max_{S_1} E\pi_1(S_1, S_2; S_3^{\text{BR}}(S_1, S_2))$$

$$S_2^{\text{BR}}(S_1) \equiv \arg \max_{S_2} E\pi_2(S_1, S_2; S_3^{\text{BR}}(S_1, S_2))$$

$$S_3^{\text{BR}}(S_1, S_2) \equiv \arg \max_{S_3} E\pi_3(S_1, S_2; S_3)$$

for all $S_1, S_2 \in \{(1, N), (1, R), (2, R)\}$ and $S_3 \in \{\emptyset, R\}$

give the firms' best responses to their rivals' corporate structure choices.

Because the potential entrant is the second-mover in the G subgame, it takes the incumbents' corporate structures as given when deriving its best response; therefore, S_3^{BR} depends on S_1, S_2 . However, firms 1 and 2 must take account of the knock-on effects of their own corporate structure choices on the potential entrant's behaviour; therefore, S_3^{BR} is endogenized within $S_1^{\text{BR}}, S_2^{\text{BR}}$. By analogy with Definition 1, this formulation of the G subgame's equilibrium makes it clear that the incumbents can potentially use their corporate structure choices to influence the potential entrant's behaviour to their own advantage.

Definition 3. $\{S_A^*; S_3^*\}$ (resp. $\{S_1^*, S_2^*; S_3^*\}$) is the *equilibrium industrial structure* of the game in Figure 1 iff

$$E\pi_A(S_A^*; S_3^*) > (\text{resp. } \leq) E\pi_1(S_1^*, S_2^*; S_3^*) + E\pi_2(S_1^*, S_2^*; S_3^*) \quad (4)$$

We refer to (4) as the *greenfield/acquisition decision rule (GADR)*. The GADR is used to select between the A- and G-equilibria, and we will say that the selected equilibrium (i.e. the equilibrium industrial structure of the overall game) *dominates* the rival candidate equilibrium.

The GADR is formally identical to the decision rule conventionally used in cooperative merger games (e.g. Salant, Switzer and Reynolds, 1983). The GADR selects the A-equilibrium iff an acquisition would be (strictly) profitable. To show this, assume for concreteness that the acquirer is firm 1. We can place lower and upper bounds on the take-over price that 1 will pay for 2. The lower bound, B_L , is such that 2 is indifferent between accepting the take-over offer and playing the G subgame (i.e. rejecting it); therefore, $B_L = E\pi_2(S_1^*, S_2^*; S_3^*)$. Likewise, the upper bound, B^U , is such that 1 is indifferent between playing the two subgames (because 2 captures the entire surplus); therefore, $E\pi_A(S_A^*; S_3^*) - B^U = E\pi_1(S_1^*, S_2^*; S_3^*)$. The GADR requires $B^U > B_L$, so that there exists a non-empty interval of take-over prices such that both firms are better off after the take-over. Note that the GADR requires take-overs to be *strictly* profitable. Following Gowrisankaran (1999), this is a simple method of incorporating an infinitesimal sunk cost of administering the take-over.

One potential drawback of the GADR is that it does not determine the equilibrium take-over price. Therefore in the normative analysis of Section 2.4 we focus on *global* social welfare (GSW), rather (e.g.) than trying to compare national welfare levels between acquisition-FDI source and host countries. The equilibrium take-over price would depend crucially on the specification of the

bargaining mechanism that the take-over terms are negotiated through, which we do not model. (For example, if 1 makes 2 a take-it-or-leave-it offer, we would expect a price of (just above) B_L ; conversely, if 2 makes 1 a take-it-or-leave-it offer, we would expect a price of (just below) B^U . A common practice – e.g. Hart and Moore (1990) – is to assume that the acquirer and the target share the surplus equally. Our GADR encompasses all these cases.)

Finally, we briefly illustrate how endogenous process R&D interacts with the GADR. Assume N ex ante identical firms compete à la Bertrand to serve a single market for a homogeneous product. Each firm possesses a process innovation that ‘succeeds’ with probability p and ‘fails’ with probability $(1 - p)$; ‘success’ and ‘failure’ are associated with marginal production costs of 0 and c respectively. In this setting (which has similarities to our modelling structure) the expected profit of any firm is $p \cdot (1 - p)^{N-1} \cdot R(0, c)$; if two firms merge, then the expected profits of any firm in the new equilibrium are $p \cdot (1 - p)^{N-2} \cdot R(0, c)$. It is straightforward to show that for $p \in [0, 0.5]$ the merger is unprofitable and for $p \in (0.5, 1]$ the merger is profitable *irrespective of N* . This contrasts sharply with outcomes in the same set-up without endogenous process R&D (i.e. where all firms’ marginal production costs are fixed at c), where *only* a merger from duopoly to monopoly is strictly profitable (although for different reasons than those behind Salant, Switzer and Reynolds’ (1983) similar finding).

2.3. Positive Analysis.

2.3.1. Equilibria in the A subgame.

Table 2.1 gives the payoff matrix in the A subgame. Because both the acquirer and the potential entrant own 2 plants, the trade cost t is irrelevant in the A subgame: international trade flows never occur in equilibrium. If the potential entrant chooses \emptyset , then the acquirer monopolises both product markets. If the potential entrant chooses R , then either firm must possess a marginal production cost advantage over its rival to earn $R(0, c)$ in both countries, which occurs with probability $p \cdot (1 - p)$ when both firms undertake R&D.

Acquirer → Potential entrant ↓	N	R
\emptyset	$E\pi_A = 2 \cdot R^M(c)$ $E\pi_3 = 0$	$E\pi_A = 2 \cdot p \cdot R^M(0) + 2 \cdot (1 - p) \cdot R^M(c) - I$ $E\pi_3 = 0$
R	$E\pi_A = 0$ $E\pi_3 = 2 \cdot p \cdot R(0, c) - 2 \cdot I$	$E\pi_A = 2 \cdot p \cdot (1 - p) \cdot R(0, c) - I$ $E\pi_3 = 2 \cdot p \cdot (1 - p) \cdot R(0, c) - 2 \cdot I$

Table 2.1: Payoff Matrix in the A subgame

We consider the potential entrant's optimal decision first, which may be conditional on the acquirer's prior choice. If the acquirer chooses N , then the potential entrant has $R \succ$ (resp. \prec) \emptyset as

$$\mu > (\text{resp. } <) \frac{I}{\frac{1}{\mu} \cdot R(0,c) \cdot p} \quad (5)$$

RHS(5) defines a critical μ -value: because μ enters $R(\cdot)$ multiplicatively, $(1/\mu) \cdot R(0,c)$ is independent of μ . In (p,μ) -space RHS(5) is a rectangular hyperbola, because a fall in p must be counterbalanced by a rise in μ , which increases the payoff to *successful* R&D.

If the acquirer chooses R , then the potential entrant has $R \succ (\text{resp. } <) \emptyset$ as

$$\mu > (\text{resp. } <) \frac{I}{\frac{1}{\mu} \cdot R(0,c) \cdot p \cdot (1-p)} \quad (6)$$

RHS(6) is a U-shaped parabola in (p,μ) -space, which is symmetric around $p = 0.5$ with asymptotes at $p = 0$ and $p = 1$. To earn strictly positive net revenue (and thereby finance the sunk costs of entry), the potential entrant requires a marginal production cost advantage over the acquirer (i.e. successful R&D is insufficient). This occurs with probability $p \cdot (1 - p)$, which approaches 0 as p approaches 1; therefore, for $p \cong 1$ a very large market is required to make $E\pi_3 > 0$ because the payoff to a marginal production cost advantage must rise to counterbalance a fall in its probability.

For $p \in (0, 1]$ RHS(6) $>$ RHS (5), so there are three distinct situations to be faced by the acquirer when making her stage-two (see Figure 1) decision. For $\mu <$ RHS(5) entry is *blockaded*: regardless of the acquirer's choice, the potential entrant chooses \emptyset . In this case the acquirer has $R \succ (\text{resp. } <) N$ as

$$\mu > (\text{resp. } <) \frac{I}{\frac{2}{\mu} \cdot [R^M(0) - R^M(c)] \cdot p} \quad (7)$$

For $\mu \in (\text{RHS}(5), \text{RHS}(6))$ the potential entrant's optimal decision is conditional on the acquirer's choice: by choosing R , the acquirer can *deter entry*; however, entry will occur if the acquirer chooses N . Therefore, the acquirer has $R \succ (\text{resp. } <) N$ as

$$\mu > (\text{resp. } <) \frac{I}{\frac{2}{\mu} \cdot R^M(c) + \frac{2}{\mu} \cdot [R^M(0) - R^M(c)] \cdot p} \quad (8)$$

Finally, for $\mu > \text{RHS}(6)$ the potential entrant chooses R regardless of the acquirer's prior choice, so the acquirer must *accommodate* entry. Therefore, the acquirer has $R \succ (\text{resp. } <) N$ as

$$\mu > (\text{resp. } <) \frac{I}{\frac{2}{\mu} \cdot R(0, c) \cdot p \cdot (1 - p)} \quad (9)$$

By comparing RHS(8) and RHS(9) to RHS(7), we derive the following result.

Lemma 2. Relative to the benchmark of blockaded entry, (i) the acquirer is 'more likely' to invest in R&D when entry can be deterred; and (ii) if entry must be accommodated, the acquirer is 'less likely' to invest in R&D for large p , but 'more likely' for small p .

Proof. Part (i) requires $\text{RHS}(7) > \text{RHS}(8)$, so that an interval of μ -values exists where the acquirer undertakes R&D to deter entry that would not be

undertaken if entry were blockaded. $RHS(7) > RHS(8)$ is clear from straightforward inspection.

Part (ii) (the 'less likely' result) requires $RHS(7) < RHS(9)$ for large p , so that an interval of μ -values exists where the acquirer undertakes R&D when entry is blockaded that would not be undertaken if entry had to be accommodated. $RHS(9) > RHS(7)$ iff $R^M(0) - R^M(c) > R(0, c) \cdot (1 - p)$, which clearly holds for $p \cong 1$. A necessary-and-sufficient condition for $RHS(9) > RHS(7)$ on $p \in (0, 1]$ is $R^M(0) - R^M(c) - R(0, c) > 0$. This condition does not hold: for $c \geq 0.5$ $R(0, c) = R^M(0)$, so $LHS = -R^M(c)$; for $c \leq 0.5$ $R(0, c) = \mu \cdot (1 - c) \cdot c$ and $LHS > 0$ iff $c > 2/3$, which is a contradiction. Therefore, for $p \cong 0$ $RHS(7) > RHS(9)$ (the 'more likely' result). QED.

The result in Lemma 2 allows us to characterise the acquirer's optimal behaviour in terms of Fudenberg and Tirole's (1984) taxonomy of an incumbent's investment strategies in anticipation of entry. When entry can be deterred, the acquirer behaves as a 'top dog' (part (i)). However, when entry must be accommodated, the acquirer behaves as a 'puppy dog' for large p but as a 'top dog' for small p (part (ii)). 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.¹⁹ In part (ii) we compare the optimal R&D behaviour of a monopolist to that of a duopolist, and the result reflects variations in the strength of Arrow's 'replacement effect': insofar as undertaking R&D gives the acquirer a chance to 'escape competition' in the duopoly (i.e. when accommodating entry), the

acquirer will have a stronger incentive to undertake R&D as a duopolist than as a monopolist. When p is small, so there is little chance that the potential entrant's R&D will succeed, the 'replacement effect' in duopoly is strong, and thus the acquirer is 'more likely' to undertake R&D when entry must be accommodated than under blockaded entry. However, when p is large, the 'replacement effect' in duopoly is weak: the potential entrant's R&D is likely to succeed, so that R&D success will not allow the acquirer to 'escape competition'. Therefore, for large p the acquirer is 'more likely' to undertake R&D under blockaded, rather than accommodated, entry.

The equilibria of the A subgame are plotted in (p, μ) -space in Figure 2.2. For $\mu < \text{RHS}(5)$ the acquirer optimally chooses R iff (7) holds. It is straightforward to show that $\text{RHS}(5) > \text{RHS}(7)$; therefore, for $\mu < \text{RHS}(7) < \text{RHS}(5)$ the A-equilibrium is $\{N; \emptyset\}$, and for $\mu \in (\text{RHS}(7), \text{RHS}(5))$ the A-equilibrium is $\{R; \emptyset\}$.²⁰ The $\{N; \emptyset\}$ and $\{R; \emptyset\}$ A-equilibria are represented in regions I and II of Figure 2.2 respectively. For $\mu \in (\text{RHS}(5), \text{RHS}(6))$ the acquirer optimally chooses R iff (8) holds. In Lemma 2(i) we showed that $\text{RHS}(7) > \text{RHS}(8)$; therefore, because $\text{RHS}(5) > \text{RHS}(7)$ (see n. 20 above), the A-equilibrium on $\mu \in (\text{RHS}(5), \text{RHS}(6))$ is $\{R; \emptyset\}$, which is represented in region II of Figure 2. For $\mu > \text{RHS}(6)$ the acquirer optimally chooses R iff (9) holds. Clearly $\text{RHS}(9) < \text{RHS}(6)$, so the A-equilibrium for $\mu > \text{RHS}(6)$ (i.e. region III of Figure 2.2) is $\{R; R\}$.

[FIGURE 2.2 IS OVERLEAF]

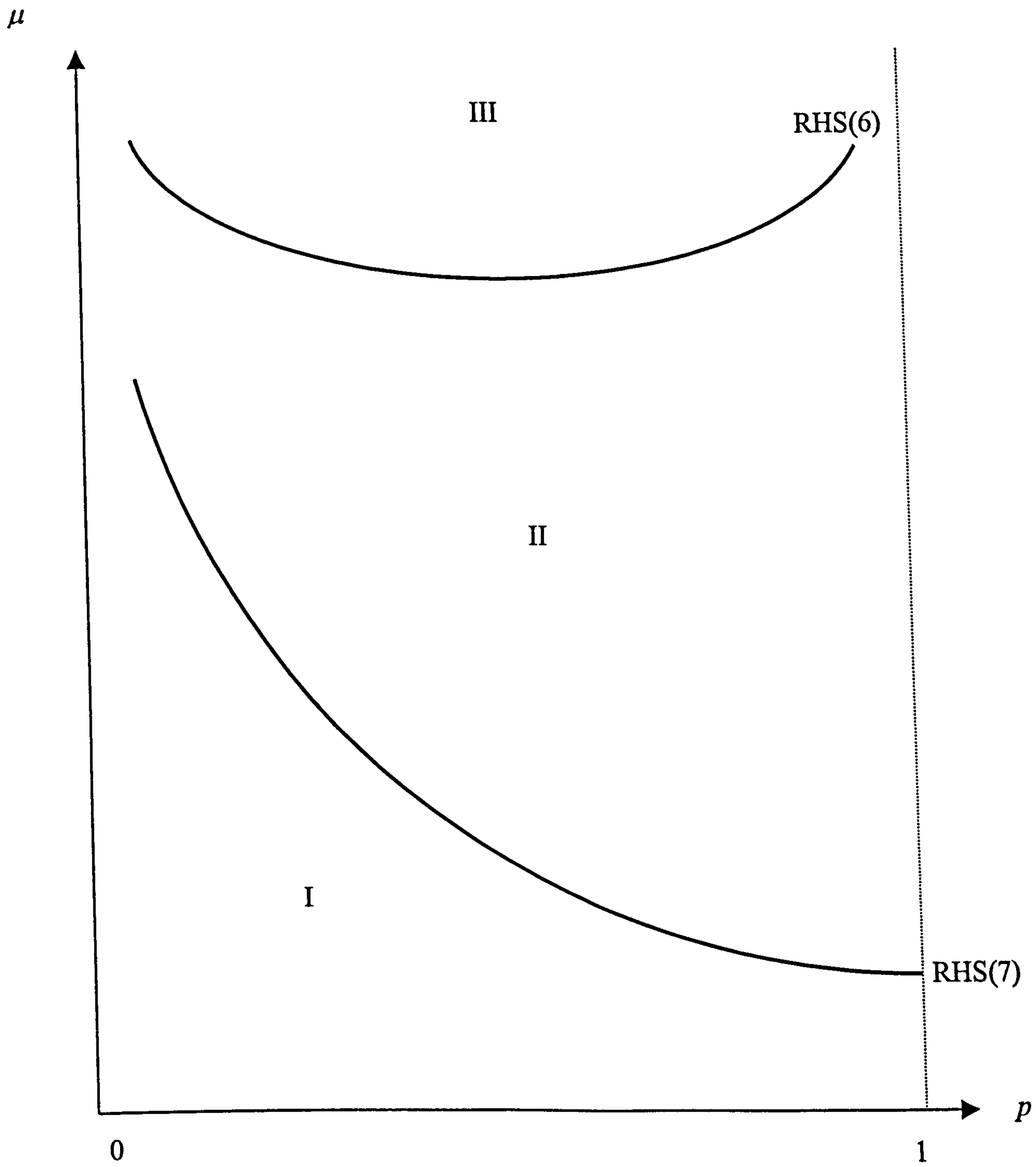


Figure 2.2: A-equilibria

Key to Figure 2.2

Region	A-equilibrium
I	$\{N; \emptyset\}$
II	$\{R; \emptyset\}$
III	$\{R; R\}$

An interesting feature of Figure 2.2 is the lack of an A-equilibrium of $\{N; R\}$. The key reason for this is the sequential-moves structure of the A subgame. If the acquirer and the potential entrant chose their corporate structures simultaneously, then $\{R; \emptyset\}$ would arise in A-equilibrium (which we label case α for ease) iff $U_\alpha > I > L_\alpha$, where $U_\alpha \equiv 2 \cdot [R^M(0) - R^M(c)] \cdot p$ and $L_\alpha \equiv R(0, c) \cdot p \cdot (1 - p)$; and $\{N; R\}$ would arise in A-equilibrium (case β) iff $U_\beta > I > L_\beta$, where $U_\beta \equiv R(0, c) \cdot p$ and $L_\beta \equiv 2 \cdot R(0, c) \cdot p \cdot (1 - p)$. U and L define (respectively) upper and lower bounds on I for the existence of the A-equilibrium. Clearly, $L_\beta > L_\alpha$ and $U_\alpha > U_\beta$ for $p \neq 0$ (see n. 20), so that in the simultaneous-moves version of the A subgame whenever $\{N; R\}$ is an A-equilibrium, so is $\{R; \emptyset\}$.²¹ (The reason for this is that the potential entrant's sunk cost of R is twice as large as the acquirer's. This in turn *decreases* L_α relative to L_β , because L defines the I -value where the non-innovating firm is indifferent between its two strategies, and *increases* U_α relative to U_β , because U defines the I -value where the innovating firm is indifferent between its two strategies. If the potential entrant could 'catch up' at zero sunk cost, so that R cost I for both firms, then we would have $L_\alpha = L_\beta$ and $U_\beta > U_\alpha$ for $p \neq 0$.²² $U_\beta > U_\alpha$ reflects the potential entrant's stronger incentive to choose R via Arrow's 'replacement effect'.)

In the sequential-moves version of the A subgame that we have analysed, the acquirer – as first-mover – chooses between A-equilibria of $\{R; \emptyset\}$ and $\{N; R\}$. The acquirer prefers $\{R; \emptyset\}$ iff $I < U_\alpha + 2 \cdot R^M(c)$, which must hold whenever $\{N; R\}$ arises as an A-equilibrium in the simultaneous-moves version because $U_\alpha > U_\beta$. (Therefore, the acquirer's R&D investment is pre-emptive in this case.) The acquirer's preference for $\{R; \emptyset\}$ over $\{N; R\}$ whenever $\{N; R\}$ arises under simultaneous-moves reflects the 'efficiency effect' (see Tirole, 1988, p. 393): the acquirer's gain from selecting $\{R; \emptyset\}$ over $\{N; R\}$ (i.e. monopoly vs. duopoly profits) is greater than the potential entrant's gain from becoming a duopolist in $\{N; R\}$.²³

Finally, note that although the entry threat in the A subgame does alter the acquirer's 'incentives' to invest in R&D (see Lemma 2), it does not alter the acquirer's equilibrium behaviour relative to the benchmark of blockaded entry. In the absence of a potential entrant, the acquirer would optimally choose R (resp. N) iff $\mu >$ (resp. $<$) RHS(7); this also describes the acquirer's equilibrium behaviour in the presence of an entry threat (see Figure 2.2).

2.3.2. Equilibria in the G subgame.

The G subgame is solved and extensively discussed in chapter 1; here, we present the solution and catalogue its properties that are relevant for our purpose. Table 2.2 gives the G subgame's payoff matrix. Rather than discussing the derivation of expected profits in each industrial structure, we highlight several

general features and then present a specimen derivation. First, note that we adopt the convention throughout, where a firm earns strictly positive net revenue in both countries in Bertrand equilibrium, of writing domestic net revenue as the first term in square brackets and foreign net revenue as the second. Expected profits can be viewed as a weighted average of realized profits across all possible 'states of nature', where each state is associated with a distinct configuration of R&D outcomes across firms and the weight applied equals the probability of that state's occurrence. (Recall from Section 2.2.1 that the probability of R&D success p is identical and independent across firms; at the end of Section 2.2.2 we provide a brief discussion of how firms' realized net revenues are influenced by their R&D outcomes and location choices.)

[TABLE 2.2 IS OVERLEAF]

Firm 1 → Firms 2 and 3 ↓	(1, N)	(1, R)	(2, R)
(1, N); ∅	$E\pi_1 = E\pi_2 = R(c, c+t)$	$E\pi_1 = p \cdot [R(0, c+t) + R(t, c)] + (1-p) \cdot R(c, c+t) - I$ $E\pi_2 = (1-p) \cdot R(c, c+t)$	$E\pi_1 = p \cdot [R(0, c+t) + R(0, c)] + (1-p) \cdot R(c, c+t) - G - I$ $E\pi_2 = 0$
(1, N); R	$E\pi_1 = E\pi_2 = 0$ $E\pi_3 = 2 \cdot p \cdot R(0, c) - 2 \cdot I$	$E\pi_1 = p \cdot (1-p) \cdot [R(0, c) + R(t, c)] - I$ $E\pi_2 = 0$ $E\pi_3 = 2 \cdot p \cdot (1-p) \cdot R(0, c) + p^2 \cdot R(0, t) - 2 \cdot I$	$E\pi_1 = 2 \cdot p \cdot (1-p) \cdot R(0, c) - G - I$ $E\pi_2 = 0$ $E\pi_3 = 2 \cdot p \cdot (1-p) \cdot R(0, c) - 2 \cdot I$
(1, R); ∅	$E\pi_1 = (1-p) \cdot R(c, c+t)$ $E\pi_2 = p \cdot [R(0, c+t) + R(t, c)] + (1-p) \cdot R(c, c+t) - I$	$E\pi_1 = E\pi_2 = p \cdot (1-p) \cdot [R(0, c+t) + R(t, c)] + p^2 \cdot R(0, t) + (1-p)^2 \cdot R(c, c+t) - I$	$E\pi_1 = p \cdot (1-p) \cdot [R(0, c+t) + R(0, c)] + p^2 \cdot R(0, t) + (1-p)^2 \cdot R(c, c+t) - G - I$ $E\pi_2 = p \cdot (1-p) \cdot [R(0, c) + R(t, c)] - I$ $E\pi_3 = p \cdot (1-p)^2 \cdot [R(0, c) + R(t, c)] + p^2 \cdot R(0, t) - G - I$
(1, R); R	$E\pi_1 = 0$ $E\pi_2 = p \cdot (1-p) \cdot [R(0, c) + R(t, c)] - I$ $E\pi_3 = 2 \cdot p \cdot (1-p) \cdot R(0, c) + p^2 \cdot R(0, t) - 2 \cdot I$	$E\pi_1 = E\pi_2 = p \cdot (1-p)^2 \cdot [R(0, c) + R(t, c)] + p^2 \cdot (1-p) \cdot R(0, t) - I$ $E\pi_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) + 2 \cdot p^2 \cdot (1-p) \cdot R(0, t) - 2 \cdot I$	$E\pi_1 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) + p^2 \cdot (1-p) \cdot R(0, t) - G - I$ $E\pi_2 = p \cdot (1-p)^2 \cdot [R(0, c) + R(t, c)] - I$ $E\pi_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) + p^2 \cdot (1-p) \cdot R(0, t) - 2 \cdot I$
(2, R); ∅	$E\pi_1 = 0$ $E\pi_2 = p \cdot [R(0, c+t) + R(0, c)] + (1-p) \cdot R(c, c+t) - G - I$	$E\pi_1 = p \cdot (1-p) \cdot [R(0, c) + R(t, c)] - I$ $E\pi_2 = p \cdot (1-p) \cdot [R(0, c+t) + R(0, c)] + p^2 \cdot R(0, t) + (1-p)^2 \cdot R(c, c+t) - G - I$	$E\pi_1 = E\pi_2 = 2 \cdot p \cdot (1-p) \cdot R(0, c) - G - I$
(2, R); R	$E\pi_1 = 0$ $E\pi_2 = 2 \cdot p \cdot (1-p) \cdot R(0, c) - G - I$ $E\pi_3 = 2 \cdot p \cdot (1-p) \cdot R(0, c) - 2 \cdot I$	$E\pi_1 = p \cdot (1-p)^2 \cdot [R(0, c) + R(t, c)] - I$ $E\pi_2 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) + p^2 \cdot (1-p) \cdot R(0, t) - G - I$ $E\pi_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) + p^2 \cdot (1-p) \cdot R(0, t) - 2 \cdot I$	$E\pi_1 = E\pi_2 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) - G - I$ $E\pi_3 = 2 \cdot p \cdot (1-p)^2 \cdot R(0, c) - 2 \cdot I$

Table 2.2: Payoff Matrix in the G subgame

(The incumbents are firms 1 and 2, and the potential entrant is firm 3. If 3 chooses ∅, $E\pi_3 = 0$ (not reported for brevity).)

For illustrative purposes, consider the firms' expected profits when firms 1 and 2 choose corporate structures of (1, R) and (2, R) respectively. If the potential entrant chooses \emptyset , then the incumbents' expected profits are

$$E\pi_1 = p \cdot (1 - p) \cdot [R(0, c) + R(t, c)] - I$$

$$E\pi_2 = p \cdot (1 - p) \cdot [R(0, c + t) + R(0, c)] + p^2 \cdot R(0, t) + (1 - p)^2 \cdot R(c, c + t) - G - I$$

Because firm 2 has a local plant in country 1, firm 1 must possess a marginal *production* cost advantage if it is to earn strictly positive net revenue. This occurs with probability $p \cdot (1 - p)$ when 1's R&D investment succeeds but 2's fails. On the other hand, firm 2 can earn strictly positive net revenue *at home* when the firms' marginal production costs are the same because the trade cost insulates its domestic plant from foreign competition.

If the potential entrant chooses R, then the firms' expected profits are

$$E\pi_1 = p \cdot (1 - p)^2 \cdot [R(0, c) + R(t, c)] - I$$

$$E\pi_2 = 2 \cdot p \cdot (1 - p)^2 \cdot R(0, c) + p^2 \cdot (1 - p) \cdot R(0, t) - G - I$$

$$E\pi_3 = 2 \cdot p \cdot (1 - p)^2 \cdot R(0, c) + p^2 \cdot (1 - p) \cdot R(0, t) - 2 \cdot I$$

Firm 1 faces two local rivals and must possess marginal production cost advantages over both with probability $p \cdot (1 - p)^2$ to earn $R(0, c)$ at home and $R(t, c)$ abroad. If firm 2 alone innovates successfully, it earns $R(0, c)$ in both countries; additionally, because firm 2 faces only one local rival (the potential entrant, firm 3), if both incumbents' R&D investments succeed but the potential entrant's fails, then firm 2 earns $R(0, t)$ at home. If the potential entrant alone innovates successfully, then it earns $R(0, c)$ in both countries; if only firm 2's R&D fails, then the potential entrant earns $R(0, t)$ in country 2. (Note that, when the potential entrant chooses R, the incumbents' expected net revenues have a factor of $p \cdot (1 - p)$: because the potential entrant owns a plant in each country, a

necessary condition for an incumbent to earn strictly positive net revenue is that its own R&D succeeds but the potential entrant's fails. Furthermore, entry reduces the incumbents' expected profits.)

Because of the complexity of the G subgame we place restrictions on the four cost parameters t, c, G, I when deriving its solution. We show in chapter 1 that the following two assumptions are sufficient to fix the form of a plot of G-equilibria in (p, μ) -space.²⁴

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

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

Assumption (B) on t, c is only slightly more restrictive than our maintained assumption (A).²⁵ (In general (B) holds if the gap $(c - t)$ is sufficiently large.) By invoking (B) and (C), both of which hold under wide ranges of variation in the cost parameters, we can draw general conclusions about equilibrium behaviour in the G subgame. (We term variations in t, c, G, I that are consistent with both (B) and (C) continuing to hold *nondrastic* variations; *drastic* variations violate (B) or (C) or both.) Given assumptions (B),(C), Figure 2.3 illustrates the equilibria of the G subgame in (p, μ) -space. The inter-regional boundaries in Figure 2.3 are defined below the key.

[FIGURE 2.3 IS OVERLEAF]

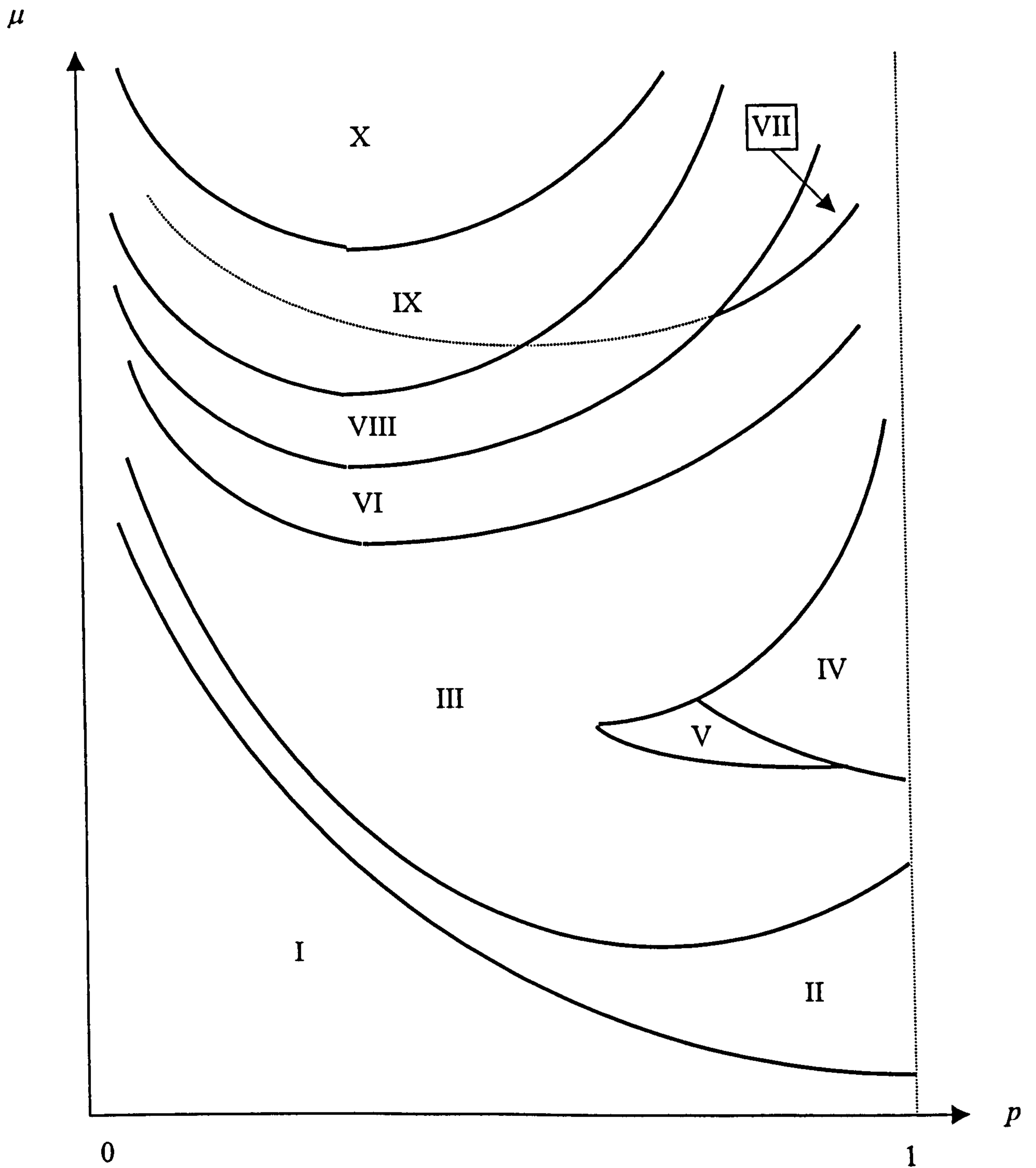


Figure 2.3: G-equilibria

Inter-regional boundaries: I/II boundary is RHS(10); II/III boundary is RHS(11); III/IV lower boundary and IV/V boundary is RHS(12); III/IV upper boundary and III/V upper boundary is RHS(13); III/V lower boundary is RHS(14); III/VI boundary is RHS(15); VI/VII boundary is RHS(16); VI/VIII boundary and VII/VIII boundary is RHS(17); VIII/IX boundary is RHS(18); IX/X boundary is RHS(19).

Key to Figure 2.3

Region	Equilibrium Industrial Structure under PE
I	$\{(1, N), (1, N); \emptyset\}$
II	$\{(1, N), (1, R); \emptyset\}$
III	$\{(1, R), (1, R); \emptyset\}$
IV	$\{(1, R), (1, R); \emptyset\}; \{(1, N), (2, R); \emptyset\}$
V	$\{(1, R), (1, R); \emptyset\}; \{(1, N), (1, N); R\}$ or $\{(1, N), (2, R); \emptyset\}$
VI	$\{(1, R), (1, R); R\}^*$ or $\{(1, R), (2, R); \emptyset\}$
VII	$\{(2, R), (2, R); \emptyset\}^*$
VIII	$\{(1, R), (1, R); R\}; \{(1, R), (1, R); R\}$ or $\{(2, R), (2, R); \emptyset\}$
IX	$\{(1, R), (1, R); R\}$
X	$\{(2, R), (2, R); R\}^*$

(Note: * denotes a dominant strategy equilibrium.)

Inter-regional boundaries in Figure 2.3

I/II boundary:

$$\mu = \frac{I}{\frac{1}{\mu} \cdot [R(0, c+t) + R(t, c) - R(c, c+t)] \cdot p} \quad (10)$$

II/III boundary:

$$\mu = \frac{I}{\frac{1}{\mu} \cdot [R(0, c+t) + R(t, c) - R(c, c+t)] \cdot p \cdot (1-p) + \frac{1}{\mu} \cdot R(0, t) \cdot p^2} \quad (11)$$

III/IV lower boundary and IV/V boundary:

$$\mu = \frac{G}{\frac{1}{\mu} \cdot [R(0, c) - R(t, c)] \cdot p} \quad (12)$$

III/IV upper boundary and III/V upper boundary:

$$\mu = \frac{I}{\frac{1}{\mu} \cdot [R(0,c) + R(t,c)] \cdot p \cdot (1-p)} \quad (13)$$

III/V lower boundary:

$$\mu = \frac{2 \cdot I}{\frac{2}{\mu} \cdot R(0,c) \cdot p \cdot (1-p) + \frac{1}{\mu} \cdot R(0,t) \cdot p^2} \quad (14)$$

III/VI boundary:

$$\mu = \frac{I}{\frac{1}{\mu} \cdot R(0,c) \cdot p \cdot (1-p)^2 + \frac{1}{\mu} \cdot R(0,t) \cdot p^2 \cdot (1-p)} \quad (15)$$

VI/VII boundary:

$$\mu = \frac{G}{\frac{1}{\mu} \cdot [R(0,c) - R(t,c)] \cdot p \cdot (1-p)} \quad (16)$$

VI/VIII boundary and VII/VIII boundary:

$$\mu = \frac{2 \cdot I}{\frac{2}{\mu} \cdot R(0,c) \cdot p \cdot (1-p)^2 + \frac{1}{\mu} \cdot R(0,t) \cdot p^2 \cdot (1-p)} \quad (17)$$

VIII/IX boundary:

$$\mu = \frac{I}{\frac{1}{\mu} \cdot R(0,c) \cdot p \cdot (1-p)^2} \quad (18)$$

IX/X boundary:

$$\mu = \frac{G}{\frac{1}{\mu} \cdot [R(0,c) - R(t,c)] \cdot p \cdot (1-p)^2} \quad (19)$$

In the key to Figure 2.3 multiple equilibria within a region are separated by semicolons. Where G-equilibria are separated by 'or', the relevant equilibrium

depends on whether entry by firm 3 is accommodated (R) or strategically deterred (\emptyset) by the incumbents. We highlight three properties of Figure 2.3 that are relevant for our purposes.

G1. (chapter 1, section 1.3.4) The shapes of regions V and VII in Figure 2.3 depend on whether

$$2 \cdot \frac{I}{G} \cdot [R(0, c) - R(t, c)] - R(0, t) > 0 \quad (20)$$

is satisfied. (The general shapes of all other regions in Figure 2.3 are robust to changes in the cost parameters, provided that assumptions (B) and (C) continue to hold.) If (20) fails, then (i) the bottom boundary of region V, RHS(14), will extend to $p = 1$, rather than meeting RHS(12) in the interior of Figure 2.3; and (ii) region VII ceases to exist. While (20) holds when $G = I$, some G, I that satisfy assumption (C) imply $\text{LHS}(20) < 0$.²⁶ Intuitively, for $G \square I$ $\text{LHS}(20) \cong -R(0, t)$, so (20) fails.

G2 and G3 concern equilibrium selection (entry-deterrence vs. -accommodation) in regions V, VI and VIII of Figure 2.3. G2 and G3 use the following necessary- and-sufficient conditions for the entry-detering G-equilibrium to be selected for all μ in the relevant region.

Region V. $\{(1, N), (2, R); \emptyset\}$ is selected over $\{(1, N), (1, N); R\}$ for all μ iff

$$\begin{aligned} & 2 \cdot \frac{I}{G} \cdot R(c, c+t) + 2 \cdot \left\{ \frac{I}{G} \cdot [R(0, c+t) - R(c, c+t)] - R(0, c) \right\} \cdot p \\ & + \left(\frac{I}{G} + 1 \right) \cdot [2 \cdot R(0, c) - R(0, t)] \cdot p^2 > 0 \end{aligned} \quad (21)$$

Region VI. $\{(1, R), (2, R); \emptyset\}$ is selected over $\{(1, R), (1, R); R\}$ for all μ iff

$$\begin{aligned} & \frac{I}{G} \cdot R(c, c+t) + \left\{ \frac{I}{G} \cdot [R(0, c+t) - 2 \cdot R(c, c+t) - R(t, c)] - R(0, c) \right\} \cdot p \\ & + \left\{ \frac{I}{G} \cdot [R(c, c+t) - R(0, c+t) + R(0, c) + 2 \cdot R(t, c)] + 2 \cdot R(0, c) - R(0, t) \right\} \cdot p^2 \quad (22) \\ & + \left\{ \frac{I}{G} \cdot [R(0, t) - R(0, c) - R(t, c)] - R(0, c) + R(0, t) \right\} \cdot p^3 > 0 \end{aligned}$$

Region VIII. $\{(2, R), (2, R); \emptyset\}$ is selected over $\{(1, R), (1, R); R\}$ as the second G-equilibrium for all μ iff $\mu > \text{RHS}(16)$ or

$$\begin{aligned} & 4 \cdot \frac{I}{G} \cdot R(0, c) \cdot (1-p) > \left(\frac{I}{G} + 1 \right) \quad (23) \\ & \times \left\{ 2 \cdot R(0, c) - [4 \cdot R(0, c) - R(0, t)] \cdot p + [2 \cdot R(0, c) - R(0, t)] \cdot p^2 \right\} \end{aligned}$$

and

$$\begin{aligned} & 2 \cdot \frac{I}{G} \cdot [R(0, c) - R(t, c)] - 2 \cdot R(0, c) + \left\{ 4 \cdot \frac{I}{G} \cdot R(t, c) + 4 \cdot R(0, c) - R(0, t) \right\} \cdot p \quad (24) \\ & - \left\{ 2 \cdot \frac{I}{G} \cdot [R(0, c) + R(t, c)] + 2 \cdot R(0, c) - R(0, t) \right\} \cdot p^2 > 0 \end{aligned}$$

G2. (chapter 1, Proposition 6 and Lemma 8) If $G = I$, then (i) $\{(1, N), (2, R); \emptyset\}$ is selected over $\{(1, N), (1, N); R\}$ for all (p, μ) in region V of Figure 2.3; (ii) given sufficiently high p , a second equilibrium of $\{(2, R), (2, R); \emptyset\}$ exists for all μ in region VIII of Figure 2.3; and (iii) given t sufficiently greater than 0, $\{(1, R), (2, R); \emptyset\}$ is (certainly) selected over $\{(1, R), (1, R); R\}$ for all (p, μ) in region VI of Figure 2.3.

Note in part (iii) of G2 that the requirement for t sufficiently greater than 0 is *consistent* with our earlier requirement in assumption (B) that the gap $(c - t)$ be sufficiently large. Finally, G3 reports on the effects of setting $G > I$.

G3. (chapter 1, Proposition 7) (i) Rises in G ceteris paribus weakly increase the size of the μ -interval for any p where entry-accommodation is selected in equilibrium in regions V, VI and VIII of Figure 2.3. (ii) In the limit as $G \rightarrow \infty$, entry-deterrence is never selected in equilibrium in region VI, although entry-deterrence is always selected for some (p, μ) -pairs in regions V and VIII.

The intuitive justification for the results in G2 and G3 concerning the influence of G relative to I on equilibrium selection is that, whereas the potential entrant 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 the potential entrant 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.)

2.3.3. Equilibrium industrial structures: A-equilibrium vs. G-equilibrium.

In this Section we compare the A- and G-equilibria for given parameter values to derive (overall) equilibrium industrial structures and the equilibrium mode of FDI. This task comprises two steps. (The mechanics are presented in the Appendix.) First, we locate the inter-regional boundaries in the A subgame

(Figure 2.2) relative to those in the G subgame (Figure 2.3), so that both the A- and G-equilibria are fixed for given parameter values. Second, we determine the equilibrium industrial structure by using the GADR to select between the A- and G-equilibria. A complication arises when there are multiple G-equilibria (A-equilibria are always unique: see Figure 2.2). In this case the selected subgame may depend on which G-equilibrium is selected *within* the G subgame. Of course, if the A-equilibrium dominates all the G-equilibria, then we can unambiguously conclude that the A subgame will be played in equilibrium (and vice versa). Figure 2.4 illustrates the model's equilibrium industrial structures in (p, μ) -space.

[FIGURE 2.4 IS OVERLEAF]

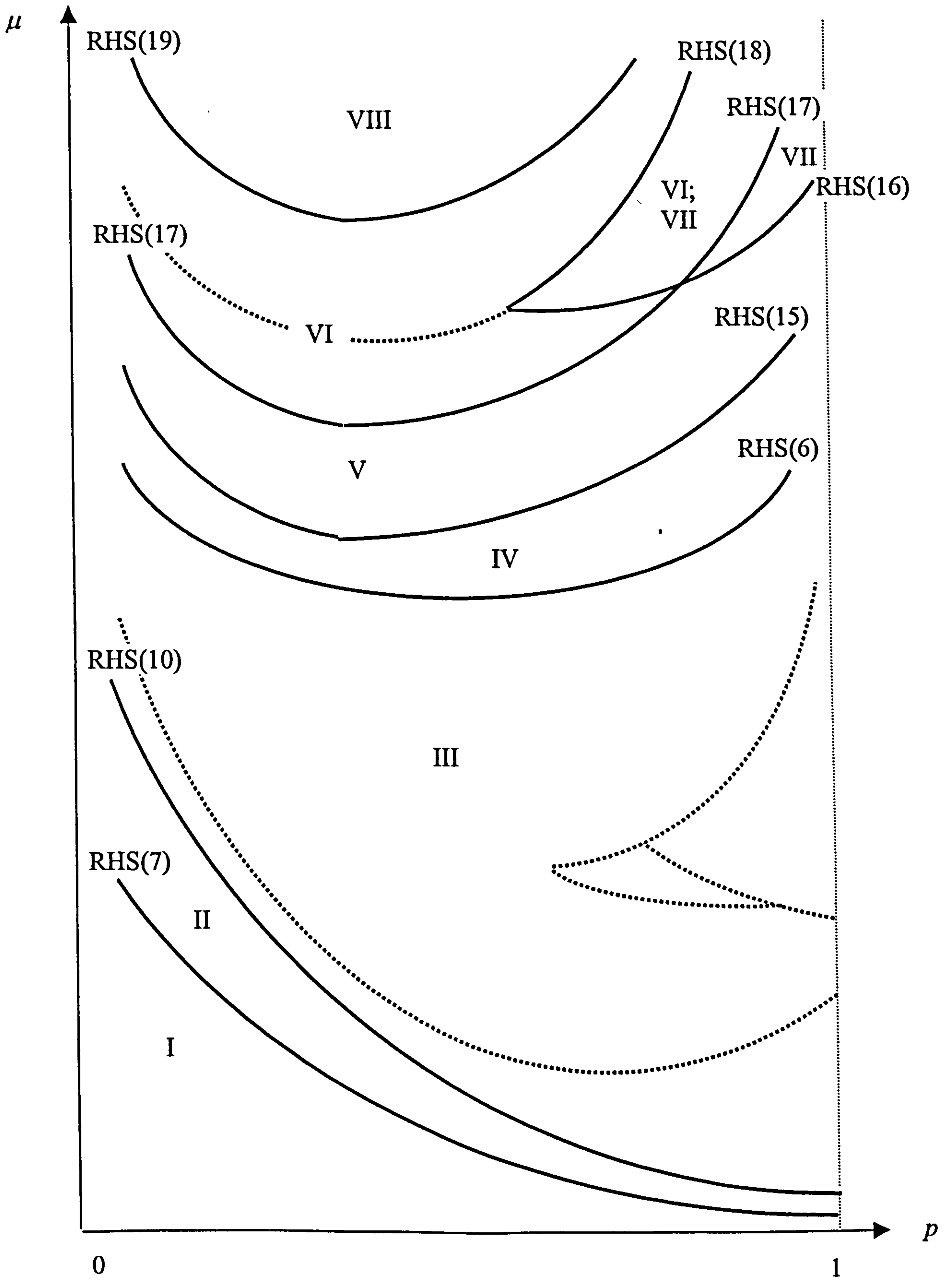


Figure 2.4: Equilibrium Industrial Structures (the G/A choice)

Bold inter-regional boundaries are labelled in the Figure. Dashed lines are inter-regional boundaries from the G subgame (included for comparison).

Key to Figure 2.4

Region	Equilibrium Industrial Structure
I	$\{(1, N), (1, N); \emptyset\}$ (resp. $\{N; \emptyset\}$) iff $t \geq$ (resp. $<$) $x^M(c) - c$
II	$\{R; \emptyset\}$ (Region II exists iff (A1) fails.)
III	$\{R; \emptyset\}$
IV	$\{(1, R), (1, R); \emptyset\}$ (Region IV exists iff $t < 0.5$.)
V	<p>G-equilibrium is $\{(1, R), (1, R); R\}$</p> <p>Small p: $\{(1, R), (1, R); R\}$ (resp. $\{R; R\}$) for small (resp. large) t</p> <p>Large p: $\{R; R\}$</p> <p>G-equilibrium is $\{(1, R), (2, R); \emptyset\}$</p> <p>$\{(1, R), (2, R); \emptyset\}$ (resp. $\{R; R\}$) for small (resp. large) G</p>
VI	<p>G-equilibrium is $\{(1, R), (1, R); R\}$</p> <p>Small p: $\{(1, R), (1, R); R\}$ (resp. $\{(1, R), (1, R); R\}$ for small I; $\{R; R\}$ for large I) for small (resp. large) t</p> <p>Large p: $\{R; R\}$ (resp. $\{(1, R), (1, R); R\}$ for small I; $\{R; R\}$ for large I) for small (resp. large) t</p>
VII	<p>G-equilibrium is $\{(2, R), (2, R); \emptyset\}$</p> <p>Small p (<i>within</i> region VII): $\{(2, R), (2, R); \emptyset\}$ (resp. $\{R; R\}$) for small (resp. large) t</p> <p>Large p: $\{(2, R), (2, R); \emptyset\}$ (resp. $\{(2, R), (2, R); \emptyset\}$ for small G, I; $\{R; R\}$ for large G, I) for small (resp. large) t</p>
VIII	<p>Small p (< 0.5): $\{(2, R), (2, R); R\}$ (resp. $\{R; R\}$) for small (resp. large) t, G, I</p> <p>Large p (≥ 0.5): $\{R; R\}$</p>

Figure 2.4 provides implications for the relationships between p , μ and equilibrium industrial structures; however, the derived relationships can be quite complex. Consider first the effects of changes in μ in small- p industries. If t is small, increasing μ shifts the equilibrium industrial structure successively from $\{N; \emptyset\}$ (region I); to $\{R; \emptyset\}$ (regions II and III); to $\{(1, R), (1, R); \emptyset\}$ (region IV); to $\{(1, R), (2, R); \emptyset\}$ for small G or $\{(1, R), (1, R); R\}$ for large G (region V); to $\{(1, R), (1, R); R\}$ (region VI); to $\{(2, R), (2, R); R\}$ for small G, I or $\{R; R\}$ for large G, I (region VIII). For large t the sequence of equilibrium industrial structures is $\{(1, N), (1, N); \emptyset\}$ (region I); $\{R; \emptyset\}$ (regions II and III); $\{(1, R), (2, R); \emptyset\}$ for small G or $\{R; R\}$ for large G (region V); $\{(1, R), (1, R); R\}$ for small I or $\{R; R\}$ for large I (region VI); $\{(2, R), (2, R); R\}$ for small G, I or $\{R; R\}$ for large G, I (region VIII) (note that region IV does not exist for large t). These sequences are summarised for ease of reference in Table 2.3.

[TABLE 2.3 IS OVERLEAF]

Table 2.3: Summary of determinants of equilibrium industrial structures in

Figure 2.4

Region*	Small p		Large p	
	Small t	Large t	Small t	Large t
I	$\{N; \emptyset\}$	$\{(1, N), (1, N); \emptyset\}$	$\{N; \emptyset\}$	$\{(1, N), (1, N); \emptyset\}$
II, III	$\{R; \emptyset\}$			
IV	$\{(1, R), (1, R); \emptyset\}$	N/A	$\{(1, R), (1, R); \emptyset\}$	N/A
V	Small G : $\{(1, R), (2, R); \emptyset\}$ Large G : $\{(1, R), (1, R); R\}$	Small G : $\{(1, R), (2, R); \emptyset\}$ Large G : $\{R, R\}$		
VII	N/A		$\{(2, R), (2, R); \emptyset\}$	Small G, I : $\{(2, R), (2, R); \emptyset\}$ Large G, I : $\{R; R\}$
VI	$\{(1, R), (1, R); R\}$	Small I : $\{(1, R), (1, R); R\}$ Large I : $\{R; R\}$	$\{R; R\}$	Small I : $\{(1, R), (1, R); R\}$ Large I : $\{R; R\}$
VIII	Small G, I : $\{(2, R), (2, R); R\}$ Large G, I : $\{R; R\}$		$\{R; R\}$	

(* Regions appear in Figure 2.4. Movements down a column reflect increases in

μ .)

The choice between $\{(1, N), (1, N); \emptyset\}$ and $\{N; \emptyset\}$ in region I depends on t in an intuitively-appealing way: large t affords the incumbents in the G subgame sufficient protection to monopoly-price, implying no (strict) profitability gains from acquisition-FDI; but if t is small, acquisition-FDI increases aggregate profits by eliminating the ‘import competition’ faced by each G-incumbent. In regions II and III the generation of acquisition-FDI in equilibrium is unsurprising because the acquirer is a global monopolist in A-equilibrium (no entry occurs). (The difference between regions II and III concerns the discarded G-equilibrium, which is $\{(1, N), (1, N); \emptyset\}$ in II and $\{(1, N), (1, R); \emptyset\}$, $\{(1, R), (1, R); \emptyset\}$, $\{(1, N), (2, R); \emptyset\}$ or $\{(1, N), (1, N); R\}$ in III; section 2.4 explores the significance of this difference in welfare terms.) In region IV the equilibrium industrial structure is the G-equilibrium of $\{(1, R), (1, R); \emptyset\}$ because both the A- and G-equilibria are duopolistic. Entry is ‘more likely’ to occur in the A subgame than in the G subgame if the entry-detering G-equilibrium is played (if not, entry could occur in a G-equilibrium of $\{(1, N), (1, N); R\}$ in region III where the A-equilibrium is $\{R; \emptyset\}$), which makes intuitive sense because the entrant faces a monopoly in the A subgame but a duopoly in the G subgame. Therefore, for intermediate μ -values (regions IV, V and VII) entry is deterred in G-equilibrium but accommodated in A-equilibrium and acquisition-FDI *does not* generate a ‘more concentrated’ industrial structure (in terms of firm numbers), which implies that the profitability gains from acquisition-FDI are limited (and perhaps non-existent).

In regions V, VI and VIII the equilibrium industrial structures are identical in the small- and large- t cases (for small p) if G, I are small. Increasing G, I causes

substitution in equilibrium away from industrial structures that involve greenfield-FDI and (relatively) large numbers of R&D investments. Therefore, in region V increasing G replaces (one-way) greenfield-FDI in equilibrium with equilibrium industrial structures involving either no FDI (small t) or acquisition-FDI (large t). In similar fashion, increasing I shifts the equilibrium industrial structure for large t in region VI from $\{(1, R), (1, R); R\}$ to $\{R; R\}$, which halves the incumbents' combined spending on R&D. (In region VIII the equilibrium industrial structure is independent of t , and large G, I cause the substitution of $\{R; R\}$ for $\{(2, R), (2, R); R\}$.) For large G, I increasing t generates 'tariff-jumping' acquisition-FDI in equilibrium in regions V and VI (recall that for small G, I equilibrium industrial structures are independent of t): $\{R; R\}$ displaces $\{(1, R), (1, R); R\}$ in both V and VI. We examine tariff-jumping acquisition-FDI in more detail below and contrast it with (the more familiar) tariff-jumping greenfield-FDI.

Finally, we can draw some tentative generalisations on the effects of changes in μ on equilibrium FDI flows and industrial structures in small- p industries. In small markets (region I) the industry is served either by two national firms (for large t) or by a monopolistic MNE (for small t), created by acquisition-FDI; R&D is never undertaken. In medium-sized markets (regions II and III) the equilibrium industrial structure is a monopolistic MNE, created by acquisition-FDI, which invests in R&D. In large markets (regions V, VI and VIII) the equilibrium industrial structure is the G-equilibrium for small G, I ; both G-incumbents undertake R&D and greenfield-FDI flows may be one-way (region V), non-existent (region VI) or cross-hauled (region VIII). For large G, I in large

markets the equilibrium industrial structure is two MNEs (the G-incumbents integrate via tariff-jumping acquisition-FDI and entry occurs), both undertaking R&D, when t is large; when t is small the equilibrium industrial structure is $\{(1, R), (1, R); R\}$ (regions V and VI) or $\{R; R\}$ (region VIII). Greenfield-FDI never occurs in large markets for large G, I .

We now turn to consider the effects of changes in μ in large- p industries. If t is small, increasing μ shifts the equilibrium industrial structure successively from $\{N; \emptyset\}$ (region I); to $\{R; \emptyset\}$ (regions II and III); to $\{(1, R), (1, R); \emptyset\}$ (region IV); to $\{(1, R), (2, R); \emptyset\}$ for small G or $\{R; R\}$ for large G (region V); to $\{(2, R), (2, R); \emptyset\}$ (region VII); to $\{R; R\}$ (regions VI and VIII). For large t the sequence of equilibrium industrial structures is $\{(1, N), (1, N); \emptyset\}$ (region I); $\{R; \emptyset\}$ (regions II and III); $\{(1, R), (2, R); \emptyset\}$ for small G or $\{R; R\}$ for large G (region V); $\{(2, R), (2, R); \emptyset\}$ for small G, I or $\{R; R\}$ for large G, I (region VII); $\{(1, R), (1, R); R\}$ for small I or $\{R; R\}$ for large I (region VI); $\{R; R\}$ (region VIII) (note that region IV does not exist for large t). See table 3 for a summary of these sequences.

Equilibrium selection in regions I to IV is identical in the large- and small- p cases. In region VIII acquisition-FDI always arises in equilibrium for large p regardless of t, G, I (the irrelevance of G, I stems from the fact that the acquirer's expected *net revenues* are greater than the G-incumbents' for $p > 0.5$ in region VIII). In regions V and VII the equilibrium industrial structures are identical in the small- and large- t cases if G, I are small, with one-way greenfield-FDI in V and greenfield-FDI cross-hauling in VII. Increasing G, I again causes substitution

in equilibrium away from industrial structures involving greenfield-FDI and (relatively) large numbers of R&D investments: acquisition-FDI arises in region V and (for large t) in region VII, displacing greenfield-FDI flows and halving the incumbents' combined R&D spending. In region VI acquisition-FDI arises in equilibrium for small t , but it is replaced by $\{(1, R), (1, R); R\}$ for large t if I is small. (If I is large, then $\{R; R\}$ is the equilibrium industrial structure for all t in region VI.) This implies that for small I increasing t in region VI will cause $\{(1, R), (1, R); R\}$ to replace $\{R; R\}$, which appears to contradict the explanation of equilibrium acquisition-FDI in terms of 'tariff-jumping' motives.

In models of equilibrium greenfield-FDI with segmented national product markets increasing t unambiguously increases a firm's 'incentive' to undertake greenfield-FDI abroad (see chapter 1 for elaboration of this point). Because national product markets are perfectly segmented, undertaking greenfield-FDI *only* affects a firm's profits from abroad (*ceteris paribus*). Foreign profits are (by definition) independent of t if greenfield-FDI is undertaken and *decreasing* in t if the foreign market is served by exporting from a domestic plant; therefore, the difference greenfield-FDI profits and exporting profits is increasing in t , creating the conventional tariff-jumping motive for greenfield-FDI.

In our modelling of acquisition-FDI the decision rule for acquisition-FDI (the GADR) compares the G-incumbents' combined profits to the acquirer's profits (which are independent of t because the potential entrant has two plants so international trade does not occur in the A subgame), which is a qualitatively different comparison to that for greenfield-FDI. Under $\{(1, R), (1, R); R\}$ the

derivative of the G-incumbents' expected profits with respect to t is

$$2 \cdot p \cdot (1-p) \cdot \left[p \cdot \frac{dR(0,t)}{dt} + (1-p) \cdot \frac{dR(t,c)}{dt} \right],$$

where $[\cdot]$ is a convex combination of $dR(0, t)/dt$ and $dR(t, c)/dt$. For small p the derivative approximately equals

$$2 \cdot p \cdot (1-p)^2 \cdot \frac{dR(t,c)}{dt} < 0,$$

so increases in t reduce the G-incumbents' profits under $\{(1, R), (1, R); R\}$ and strengthen the incentive to undertake (tariff-jumping) acquisition-FDI. This effect was observed for small p and large G, I in regions V and VI. However, for large p the derivative approximately equals

$$2 \cdot p^2 \cdot (1-p) \cdot \frac{dR(0,t)}{dt} \geq 0,$$

so increases in t increase the G-incumbents' profits under $\{(1, R), (1, R); R\}$ and weaken the incentive for acquisition-FDI. This latter effect occurs for large p and small I in region VI.²⁷ Aside from regions V and VI,

changes in t also cause switches between acquisition-FDI and G-equilibria involving no greenfield-FDI in region I, where the relationship is again perverse: *decreases* in t generate acquisition-FDI (because $dR(c, c+t)/dt \geq 0$).

In general, changes in μ affect equilibrium FDI flows and industrial structures for large p as follows. In small (region I) and medium-sized (regions II and III) markets the equilibrium industrial structures are identical to those for small p . In large markets (regions V, VI, VII and VIII) the equilibrium industrial structure is two MNEs, one created by acquisition-FDI, for large G, I . For small G, I the equilibrium industrial structure is either $\{R; R\}$ in 'very large' markets (regions VI and VIII) or the G-equilibrium (regions V and VII), where entry never occurs, both G-incumbents undertake R&D, and greenfield-FDI flows are either one-way or cross-hauled.

By comparing the small- and large- p cases, we can gain some intuition on the effects of changes in p on equilibrium industrial structures. In small (region I) and medium-sized (regions II and III) markets the equilibrium industrial structures are independent of p . In large markets (regions V, VI, VII and VIII) increases in p make acquisition-FDI 'more likely'. This is clear in region VIII, and also for small t in region VI and region V (if G large). Note, moreover, that there are *no* t, G, I where *decreasing* p switches the equilibrium industrial structure to include acquisition-FDI where previously the G-equilibrium was selected. To provide intuition on this (weak) positive relationship between p and acquisition-FDI flows, compare the incumbents' net revenues between the G and A subgames in region VIII. The probability that the acquirer earns net revenue of $R(0, c)$ in each country is $p \cdot (1 - p)$; the equivalent probability for the G-incumbents is $2 \cdot p \cdot (1 - p)^2$: the G subgame offers two chances to win both markets, but each is less likely than the acquirer's single chance. Clearly, $p \cdot (1 - p) > 2 \cdot p \cdot (1 - p)^2$ iff $p > 0.5$, which is merely a straightforward comparative mathematical property of the probabilities of winning the markets, so acquisition-FDI certainly arises in equilibrium in region VIII for $p > 0.5$ because acquisition *also* reduces the incumbents' sunk costs.

Proposition 1 summarises the comparative-statics effects on the equilibrium industrial structure of variations in p, μ, t, G, I that were discussed above.

Proposition 1. (i) A (weak) positive association exists between p and equilibrium intra-industry acquisition-FDI. (ii) The association between μ and equilibrium acquisition-FDI can be positive, negative, U-shaped or hump-shaped. (iii) The association between t and equilibrium acquisition-FDI is positive ('conventional') for small p but negative ('perverse') for large p . (iv) There are negative associations in equilibrium between G , I and (respectively) intra-industry greenfield-FDI flows and industry R&D spending. Increases in G can cause the substitution in equilibrium of acquisition-FDI for greenfield-FDI.

The equilibrium properties of the model described in Proposition 1 are clear from Figure 2.4 and Table 2.3 (and the preceding discussion). Two comments are in order. First, Proposition 1 refers to associations between structural variables and acquisition-FDI, rather than acquisition-FDI flows. Recall that the size and direction of acquisition-FDI flows are not explicitly determined in our model; therefore, Proposition 1 is best interpreted as highlighting associations between structural variables and the *occurrence of acquisition*. Second, although some of the associations in Proposition 1 (e.g. in part (ii)) can take several forms, this *does not* imply that they are indeterminate. For example, the form of the association between acquisition-FDI and μ is determined by p , t , G , I as follows: (a) *positive* for {large p , large t ; all G , I } and for {small p , large t , large G , I }; (b) *negative* for {small p , small t , small G , I }; (c) *U-shaped* for {small p , small t , large G , I } and for {large p , small t , all G , I }; and (d) *hump-shaped* for {small p , large t , small G , I }.

Figure 2.4 and Table 2.3 also allow us to substantiate a claim made in the Introduction: that by excluding strategies of greenfield-FDI from the determination of the threat point, previous models of equilibrium acquisition-FDI may 'misleadingly' predict the occurrence of acquisition-FDI in equilibrium. (Note that these models are 'misleading' in terms of their application to reality, where firms *can* undertake greenfield-FDI; they are correct in terms of their own assumptions on firms' strategy spaces.) Observe in region V of Figure 2.4 that if p is large then $\{R; R\}$ is selected over $\{(1, R), (1, R); R\}$. However, for sufficiently small G $\{(1, R), (2, R); \emptyset\}$ is selected over $\{R; R\}$. Therefore, if greenfield-FDI strategies were excluded, then $\{R; R\}$ would arise in equilibrium for large p in region V. However, if greenfield-FDI strategies are admitted, then (for sufficiently small G) $\{(1, R), (2, R); \emptyset\}$ is chosen over $\{(1, R), (1, R); R\}$ in the G subgame *and* over $\{R; R\}$ in the 'overall' game. Greenfield-FDI is used by one G -incumbent to deter entry and bolster the G -incumbents' profits, thereby rendering acquisition-FDI unprofitable. Therefore, in order to explain acquisition-FDI in equilibrium, greenfield-FDI strategies must also be included in the model.

2.4. Normative Analysis

In this Section we perform some illustrative welfare comparisons between the A- and G-equilibria. Our welfare concept is *global social welfare*, which is composed of total expected consumer surplus across both countries and total expected profits across the three firms. To keep the analysis tractable and brief, we concentrate on four distinct pairings of A- and G-equilibria that arise in Figure 2.4 (each is coded with a 'C' to represent 'comparison'):

C1. In region I of Figure 2.4 we compare the welfare properties of the G-equilibrium of $\{(1, N), (1, N); \emptyset\}$ to those of the counterpart A-equilibrium of $\{N; \emptyset\}$.

C2. In region II of Figure 2.4 we compare the welfare properties of the G-equilibrium of $\{(1, N), (1, N); \emptyset\}$ to those of the counterpart (and selected) A-equilibrium of $\{R; \emptyset\}$.

C3. In region III of Figure 2.4 we compare the welfare properties of the G-equilibrium of $\{(1, R), (1, R); \emptyset\}$ to those of the counterpart (and selected) A-equilibrium of $\{R; \emptyset\}$. (Note that $\{(1, R), (1, R); \emptyset\}$ is *not* a G-equilibrium below the lowest dashed line in Figure 2.4.)

C4. In region VIII of Figure 2.4 we compare the welfare properties of the G-equilibrium of $\{(2, R), (2, R); R\}$ to those of the counterpart A-equilibrium of $\{R; R\}$.

The welfare comparisons set out in C1 – C4 concentrate on small and medium-sized markets ($\mu < \text{RHS}(6)$ in Figure 2.4) and on very large markets ($\mu > \text{RHS}(19)$ in Figure 2.4). In each of C1 – C4 the A- and G-equilibria considered are symmetric (identical) across the two countries, so we can focus on *national* social welfare in a ‘representative’ country (which on both the consumer surplus and profit measures will be exactly half global social welfare).

First we consider consumer surplus in each pairing of A- and G-equilibria. Let

$$S[x_j] = \frac{\mu}{2} \cdot (1 - x_j)^2$$

denote consumer surplus in country j at a market price of x_j . (The $S[\cdot]$ expression gives the area of the triangle above the market price and below the national demand function in (1). We are implicitly assuming that the income effects of price changes are negligible, e.g. that the good in question represents a small share of the ‘representative’ consumer’s spending.) *Expected* consumer surplus in a given A- or G-equilibrium is the weighted sum of $S[\cdot]$ ’s, where the weights are the probabilities of the various possible (Bertrand) equilibrium market prices. Note that $S[x_j]$ is strictly decreasing in x_j on $x_j \in [0, 1)$ because price rises reduce consumer welfare. ($S[\cdot]$ is also strictly convex in x_j on the same domain because a given price rise is more harmful, the lower the initial price level since the scale of consumption is greater.)

The following results for expected consumer surplus, $ES[x_j]$, in the three possible A-equilibria are straightforwardly derivable:

$$\text{In } \{N; \emptyset\}, ES[x_j] = S[x^M(c)].$$

$$\text{In } \{R; \emptyset\}, ES[x_j] = p \cdot S[0.5] + (1-p) \cdot S[x^M(c)].$$

$$\text{In } \{R; R\}, ES[x_j] = p^2 \cdot S[0] + 2 \cdot p \cdot (1-p) \cdot S[\min\{c, 0.5\}] + (1-p)^2 \cdot S[c]$$

Note that $x^M(0) = 0.5$, so $S[0.5]$ is the consumer surplus associated with monopoly-pricing on the basis of a marginal cost of 0. Note also that $S[0.5] > S[x^M(c)]$ for all $c > 0$ because the equilibrium monopoly price is increasing in marginal cost. Expected consumer surplus rises as we move (successively) through the A-equilibria from $\{N; \emptyset\}$, to $\{R; \emptyset\}$, to $\{R; R\}$. (The comparison between $\{R; \emptyset\}$ and $\{N; \emptyset\}$ is straightforward because – as noted above – $S[0.5] > S[x^M(c)]$. To make the comparison between $\{R; R\}$ and $\{R; \emptyset\}$, rewrite $ES[\cdot]$ in $\{R; R\}$ as

$$p \cdot [p \cdot S[0] + (1-p) \cdot S[\min\{c, 0.5\}]] + (1-p) \cdot [p \cdot S[\min\{c, 0.5\}] + (1-p) \cdot S[c]]$$

and note that both terms in $[\cdot]$ are greater than the respective weights on p and $(1-p)$ in $ES[\cdot]$ under $\{R; \emptyset\}$.) This result is intuitive: extra R&D investments and tougher ‘competition’ (via entry) both benefit consumers.

Expected consumer surplus in the three G-equilibria in C1 – C4 is:

$$\text{In } \{(1, N), (1, N); \emptyset\}, ES[x_j] = S[\min\{c+t, x^M(c)\}].$$

$$\text{In } \{(1, R), (1, R); \emptyset\},$$

$$ES[x_j] = p^2 \cdot S[\min\{t, 0.5\}] + p \cdot (1-p) \cdot S[\min\{c+t, 0.5\}] \\ + p \cdot (1-p) \cdot S[\min\{c, x^M(t)\}] + (1-p)^2 \cdot S[\min\{c+t, x^M(c)\}]$$

(Here the weighted terms represent (successively) consumer surplus if both firms' R&D efforts succeed; if the domestic firm's R&D effort alone succeeds; if the foreign firm's R&D effort alone succeeds; and if both firms' R&D efforts fail.)

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

$$ES[x_j] = p^3 \cdot S[0] + 3 \cdot p \cdot (1-p)^2 \cdot S[\min\{c, 0.5\}] \\ + 3 \cdot p^2 \cdot (1-p) \cdot S[0] + (1-p)^3 \cdot S[c]$$

(Here the weighted terms represent (successively) consumer surplus if all three firms' R&D efforts succeed; if only one firm's R&D effort succeeds; if only one firm's R&D effort fails; and if all three firms' R&D efforts fail.)

As with the A-equilibria examined above, it is straightforward to show that expected consumer surplus rises as we move (successively) through the G-equilibria from $\{(1, N), (1, N); \emptyset\}$, to $\{(1, R), (1, R); \emptyset\}$, to $\{(2, R), (2, R); R\}$. (The proof is tedious, so we omit it; however, it involves rearranging one $ES[\cdot]$ expression so its weights are the same as those in the comparator, and then comparing the weighted terms across $ES[\cdot]$ expressions. See, for example, how we rearranged $ES[\cdot]$ in $\{R; R\}$ above to facilitate the comparison with $\{R; \emptyset\}$.) The intuition for these rises in consumer surplus is also the same as with the A-equilibria: extra R&D investments and tougher 'competition' (both via inward greenfield-FDI and de novo entry) both benefit consumers.

Before carrying out the welfare comparisons described in C1 – C4, the results of which are summarized below in Proposition 2, we consider total expected profits in each pairing of A- and G-equilibria. The useful feature for this purpose of the small and medium-sized markets considered in C1 – C3 is that entry occurs in neither the A- nor the G-equilibrium. Therefore, the comparison of total profits between the two equilibria has already been accomplished in our application of the GADR, (4). A simple way of undertaking the profit comparison in C4 is to note that the entrant firm makes higher expected profits in $\{R; R\}$ than in $\{(2, R), (2, R); R\}$, so a *sufficient* (but unnecessary) condition for total expected profits to be higher in $\{R; R\}$ is that the *incumbents* prefer $\{R; R\}$. This occurs for large (≥ 0.5) p (see the key to Figure 2.4).

We summarize the results of our welfare comparisons in C1 – C4 in Proposition 2.

Proposition 2. (i) *Within both the A and G subgames, increases in industry spending on R&D and greenfield-FDI increase (expected) consumer surplus.* (ii) *A sufficient condition for consumers to prefer the G- to the A-equilibrium is that industry spending on R&D is higher at the G-equilibrium.* (iii) *The welfare comparison of A- and G-equilibria often involves a Williamson (1968)-type trade-off between profits and consumer surplus.* (iv) *The possibility of Pareto improving (dominant) acquisition-FDI exists in small markets when industry R&D spending is larger at the A- than the G-equilibrium (i.e. in C2).*

We have proved part (i) of Proposition 2 comprehensively for the A subgame above; our analysis of the effects of changes in industrial structure on consumer surplus in the G subgame is limited to the three G-equilibria included in C1 – C4. However, it seems likely that (i) will hold generally within the G subgame because – within our modelling structure – increases in spending on R&D and greenfield-FDI both increase ‘competition’ (i.e. lower firms’ marginal costs). Part (ii) of Proposition 2 is clear from the consumer surplus comparisons in C3 and C4. (That consumers prefer $\{(1, R), (1, R); \emptyset\}$ to $\{R; \emptyset\}$ and $\{(2, R), (2, R); R\}$ to $\{R; R\}$ is both intuitive and easily demonstrated by using the types of manipulations we employed above to show that consumer surplus is higher under $\{R; R\}$ than $\{R; \emptyset\}$.) However, note that (ii) is *not* a necessary condition. For example, in C1 consumer surplus is strictly higher in $\{(1, N), (1, N); \emptyset\}$ than in $\{N; \emptyset\}$ iff $x^M(c) > c + t$ (despite the fact that no R&D is undertaken in either industrial structure) because the G-incumbents cannot monopoly-price in $\{(1, N), (1, N); \emptyset\}$. (If $c + t \geq x^M(c)$, consumers are indifferent between the A- and G-equilibria in C1.) Furthermore, in C2 consumers strictly prefer $\{(1, N), (1, N); \emptyset\}$ to $\{R; \emptyset\}$ (despite the fact that *more* R&D investment is undertaken at the A-equilibrium) for all p iff $c + t < 0.5$, which ensures $S[\min\{c + t, x^M(c)\}] > S[0.5]$ (the other end-point condition, $S[\min\{c + t, x^M(c)\}] \geq S[x^M(c)]$, automatically holds). If $c + t < 0.5$, then the equilibrium price at the duopolistic G-equilibrium will be less than that at the monopolistic A-equilibrium if the integrated firm’s R&D effort is successful.

We turn now to discuss parts (iii) and (iv) of Proposition 2. In part (iii) the Williamson trade-off referred to means that total expected profits are higher, but

consumer surplus lower, at the A-equilibrium than at the G-equilibrium. In all of C1 – C4 the occurrence of acquisition-FDI in equilibrium is sufficient for industry profits to be higher at the A-equilibrium than at the G-equilibrium (in C1 – C3 it is necessary too.) Acquisition-FDI ‘certainly’ (i.e. for all permissible parameter values) occurs in equilibrium in C2 and C3, and it occurs in equilibrium in C1 iff $x^M(c) > c + t$ and in C4 iff p is ‘large’ (≥ 0.5). On the other hand, consumer surplus is ‘certainly’ lower under acquisition-FDI in C3 and C4. Consumer surplus is lower under acquisition-FDI in C1 iff $x^M(c) > c + t$ (i.e. iff acquisition-FDI arises there in equilibrium); and in C2 consumer surplus is lower for all p under acquisition-FDI iff $c + t < 0.5$ (established above). Therefore, the occurrence of acquisition-FDI in equilibrium in C1, C3 and C4 is accompanied by a loss of consumer welfare relative to the alternative G-equilibrium (the Williamson trade-off), and the occurrence of acquisition-FDI in equilibrium in C2 reduces consumer welfare for all p iff $c + t < 0.5$. These differential welfare properties (in terms of profits and consumer surplus) of the A- and G-equilibria could be used to justify a role for public policy in regulating acquisition-FDI flows if the weight placed on consumer surplus in the social welfare function is sufficiently large.

However, there are circumstances in our model when the A-equilibrium Pareto dominates the G-equilibrium so no Williamson trade-off exists (part (iv) of Proposition 2): both total profits and consumer surplus are higher at the A-equilibrium. In C2 (region II of Figure 2.4) acquisition-FDI clearly raises total profits (relative to the G-equilibrium ‘threat point’). Furthermore, for sufficiently large p expected consumer surplus is higher under $\{R; \emptyset\}$ than $\{(1, N), (1,$

$N; \emptyset\}$ iff $c + t > 0.5$ (i.e. the equilibrium monopoly price if R&D is successful in $\{R; \emptyset\}$ is below the equilibrium price in $\{(1, N), (1, N); \emptyset\}$).²⁸ Therefore, the A-equilibrium *can* Pareto dominate the G-equilibrium if industry R&D spending is larger following acquisition-FDI than it would be otherwise. This gives some (limited) support to the argument that acquisition-FDI can foster ‘technological progress’ (the benefits of which outweigh the costs of monopolization) and qualifies our result above (part (iii)) on the Williamson trade-off between the A- and G-equilibria (and its related policy implications).

The finding that for given parameter values R&D can occur in A- but not in G-equilibrium is perhaps counter-intuitive because the G subgame is ‘more competitive’: for example, Aghion et al. (2001, p. 468) argue that ‘an increase in PMC [product market competition] can stimulate R&D by increasing the incremental profit from innovating, that is, by strengthening the motive to innovate in order to *escape* competition with “neck-and-neck” rivals’. The key to the puzzle lies in comparing firms’ ‘incentives’ to innovate (i.e. increases in net revenues) in the A and G subgames. In region II of Figure 2.4 entry by firm 3 into the A subgame is blockaded (because $RHS(5) > RHS(10)$), so the acquirer’s ‘incentive’ to innovate is $2 \cdot p \cdot [R^M(0) - R^M(c)]$; a G-incumbent’s ‘incentive’ to choose $(1, R)$ over $(1, N)$ in response to $(1, N)$ (given that 3 will subsequently choose \emptyset) is $p \cdot [R(0, c + t) - R(c, c + t) + R(t, c)]$. The ‘incentive’ to innovate is stronger for the acquirer if and only if condition (A1) in the Appendix fails (this is also required for the *existence* of region II), which occurs for ‘sufficiently large’ t (see Figure A2.2). If t is very large and no greenfield-FDI is undertaken, then for either R&D outcome a G-incumbent investing in R&D will be able to

monopoly-price at home but will export nothing. Therefore, such a firm undertaking R&D would expect to earn exactly *half* the net revenues of the acquirer undertaking R&D in the A subgame. This limiting example highlights clearly the source of the acquirer's stronger 'incentive' to innovate in region II of Figure 2.4: its larger output base, over which a process innovation can be spread, due to the elimination ('jumping') of trade costs following acquisition-FDI. The cause of Pareto dominant acquisition-FDI in our model (an 'output base' effect) differs from that in Horn and Persson (2001b), where mergers are associated with savings in fixed and variable production costs ('synergies').

2.5. Concluding Comments

By building a model where the *form* of FDI (greenfield-FDI or acquisition-FDI) is endogenously selected, the key aim of this chapter was to isolate the determinants of the equilibrium form of FDI. Furthermore, by allowing other aspects of industrial structure to be endogenously determined in equilibrium (i.e. firms' investment levels in R&D and the number of firms), our modelling structure can be used to investigate the differential relationships between the two forms of FDI and those wider industry characteristics. In our illustrative welfare analyses (section 2.4), the inclusion of endogenous R&D decisions also allows us to examine whether acquisition-FDI can sometimes be justified (despite the welfare costs associated with possible monopolization) because it fosters 'technological development' by increasing industry R&D spending.

Some of our key positive results are:

- Acquisition-FDI 'often' (i.e. for 'large' sets of parameter values) arises in equilibrium in small and medium-sized markets, where it is 'unlikely' to encourage subsequent (rent-dissipating) de novo entry.
- For greenfield-FDI to arise in equilibrium, two conditions appear necessary (see Table 2.3): a 'large' market size; and 'small' sunk costs of greenfield-FDI and R&D. (In large markets the profitability of acquisition-FDI is likely to be reduced by subsequent de novo entry, which is 'more likely' if the incumbents choose acquisition-FDI than if they choose exporting or greenfield-FDI.)
- The strategic use of greenfield-FDI by the incumbents to deter de novo entry by the 'outside' firm may prevent acquisition-FDI from arising in equilibrium by bolstering the incumbents' 'disagreement profits' and rendering an acquisition unprofitable. This finding illustrates the importance of analysing both forms of FDI simultaneously: the option of undertaking greenfield-FDI makes acquisition-FDI unprofitable in equilibrium, a point that would be missed in models concentrating exclusively on one type of FDI.
- Increases in the sunk costs of greenfield-FDI and R&D can cause the substitution (in large markets) of acquisition-FDI for greenfield-FDI in equilibrium. (Because the integrated firm formed by acquisition-FDI runs only one research lab by assumption, undertaking acquisition-FDI allows the incumbent firms to economise on R&D investments.)
- The association between trade costs and equilibrium acquisition-FDI is positive (as in the case of 'tariff-jumping' greenfield-FDI) if the

probability of R&D success is small but *negative* if it is large. For a large probability of R&D success, we show that increases in trade costs offer heightened protection to rival national firms in their home markets, thus (potentially) rendering integration via acquisition-FDI unprofitable.

We compared (for a limited set of parameter values) the welfare properties of industrial structures associated with acquisition-FDI to those of the corresponding 'threat point' equilibria (i.e. where the incumbents choose between exporting and greenfield-FDI as means of serving the foreign product market). We found some evidence that acquisition-FDI flows are associated with a Williamson (1968)-type welfare trade-off between industry profits and consumer surplus, which could suggest a role for public policy in protecting consumers' interests in the presence of acquisition-FDI flows. However, it is not true that acquisition-FDI *always* reduces consumer welfare (relative to the 'threat point'): when acquisition-FDI raises industry R&D spending, it can also raise consumer surplus despite monopolization. (Nevertheless, such Pareto dominant acquisition-FDI, which could be viewed as verifying the 'failing firm' defence of international takeovers, occurs in very special circumstances.)

A general conclusion of this chapter is that greenfield- and acquisition-FDI are theoretically quite distinct (in terms of both the positive and the normative aspects of the industrial structures that they are associated with), which casts doubt on the legitimacy of many analyses that treat FDI as a homogeneous flow of funds. However, further work is needed to test the robustness both of this general conclusion and of our more specific results. Our modelling structure is

relatively stylised, and future work will attempt to relax some of our assumptions. In particular, the implicit assumption that a global 'competition authority' permits only one possible takeover (i.e. the integration of the two incumbent firms), which requires the 'outside' firm to use de novo entry, could be relaxed by using the co-operative game-theoretic methods of Horn and Persson (2001a, 2001b) to analyse equilibrium industrial structures while continuing to permit greenfield-FDI strategies.

2.6. Endnotes.

¹ By using the term ‘acquisition-FDI’, we have implicitly identified all non-greenfield-FDI with international take-overs. However, there are in reality a variety of activities that are neither greenfield investment nor cross-border take-overs, which nevertheless would generate FDI flows as conventionally measured: e.g. the partial acquisition of a foreign firm or a cross-border merger. Essentially, the problem is that the distinction between foreign portfolio investment and FDI can be made sharper in theory than it is in practice. (See the Appendix to Julius (1990) for an accessible discussion of the compilation methodology for FDI data: the key point is that FDI data are constructed to reflect the reach of corporate *control* overseas rather than *outright ownership*, and a complete acquisition is not necessary to exert some control.) For analytical clarity, we restrict the spectrum of forms of FDI to greenfield investment versus take-over (greenfield-FDI versus acquisition-FDI), which represents the most interesting distinction from an industrial-organization viewpoint; and this is justifiable because they are dominant components of FDI data: e.g. ‘[l]ess than 3 per cent of the total number of cross-border M&As are officially classified as mergers... the rest are acquisitions’ (UNCTAD, 2000, p. 15).

A related point is that FDI data understate the growth of international production because of the balance-of-payments methodology underlying them. (Only funds passing through the balance-of-payments accounts are included in reported FDI data, so foreign expansion financed by funds raised in the host country is omitted.) Again, our analysis abstracts from this problem, which is primarily empirical.

² Two qualifying observations are in order. First, these models focus on the determinants of international *integration* between rival firms (‘equilibrium ownership structures’ in the terminology of Horn and Persson), rather than on international take-overs (and thus acquisition-FDI) per se. Because take-overs are a strict subset of all possible forms of interfirm integration (e.g. integration could also arise via merger), the emergence of integration in equilibrium is a necessary but insufficient condition for a flow of acquisition-FDI. (A further necessary

condition for acquisition-FDI is that the *owners* of the target live in a different country to those of the predator firm.) Therefore, what we term 'acquisition-FDI' could be relabelled 'integration-FDI'. Second, in an international oligopoly with more than two incumbent firms (as modelled by Horn and Persson) a formal analysis of equilibrium ownership structures requires consideration of *all* possible configurations of the incumbents within larger integrated units, rather than just one potential acquisition in isolation. However, because our modelling structure contains only two incumbents, these complications need not concern us. Furthermore, the subsequent arguments in the main text concerning the exclusion of greenfield-FDI can easily be extended to the Horn/Persson case.

³ Indeed, it is a striking fact that models where either greenfield- or acquisition-FDI arises endogenously invariably omit the second form of FDI by assumption (e.g. compare the Horstmann and Markusen (1992) model of equilibrium greenfield-FDI with the Barros and Cabral (1994) model of equilibrium acquisition-FDI).

⁴ Indeed, many analyses see this 'concentration effect' as the key distinction between the two forms of FDI: e.g. 'green-field entry by the MNE adds a new enterprise unit to the national market, whereas entry by acquisition does not' (Caves, 1996, p. 69).

⁵ A further necessary assumption for this example is that only the two firms mentioned have the competence to produce the good in question (i.e. there are no third firms).

⁶ Note that under Bertrand competition the foreign firm will not export in equilibrium, because the lower-cost local firm will serve the entire market. However, its ability to export does affect equilibrium outcomes. Furthermore, this effect would also operate if Cournot competition were assumed, although it would not be as pronounced. Under Cournot competition the foreign firm's decision to export would create a monopoly equilibrium in the host country only if the local firm's monopoly price is less than $c + t$: otherwise, monopolistic

behaviour by the local firm will induce the foreign firm to export positive quantities to the host country, which will itself undermine the monopoly equilibrium (i.e. monopolistic behaviour is not a Nash equilibrium).

⁷ For example, Schenk (1999, pp. 187-89) catalogues the 'persistent love affair with mergers and corporate bigness' (p. 187) that has long characterised government policies worldwide. Two recent examples merit specific mention. During the 1980s, the Reagan administration promoted horizontal mergers, arguing inter alia that only large firms would be able to finance the high R&D bills necessary for success. More recently, it appears that the 1992 Single Market Programme in Europe was in part viewed by the European Commission as a vehicle for restructuring European industry, in order to create 'large pan-European firms able to compete on a par with their US or Japanese rivals' (Geroski, 1989, p. 29, cited in Schenk, 1999, p. 188).

⁸ Therefore c must exceed the monopoly price associated with zero marginal cost.

⁹ $R^M(c)$ denotes the revenue net of variable costs of a monopolist with a marginal cost of c . It is introduced formally in Section 2.2.

¹⁰ These results are easily verifiable. If its rival does R&D, a firm will never do R&D itself, because that would result in a market price of 0 alongside sunk costs of I . However, if its rival does not undertake R&D, a firm will do R&D if it offers a positive profit, i.e. iff $R^M(0) - I > 0$. Therefore, for $R^M(0) > I$, the game exhibits the characteristics of a game of 'chicken'.

¹¹ This critical I -value is $R^M(0)$ in the duopoly but only $R^M(0) - R^M(c)$ for the monopolist. An innovating duopolist benefits not only from zero marginal cost, but also from the removal of competitive pressure. (See Stenbacka (1992) for a complementary analysis within the context of Cournot competition and R&D spillovers.)

¹² The decision rule uses a strict inequality to allow for infinitesimal costs of administering the take-over.

¹³ 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 the potential entrant possesses pre-existing but highly (productively) inefficient plants in both countries, our model incorporates a von Weizsäcker-type entry decision for the potential entrant *without introducing a location decision*. This restriction on the potential entrant'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 the potential entrant must sink an investment of G to establish each plant). However, the question of how to interpret entry by the potential entrant remains. A neat interpretation is to view the potential entrant 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.

¹⁴ Note that if firm 3 enters the industry, its marginal cost is restricted to $\{0, c\}$ because firm 3 has two plants by assumption.

¹⁵ The material in this Section is developed more fully in Sections 1.2.2 and 1.2.3 of chapter 1.

¹⁶ Net revenue is sometimes called 'variable profit'.

¹⁷ Firm i 's net revenue if it sets a price of x_i and serves the entire market is $\mu(1 - x_i) \cdot (x_i - c_i)$, which is strictly concave in x_i with a maximum at $x_i = x^M(c_i)$. Therefore, for $x_i < x^M(c_i)$, increases in x_i will increase i 's net revenue; and if i is constrained to set x_i below $x^M(c_i)$, it will optimally set x_i as close to $x^M(c_i)$ as possible. See Vives (1999, p. 123 and p. 368, n. 8 on the 'open set problem').

¹⁸ This definition is formally identical to Definition 2 in chapter 1.

¹⁹ Fudenberg and Tirole's (1984) analysis of investment behaviour in anticipation of entry is really only tangentially applicable here. Fudenberg/Tirole examined a duopolist's incentives to invest in shifting its best-response function under a variety of assumptions about the nature of competition (strategic complements vs. substitutes) and the effects of investment (which way the best-response function shifts). However, in their model only one firm could vary its level of investment and the investment decision variable was continuous; whereas our analysis has both firms undertaking discrete investment projects. Nevertheless, the investment incentives in our model accord with Fudenberg/Tirole's conclusions when investment makes the investor 'tough' and competition is in strategic complements. Furthermore, Fudenberg/Tirole use the open-loop equilibrium (where all players move simultaneously or cannot observe preceding moves), rather than the blockaded case, as a benchmark

²⁰ $\text{RHS}(5) > \text{RHS}(7)$ for $p \neq 0$ iff $2 \cdot [R^M(0) - R^M(c)] - R(0, c) > 0$. For $c \geq 0.5$ $R(0, c) = R^M(0)$, so the inequality becomes $R^M(0) - 2 \cdot R^M(c) > 0$, which holds for all $c > 1 - \sqrt{0.5} \approx 0.29$. For $c \leq 0.5$ $R(0, c) = \mu \cdot (1 - c) \cdot c$, and the inequality holds for all c .

²¹ Note that the interval (L_β, U_β) is non-empty iff $p > 0.5$.

²² For $p \neq 0$ $U_\beta > U_\alpha$ iff $R(0, c) > R^M(0) - R^M(c)$. This clearly holds for $c \geq 0.5$ when $R(0, c) = R^M(0)$. For $c \leq 0.5$ the inequality holds iff $c \cdot (2 - 3 \cdot c) > 0$, which is satisfied when $c < 2/3$ (given that $c > 0$ in assumption (A)).

²³ It is important to recognise the distinction between Arrow's 'replacement effect' and the 'efficiency effect' (see Tirole, 1988, pp. 392-3). The 'replacement effect' compares a monopolist's incentive to innovate to that of a firm *within* a duopoly: the latter is (generally) greater because the innovator can 'escape competition'. However, the 'efficiency effect' compares a potential entrant's

incentive to *become* a duopolist (via entry) to an incumbent's incentive to remain a monopolist: the latter is (generally) greater because monopoly profits exceed industry profits under duopoly.

²⁴ Assumptions (B),(C) are unnecessary to generate Figure 2.3. However, the necessary-and-sufficient conditions are considerably more intractable than (B) and (C).

²⁵ Assumption (B) as presented here is identical to assumption (B)' in chapter 1.

²⁶ *Proof.* When $G = I$ (A8) becomes $2 \cdot R(0, c) - 2 \cdot R(t, c) - R(0, t) > 0$. When $t = 0$, LHS = 0. Now consider progressive rises in t from 0 to c . $\partial \text{LHS} / \partial t > 0$ requires $-2 \cdot (\partial R(t, c) / \partial t) > \partial R(0, t) / \partial t$. For $t \leq 0.5$, $R(0, t) = \mu \cdot (1 - t) \cdot t$ and $R(t, c) = \mu \cdot (1 - c) \cdot (c - t)$ for $x^M(t) \geq c$ and $R^M(t)$ for $x^M(t) \leq c$. Given either functional form for $R(t, c)$, $\partial \text{LHS} / \partial t > 0$. (Note that $\partial \text{LHS} / \partial t > 0$ when $R(t, c) = \mu \cdot (1 - c) \cdot (c - t)$ iff $t > c - 0.5$, which is implied by $x^M(t) \geq c$ for $t > 0$.) For $t \geq 0.5$, $R(0, t) = R^M(0)$, so $\partial R(0, t) / \partial t = 0$ and therefore $\partial \text{LHS} / \partial t > 0$.

²⁷ To understand these results intuitively, note that an increase in t affects an incumbent's profits under $\{(1, R), (1, R); R\}$ in two, opposing ways: it reduces the incumbent's net revenues abroad when both its rivals' R&D efforts fail (i.e. $dR(t, c)/dt < 0$), but it weakly increases the incumbent's domestic net revenues when both incumbents innovate successfully by offering greater protection from import competition (i.e. $dR(0, t)/dt \geq 0$).

²⁸ $t > 0.5 - c$ is compatible with the existence of region II in Figure 2.4. (A1) fails for sufficiently large t : see Figure A4.2 in the Appendix.

2.7. Appendix.

2.7.1. Equilibrium Industrial Structures

Our derivation of equilibrium industrial structures proceeds in two steps. In step one we locate the inter-regional boundaries in the A subgame (Figure 2.2) relative to those in the G subgame (Figure 2.3), so that both the A- and the G-equilibria are fixed for given parameter values. In step two we determine the equilibrium industrial structure by using the GADR to select between the A- and G-equilibria.

Step 1. We begin by locating RHS(7) on Figure 2.3. $\text{RHS}(7) > \text{RHS}(10)$ iff

$$\begin{aligned} R(0, c+t) + R(t, c) - R(c, c+t) - R(0, c) \\ - \{2 \cdot [R^M(0) - R^M(c)] - R(0, c)\} > 0 \end{aligned} \quad (\text{A1})$$

From n. 20 $\{\cdot\} > 0$, so (A1) is more restrictive than assumption (B). However, (A1) is satisfied by some (c, t) -pairs within assumption (A): when $t \cong 0$, (A1) holds iff $R(0, c) - R^M(0) + R^M(c) > 0$, which was shown to be satisfied for all c in n. 22. We isolate the set of (c, t) -pairs that satisfies assumption (B) in the Appendix of chapter 1. There are two immediate problems in analysing assumption (B) (and constraints (A1), (A8) and (A9) on t, c that we introduce in this Appendix): first, t, c do not enter assumption (B) explicitly; and, second, each of the five nonzero realisations of $R(\cdot)$ takes one of two possible functional forms, depending on whether the Bertrand equilibrium involves undercutting or monopoly-pricing. Therefore

$$R(0,t) = \begin{cases} \mu \cdot (1-t) \cdot t & \text{for } t \leq 0.5 \\ R^M(0) & \text{for } t \geq 0.5 \end{cases}$$

$$R(0,c) = \begin{cases} \mu \cdot (1-c) \cdot c & \text{for } c \leq 0.5 \\ R^M(0) & \text{for } c \geq 0.5 \end{cases}$$

$$R(0,c+t) = \begin{cases} \mu \cdot (1-c-t) \cdot (c+t) & \text{for } c+t \leq 0.5 \\ R^M(0) & \text{for } c+t \geq 0.5 \end{cases}$$

$$R(t,c) = \begin{cases} \mu \cdot (1-c) \cdot (c-t) & \text{for } c \leq x^M(t) \\ R^M(t) & \text{for } c \geq x^M(t) \end{cases}$$

$$R(c,c+t) = \begin{cases} \mu \cdot (1-c-t) \cdot t & \text{for } c+t \leq x^M(c) \\ R^M(c) & \text{for } c+t \geq x^M(c) \end{cases}$$

Figure A2.1 divides (c, t) -space below the 45° line (recall that assumption (A) is maintained throughout) up into 9 distinct regions. In each region the functional form of $R(\cdot)$ is fixed, so constraints on t, c can be written explicitly.

[FIGURE A2.1 IS OVERLEAF]

Key to Figure A2.1

Region	Form of $R(\cdot)$ (N.B. U = 'undercutting', M = 'monopoly-pricing')				
	$R(0, t)$	$R(0, c)$	$R(0, c + t)$	$R(t, c)$	$R(c, c + t)$
I	U	U	U	U	U
II	U	U	M	U	U
III	U	U	M	U	M
IV	U	M	M	U	U
V	U	M	M	U	M
VI	M	M	M	U	M
VII	U	M	M	M	U
VIII	U	M	M	M	M
IX	M	M	M	M	M

Using the specific functional forms of $R(\cdot)$, we can derive the sets of t - and c -values where our constraints on t, c hold for each region in Figure A2.1. These sets are defined in Table A2.1 and plotted in Figure A2.2.

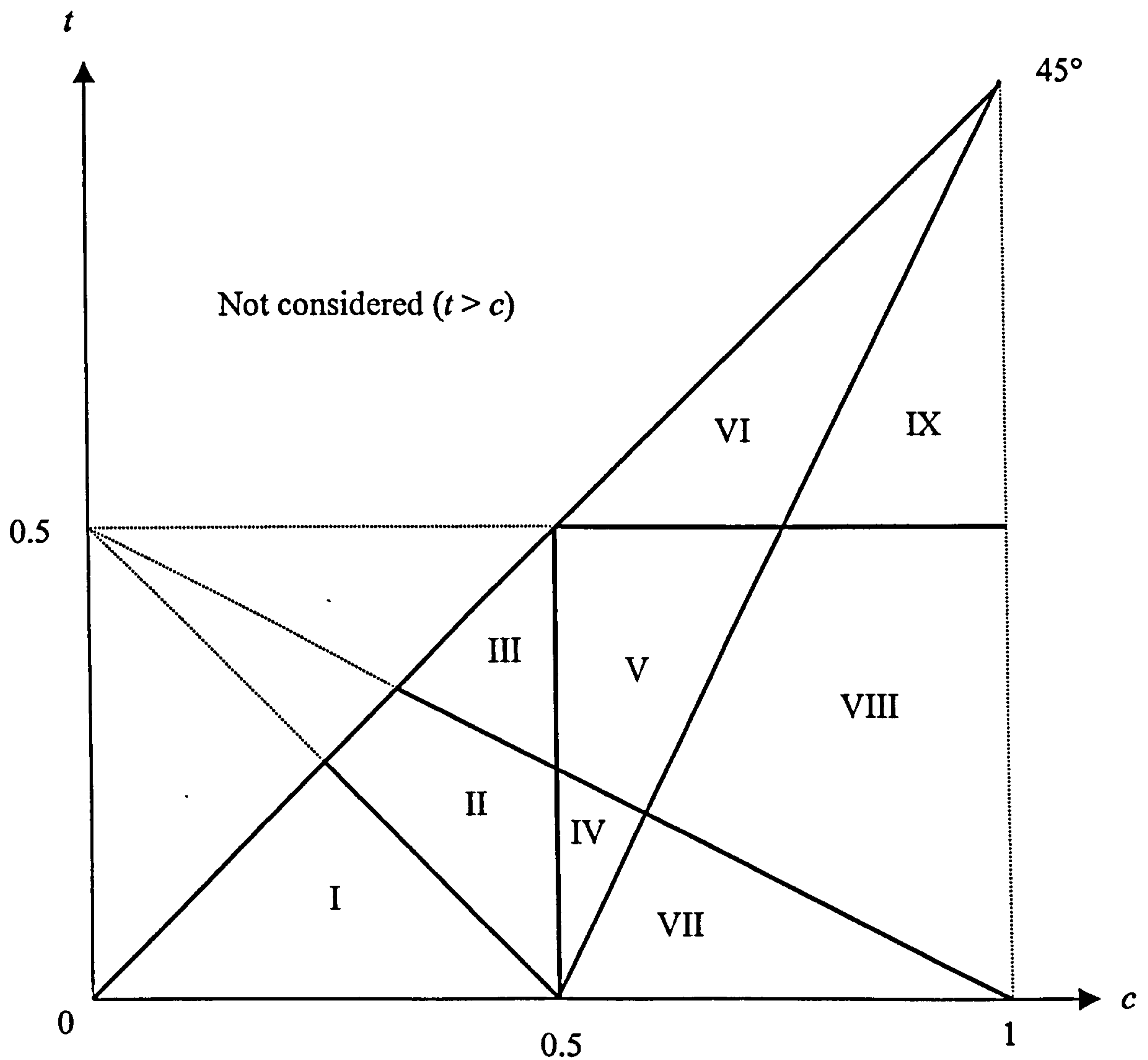


Figure A2.1: Feasible set of c - and t -values

Inter-regional boundaries: I/II boundary is $c + t = x^M(0) = 0.5$; II/III, IV/V and VII/VIII boundaries are $c + t = x^M(c)$; IV/VII, V/VIII and VI/IX boundaries are $c = x^M(t)$.

Table A2.1: Explicit constraints on t , c . (See notes below.)

Region	Constraints on t , c imposed by assumptions (B), (A1), (A8) and (A9).
I	<p>(B) holds iff $t < c \cdot (1 - c)$ for all $c \in (0, 0.293]$</p> <p>(A1) holds iff $t < c \cdot (1 - 1.5 \cdot c)$ for all $c \in (0, 0.333]$</p> <p>(A8) holds iff $t > \frac{2 - c - \sqrt{4 - 8 \cdot c + 7 \cdot c^2}}{2}$ for all $c \in (0, 0.392]$</p> <p>(A9) holds iff $t > \frac{(1 - c) \cdot (5 \cdot c - 1)}{2 \cdot (1 + c)}$ for all $c \in (0, 0.333]$</p>
II	<p>(B) holds iff $t < \frac{2 \cdot (1 - c) - \sqrt{4 \cdot (1 - c)^2 - 1}}{2}$ for all $c \in [0.293, 0.423]$</p> <p>(A1) holds iff $t < \frac{2 \cdot (1 - c) - \sqrt{4 \cdot (1 - c)^2 - 1 + 2 \cdot c^2}}{2}$ for all $c \in [0.333, 0.5]$</p> <p>(A8) holds iff $t > \frac{3 \cdot (1 - c) - \sqrt{7 - 18 \cdot c + 13 \cdot c^2}}{4}$ for all $c \in [0.392, 0.5]$</p> <p>(A9) is violated for all (t, c) that satisfy (A1)</p>
III	<p>(B) holds iff $t < \frac{c \cdot (2 - c)}{4 \cdot (1 - c)}$ for all $c \in [0.423, 0.5]$</p> <p>(A1) is violated throughout</p> <p>(A8), (A9): N/A</p>
IV	<p>(B) holds throughout</p> <p>(A1) holds iff $t < \frac{2 \cdot (1 - c) - \sqrt{4 \cdot (1 - c)^2 - 1 + 2 \cdot c^2}}{2}$ for all $c \in [0.5, 0.561]$</p> <p>(A8) holds iff $t > \frac{3 \cdot (1 - c) - \sqrt{7 - 18 \cdot c + 13 \cdot c^2}}{4}$ for all $c \in [0.5, 0.543]$</p> <p>(A9) is violated throughout</p>
V	<p>(B) holds iff $t < \frac{1}{4} \cdot (5 \cdot c - 1)$ for all $c \in [0.5, 0.6]$</p> <p>(A1) is violated throughout</p> <p>(A8), (A9): N/A</p>
VI	<p>(B) holds iff $t < \frac{1}{4} \cdot (5 \cdot c - 1)$ for all $c \in [0.6, 1)$</p> <p>(A1) is violated throughout</p> <p>(A8), (A9): N/A</p>
VII	<p>(B) holds throughout</p> <p>(A1) holds iff $t < \frac{3 - 2 \cdot c - \sqrt{-6 \cdot c^2 + 8 \cdot c - 1}}{5}$ for all $c \in [0.561, 1)$</p> <p>(A8) holds iff $t > \frac{5 - 4 \cdot c - \sqrt{7 - 4 \cdot c - 2 \cdot c^2}}{9}$ for all $c \in [0.543, 1)$</p> <p>(A9) is violated throughout</p>

Table A2.1 continued...

Region	Constraints on t, c imposed by assumptions (B), (A1), (A8) and (A9).
VIII	(B) holds throughout (A1) is violated throughout (A8), (A9): N/A
IX	(B) holds throughout (A1) is violated throughout (A8), (A9): N/A

(Notes: Extreme c -values in each region were calculated using *Maple*. Constraints (A8) and (A9) are only applicable in regions where assumption (A1) is *not* 'violated throughout'. Exception of (A8), which is used between RHS(11) and RHS(6).)

[FIGURE A2.2 IS OVERLEAF]

If (A1) is satisfied (resp. violated), then RHS(7) lies universally above (resp. below) RHS(10). In the case where (A1) holds, we can place upper bounds on the position of RHS(7). We show below that $\text{RHS}(15) > \text{RHS}(6)$ on $p \in (0, 1)$, so $\text{RHS}(15) > \text{RHS}(7)$ because $\text{RHS}(6) > \text{RHS}(7)$. We have $\text{RHS}(14) > \text{RHS}(7)$ iff

$$2 \cdot \{2 \cdot [R^M(0) - R^M(c)] - R(0, c)\} + [2 \cdot R(0, c) - R(0, t)] \cdot p > 0 \quad (\text{A2})$$

and $\text{RHS}(12) > \text{RHS}(7)$ iff

$$2 \cdot [R^M(0) - R^M(c)] - \frac{I}{G} \cdot [R(0, c) - R(t, c)] > 0 \quad (\text{A3})$$

A sufficient condition for both (A2) and (A3) to hold is $2 \cdot [R^M(0) - R^M(c)] - R(0, c) > 0$, which was shown to hold for all c in n. 20. (To verify this sufficiency claim, note that $[2 \cdot R(0, c) - R(0, t)] \cdot p \geq 0$ for all $p \in [0, 1]$ in (A2) and that $R(0, c) > \frac{I}{G} \cdot [R(0, c) - R(t, c)]$ in (A3) from assumption (C).)

Therefore, $\text{RHS}(14), \text{RHS}(12) > \text{RHS}(7)$.

Finally, we need to locate RHS(7) in the case where (A1) holds relative to RHS(11). $\text{RHS}(7) > \text{RHS}(11)$ iff

$$R(0, c+t) + R(t, c) - R(c, c+t) - R(0, c) - \{2 \cdot [R^M(0) - R^M(c)] - R(0, c)\} - [R(0, c+t) + R(t, c) - R(c, c+t) - R(0, t)] \cdot p > 0 \quad (\text{A4})$$

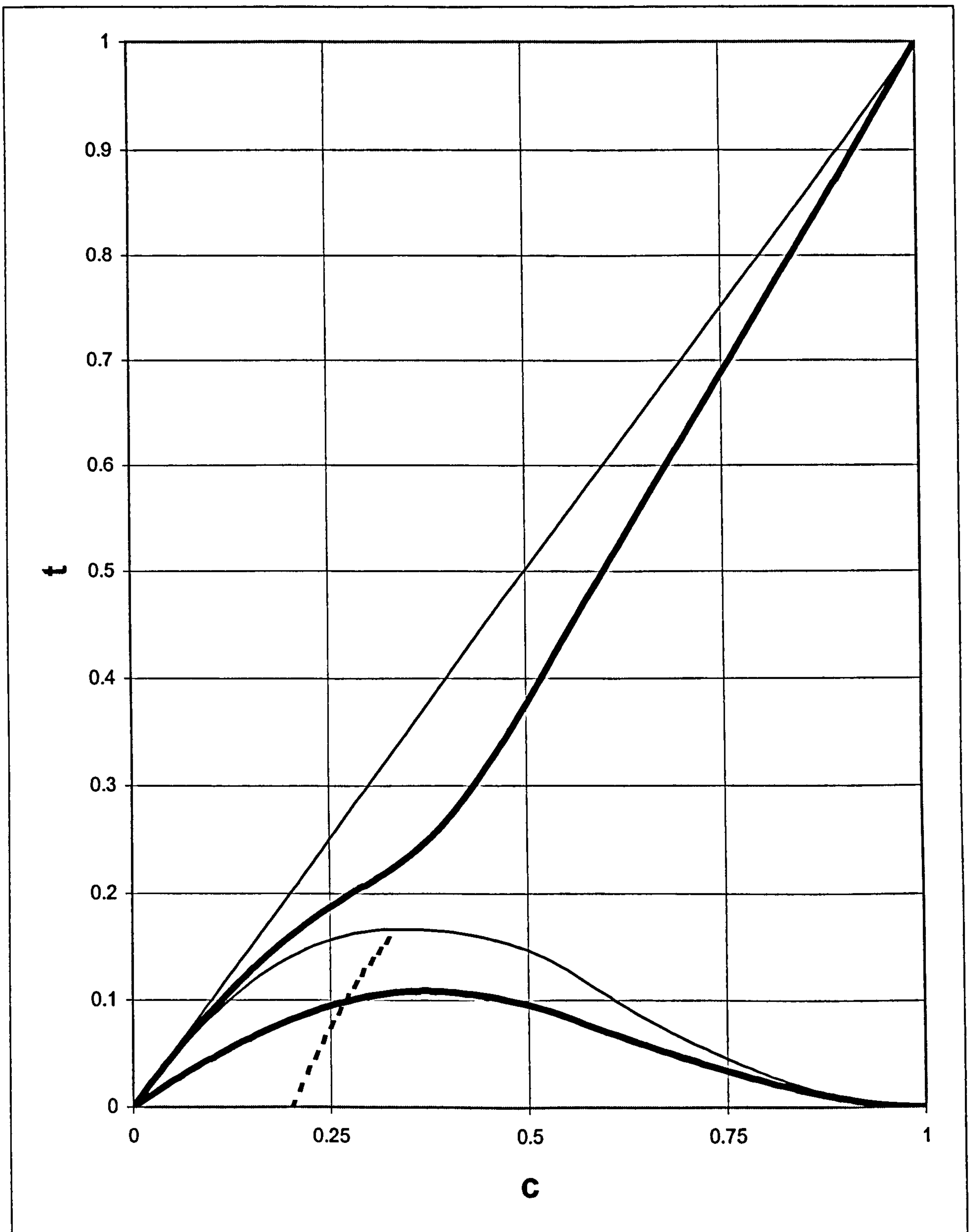


Figure A2.2: Feasible (c, t) -pairs

(c, t) -pairs above the 45° line are ruled out by the maintained assumption (A). The upper (resp. lower) bold line is the locus of (c, t) -pairs where constraint (B) (resp. (A8)) binds. The dashed (resp. light, solid) line is the locus of (c, t) -pairs where constraint (A9) (resp. (A1)) binds. (B), (A1) hold *below* the lines; (A8), (A9) hold *above* the lines.

LHS(A4) is linear in p . At $p = 0$ (A4) is identical to (A1), so if (A1) holds then $\text{RHS}(7) > \text{RHS}(11) > \text{RHS}(10)$ for small p . (If (A1) fails, then $\text{RHS}(11) > \text{RHS}(10) > \text{RHS}(7)$ for small p .) At $p = 1$ (A4) becomes $2 \cdot [R^M(0) - R^M(c)] - R(0, t) < 0$, which cannot hold because (from n. 20) $2 \cdot [R^M(0) - R^M(c)] - R(0, c) > 0$ and $R(0, c) \geq R(0, t)$ under assumption (A).

We conclude that $\text{RHS}(7)$ takes one of two possible positions in Figure 2.3, depending on whether (A1) holds. If (A1) holds, then $\text{RHS}(7)$ lies between $\text{RHS}(11)$ and $\text{RHS}(15)$ for small p , and between $\text{RHS}(10)$ and $\text{RHS}(11)$ for large p . (Note in this case that regions IV and V in Figure 2.3 will lie entirely above $\text{RHS}(7)$.) If (A1) fails, then $\text{RHS}(10) > \text{RHS}(7)$ for all p . As a matter of record, we show in the main text that the latter case (i.e. (A1) violated) is 'more general' given our assumptions in (A) and (B) on t, c . (Note that it is impossible for $\text{RHS}(7)$ to lie (strictly) between $\text{RHS}(10)$ and $\text{RHS}(11)$ for all p . Both $\text{RHS}(7)$ and $\text{RHS}(10)$ are rectangular hyperbolas, so they cannot intersect on $p \in (0, 1]$; however, $\text{RHS}(11) \rightarrow \text{RHS}(10)$ as $p \rightarrow 0$. Therefore, if $\text{RHS}(7) \in (\text{RHS}(10), \text{RHS}(11))$ at $p = 1$, $\text{RHS}(7)$ must intersect $\text{RHS}(11)$ at some sufficiently small p .)

We turn now to positioning $\text{RHS}(6)$ on Figure 2.3. $\text{RHS}(6)$ is more straightforward to position than $\text{RHS}(7)$. It is straightforward to show that for $p \neq 0, 1$ $\text{RHS}(15) > \text{RHS}(6)$ iff $R(0, c) > R(0, t)$, i.e. iff $t < 0.5$. (Therefore, for $t \geq 0.5$ $\text{RHS}(15) = \text{RHS}(6)$.) On the lower side, $\text{RHS}(6) > \text{RHS}(13)$ for $p \neq 0, 1$ iff $R(t, c) > 0$, which is guaranteed by assumption (A). $\text{RHS}(6) > \text{RHS}(11)$ iff

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

which holds because $[\cdot] > 0$ from assumption (B).

Figures A2.3 and A2.4 sum up the results of step one by plotting $\text{RHS}(6)$ and $\text{RHS}(7)$ relative to the inter-regional boundaries from the G subgame. In Figure A2.3 we assume that (A1) holds, whereas in Figure A2.4 (A1) is violated. Note that, regardless of whether (A1) holds, regions VI to X in Figure 2.3 will be associated with (counterpart) A-equilibria of $\{R; R\}$.

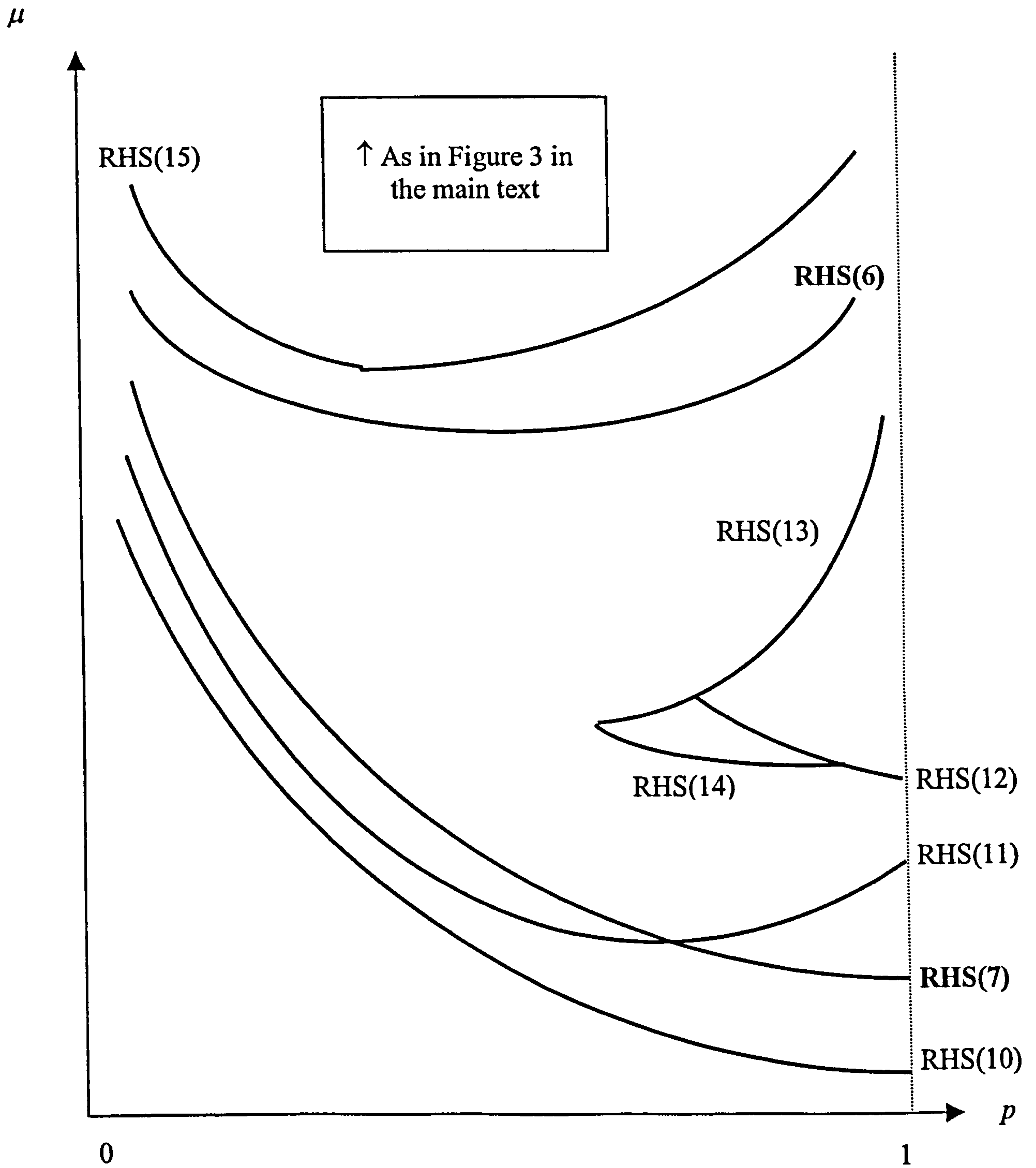


Figure A2.3: Relative positions of inter-regional boundaries in the A and G subgames when (A1) holds

Inter-regional boundaries from the A subgame are shown in bold. Only the position of RHS(7) depends on whether (A1) holds or fails. The space between RHS(6) and RHS(15) is non-empty iff $t < 0.5$.

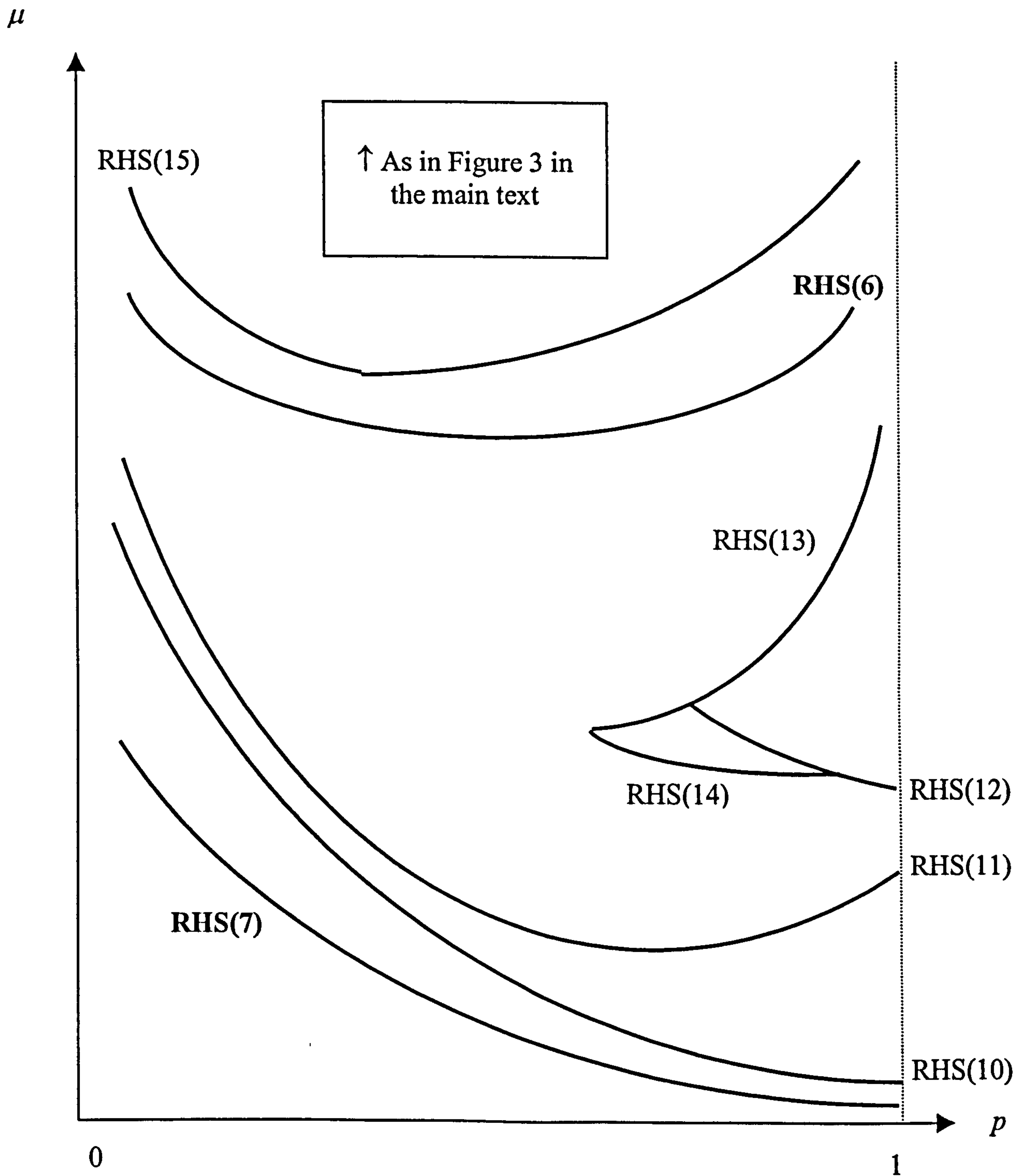


Figure A2.4: Relative positions of inter-regional boundaries in the A and G subgames when (A1) fails

Inter-regional boundaries from the A subgame are shown in bold. Only the position of RHS(7) depends on whether (A1) holds or fails. The space between RHS(6) and RHS(15) is non-empty iff $t < 0.5$.

Step 2. We begin by considering the implementation of the GADR below RHS(6).

A-equilibria of $\{N; \emptyset\}$ and $\{R; \emptyset\}$

For $\mu \in (0, \min\{\text{RHS}(7), \text{RHS}(10)\})$ the G- and A-equilibria are $\{(1, N), (1, N); \emptyset\}$ and $\{N; \emptyset\}$ respectively. Using the GADR, $\{N; \emptyset\}$ is selected iff $R^M(c) > R(c, c+t)$, which holds iff $t < x^M(c) - c$. For $t \geq x^M(c) - c$ the trade cost offers the incumbents in the G subgame sufficient protection for monopoly-pricing, so integration (acquisition-FDI) does not strictly increase their combined profits.

The interval $\mu \in (\text{RHS}(7), \text{RHS}(10))$ is non-empty iff condition (A1) fails, in which case it is associated with G- and A-equilibria of $\{(1, N), (1, N); \emptyset\}$ and $\{R; \emptyset\}$ respectively. Using the GADR, $\{R; \emptyset\}$ is selected iff

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

Because $R^M(c) \geq R(c, c+t)$, it is sufficient for this inequality to hold to have $2 \cdot p \cdot [R^M(0) - R^M(c)] > I$, which holds by definition above RHS(7).

For $\mu \in (\text{RHS}(10), \text{RHS}(11))$ the G-equilibrium is $\{(1, N), (1, R); \emptyset\}$, and there are two possible A-equilibria if condition (A1) holds:

Case (i). For $\mu \in (\text{RHS}(10), \min\{\text{RHS}(7), \text{RHS}(11)\})$ the A-equilibrium is $\{N; \emptyset\}$, which is selected iff

$$I > 2 \cdot [R(c, c+t) - R^M(c)] + [R(0, c+t) + R(t, c) - 2 \cdot R(c, c+t)] \cdot p \quad (\text{A5})$$

which sets a lower bound on I (intuitively, because the A-equilibrium does not involve R&D). $\mu \in (\text{RHS}(10), \min\{\text{RHS}(7), \text{RHS}(11)\})$ itself implies that

$$I \in \left(\max \left\{ \begin{array}{l} 2 \cdot [R^M(0) - R^M(c)] \cdot p, \\ [R(0, c+t) + R(t, c) - R(c, c+t)] \cdot p \cdot (1-p) + R(0, t) \cdot p^2 \end{array} \right\}, [R(0, c+t) + R(t, c) - R(c, c+t)] \cdot p \right) \quad (\text{A6})$$

where the first (resp. second) argument in $\{\cdot\}$ binds as

$$p > (\text{resp. } <) \frac{R(0, c+t) + R(t, c) - R(c, c+t) - 2 \cdot [R^M(0) - R^M(c)]}{R(0, c+t) + R(t, c) - R(c, c+t) - R(0, t)} \quad (\text{A7})$$

RHS(A7) > 0 if (A1) holds. For $p \in (0, \text{RHS(A7)})$ all I in (A6) satisfy (A5) iff

$$\{R(c, c+t) - [R(0, c+t) + R(t, c) - R(c, c+t) - R(0, t)] \cdot p\} \cdot p > 2 \cdot [R(c, c+t) - R^M(c)]$$

where RHS ≤ 0 ; LHS = 0 at $p = 0$ and LHS is strictly concave in p (note that $[\cdot]$ in LHS > 0 from assumption (B) plus $R(0, c) \geq R(0, t)$ under assumption (A)). To keep the analysis tractable, we investigate two simple sufficient conditions for the above inequality to hold. First, note that LHS > 0 on

$$0 < p < \frac{R(c, c+t)}{R(0, c+t) + R(t, c) - R(c, c+t) - R(0, t)}$$

which holds for all $p \in (0, \text{RHS(A7)})$ iff

$$R(c, c+t) \geq \text{LHS(A1)} \quad (\text{A8})$$

Second, note that the inequality holds at $p = 1$ iff

$$2 \cdot R^M(c) + R(0, t) - R(0, c+t) - R(t, c) > 0 \quad (\text{A9})$$

The sets of (c, t) -pairs that satisfy (A8) and (A9) are defined in Table A2.1 and plotted in Figure A2.2. Together they cover a reasonable proportion of the area where (A1) holds. In particular, note that for $c < 0.2$ all $t > 0$ satisfy (A9). Finally, we use the following argument to support the conjecture that the inequality above holds for all (c, t) that satisfy (A1). For $t \cong 0$, the inequality becomes

$$p^2 < \frac{R^M(c)}{R(0, c)} \quad (\text{A10})$$

and

$$\text{RHS(A7)} = \frac{R(0, c) - R^M(0) + R^M(c)}{R(0, c)}$$

(A10) is satisfied by all $p < \frac{R^M(c)}{R(0, c)}$, so a sufficient condition for (A10) to hold

on all $p \in (0, \text{RHS(A7)})$ when $t \cong 0$ is $R^M(0) \geq R(0, c)$, which holds by definition. (Add at start of Case (i) observation that some large I in (A6) will

certainly satisfy (A5), because this requires only

$$0 > 2 \cdot [R(c, c+t) - R^M(c)] - p \cdot R(c, c+t).$$

For $p \in (\text{RHS}(A7), 1)$ all I in (A6) satisfy (A5) iff

$$\{2 \cdot [R^M(0) - R^M(c)] - R(0, c+t) - R(t, c) + 2 \cdot R(c, c+t)\} \cdot p > 2 \cdot [R(c, c+t) - R^M(c)]$$

where $\text{RHS} \leq 0$; the inequality (weakly) holds at $p = 0, 1$ (at $p = 1$ the inequality becomes $2 \cdot R^M(0) > R(0, c+t) + R(t, c)$, which holds). Therefore, because LHS is linear in p , the inequality holds for all $p \in (0, 1)$.

Case (ii). For $\mu \in (\text{RHS}(7), \text{RHS}(11))$, which is non-empty iff $p > \text{RHS}(A7)$, the A-equilibrium is $\{R; \emptyset\}$; $\{R; \emptyset\}$ is selected over $\{(1, N), (1, R); \emptyset\}$ iff

$$2 \cdot p \cdot R^M(0) + 2 \cdot (1-p) \cdot R^M(c) > [R(0, c+t) + R(t, c)] \cdot p + 2 \cdot (1-p) \cdot R(c, c+t)$$

which certainly holds: whether R&D succeeds (coefficients on p) or fails (coefficients on $(1-p)$), the monopolist's profits in the A subgame exceed industry profits in the G subgame.

Case (ii) above encompasses all $\mu \in (\text{RHS}(10), \text{RHS}(11))$ when condition (A1) fails. We conclude that, irrespective of whether condition (A1) holds, the GADR selects the A-equilibrium over $\{(1, N), (1, R); \emptyset\}$ for $\mu \in (\text{RHS}(10), \text{RHS}(11))$.

For $\mu \in (\text{RHS}(11), \text{RHS}(6))$ a G-equilibrium of $\{(1, R), (1, R); \emptyset\}$ exists, and there are two possible counterpart A-equilibria if condition (A1) holds.

Case (i). For $\mu \in (\text{RHS}(11), \text{RHS}(7))$, which is non-empty iff $p < \text{RHS}(A7)$, the A-equilibrium is $\{N; \emptyset\}$. $\{N; \emptyset\}$ is selected over $\{(1, R), (1, R); \emptyset\}$ iff

$$I > p \cdot (1-p) \cdot [R(0, c+t) + R(t, c)] + p^2 \cdot R(0, t) + (1-p)^2 \cdot R(c, c+t) - R^M(c) \quad (\text{A11})$$

which sets a lower bound on I (intuitively, because the A-equilibrium does not involve R&D). $\mu < \text{RHS}(7)$ itself implies that

$$I > 2 \cdot [R^M(0) - R^M(c)] \cdot p \quad (\text{A12})$$

All I satisfying (A12) also satisfy (A11) iff

$$R(c, c+t) - R^M(c) + \left[R(0, c+t) + R(t, c) - 2 \cdot R(c, c+t) - 2 \cdot \{R^M(0) - R^M(c)\} \right] \cdot p - \left[R(0, c+t) - R(c, c+t) + R(t, c) - R(0, t) \right] \cdot p^2 < 0$$

where LHS is strictly concave in p and LHS ≤ 0 at $p = 0$. It is sufficient for the inequality to hold to have $d\text{LHS}/dp < 0$ at $p = 0$, which occurs when (A8) is satisfied. When (A8) fails t is small ($\cong 0$) and the inequality approximates

$$-R^M(c) + 2 \cdot \left[R(0, c) - R^M(0) + R^M(c) \right] \cdot p - 2 \cdot R(0, c) \cdot p^2 < 0$$

which is also upward-sloping at $p = 0$ (see n. 22). However, it is sufficient for the inequality to hold to have $R(0, c) - R^M(0) + R^M(c) - p \cdot R(0, c) \leq 0$ (i.e. the sum of the last two terms on LHS negative) or $-R^M(c) + 2 \cdot \left[R(0, c) - R^M(0) + R^M(c) \right] \cdot p \leq 0$ (i.e. the tangent to LHS at $p = 0$ negative). These two sufficient conditions together cover all p iff $R(0, c) \cdot R^M(c) \geq 2 \cdot \left[R(0, c) - R^M(0) + R^M(c) \right]^2$. For $c \geq 0.5$ $R(0, c) = R^M(0)$, and this becomes $R^M(0) \geq 2 \cdot R^M(c)$, which holds for all $c \geq 1 - (1/\sqrt{2}) \cong 0.29$. For $c \leq 0.5$ the inequality becomes $(1-c)^3 \geq (c/2) \cdot (2-3 \cdot c)^2$, which holds for all $c \leq 0.74$ (root calculated using *Maple*).

Case (ii). For $\mu \in (\max\{\text{RHS}(7), \text{RHS}(11)\}, \text{RHS}(6))$, where the first (resp. second) argument in $\{\cdot\}$ binds as $p <$ (resp. $>$) $\text{RHS}(A7)$, the A-equilibrium is $\{R; \emptyset\}$. If (A1) fails, then $\{R; \emptyset\}$ is the counterpart A-equilibrium to $\{(1, R), (1, R); \emptyset\}$ for all $\mu \in (\text{RHS}(11), \text{RHS}(6))$. $\{R; \emptyset\}$ is selected over $\{(1, R), (1, R); \emptyset\}$ iff

$$I > 2 \cdot p \cdot (1-p) \cdot \left[R(0, c+t) + R(t, c) \right] + 2 \cdot p^2 \cdot R(0, t) + 2 \cdot (1-p)^2 \cdot R(c, c+t) - 2 \cdot p \cdot R^M(0) - 2 \cdot (1-p) \cdot R^M(c) \quad (\text{A13})$$

which sets a lower bound on I (intuitively, because the A-equilibrium economises on sunk investments in R&D). $\mu < \text{RHS}(6)$ itself implies that $I > R(0, c) \cdot p \cdot (1-p)$, which is at least as restrictive as (A13) iff

$$R(0, c) \cdot p \cdot (1-p) \geq 2 \cdot p \cdot \left[(1-p) \cdot R(0, c+t) + p \cdot R(0, t) - R^M(0) \right] + 2 \cdot (1-p) \cdot \left[p \cdot R(t, c) + (1-p) \cdot R(c, c+t) - R^M(c) \right] \quad (\text{A14})$$

(A14) is analytically intractable; however, because $R^M(0) \geq (1-p) \cdot R(0, c+t) + p \cdot R(0, t)$ for all p , we can work with the following (simpler) sufficient condition for (A14) to hold:

$$2 \cdot [R(c, c+t) - R^M(c)] + [2 \cdot R(t, c) - 2 \cdot R(c, c+t) - R(0, c)] \cdot p \leq 0 \quad (\text{A15})$$

(A15) holds (weakly) at $p = 0$, and it holds at $p = 1$ (and therefore via linearity for all p) iff

$$R(0, c) \geq 2 \cdot [R(t, c) - R^M(c)] \quad (\text{A16})$$

In terms of the specific functional forms of $R(0, c)$ and $R(t, c)$, there are three cases to consider under assumption (A) (see Figure A2.1). First, for $0 < t < c \leq 0.5$ $R(0, c) = \mu \cdot (1-c) \cdot c$ and $R(t, c) = \mu \cdot (1-c) \cdot (c-t)$; therefore, (A16) requires $t \geq (3/4) \cdot c - (1/4)$, where RHS = 0.125 at $c = 0.5$ (however, note that RHS ≤ 0 on $c \in (0, 1/3]$). Second, for $c \in [0.5, 1)$ and $t \in [2 \cdot c - 1, c)$ $R(0, c) = \mu/4$ and $R(t, c) = \mu \cdot (1-c) \cdot (c-t)$; therefore, (A16) requires $t \geq [2 \cdot (1-c) \cdot (5 \cdot c - 1) - 1] / [8 \cdot (1-c)]$, where RHS = 0.125 at $c = 0.5$ and RHS = $2 \cdot c - 1 \cong 0.18$ at $c = 1 - (\sqrt{6}/6) \cong 0.59$. Third, for $c \in [0.5, 1)$ and $t \in (0, 2 \cdot c - 1]$ $R(0, c) = \mu/4$ and $R(t, c) = (\mu/4) \cdot (1-t)^2$; therefore, (A16) requires $t \geq 1 - \sqrt{0.5 + (1-c)^2}$. In general, the sufficient condition (A16) fails for small t . For $t \cong 0$ (A14) is approximated by

$$0 \geq -2 \cdot R^M(c) + [3 \cdot R(0, c) - 2 \cdot R^M(0) + 2 \cdot R^M(c)] \cdot p - 3 \cdot R(0, c) \cdot p^2$$

which has a global maximum in c on $(0, 1)$. (At $p = 0$ $d\text{RHS}/dp = 3 \cdot R(0, c) - 2 \cdot R^M(0) + 2 \cdot R^M(c) > 0$ from n. 22, and at $p = 1$ $d\text{RHS}/dp = 2 \cdot R^M(c) - 2R^M(0) - 3 \cdot R(0, c) < 0$.) Setting $d\text{RHS}/dp = 0$, the maximum value of RHS is (weakly) negative iff

$$24 \cdot R(0, c) \cdot R^M(c) \geq [3 \cdot R(0, c) - 2 \cdot R^M(0) + 2 \cdot R^M(c)]^2 \quad (\text{A17})$$

For $c \leq 0.5$ $R(0, c) = \mu \cdot (1-c) \cdot c$ and (A17) becomes $96 \cdot (1-c)^3 \geq c \cdot (4 - 5 \cdot c)^2$, which holds on all $c \in (0, 0.5]$. For $c \geq 0.5$ $R(0, c) = \mu/4$ and (A17) becomes $24 \cdot (1-c)^2 \geq [1 + 2 \cdot (1-c)^2]^2$, which holds on $c \in [0.5, 2 - (\sqrt{6}/2) \cong 0.78]$.

Despite this finding that the maximum of (A14) is strictly positive for $t \cong 0$ and c

> 0.78 , it should be noted that when $t \cong 0$ (A14) holds for all c if p is sufficiently small or large. The reason for the difficulty in comparing expected industry profits under $\{(1, R), (1, R); \emptyset\}$ and $\{R; \emptyset\}$ (which, intuitively, would appear to be a straightforward comparison between monopoly and duopoly profits) is that the *number* of R&D investments differs between the two equilibria under comparison. (If the acquirer undertook two R&D investments, which the structure of our model does not permit, then the comparison would be considerably easier.)

Irrespective of whether (A1) holds or fails, G-equilibria of $\{(1, N), (1, N); R\}$ (region V of Figure 2.3) and $\{(1, N), (2, R); \emptyset\}$ (regions IV and V of Figure 2.3) both have counterpart A-equilibria of $\{R; \emptyset\}$. It is straightforward to show that both G-equilibria are dominated by $\{R; \emptyset\}$. ($\{(1, N), (1, N); R\}$ is dominated by $\{R; \emptyset\}$ iff $\mu > \text{RHS}(8)$, where $\text{RHS}(8) < \text{RHS}(7)$ from Lemma 2. The $(2, R)$ -firm in $\{(1, N), (2, R); \emptyset\}$ incurs higher sunk costs and earns lower global net revenues for either R&D outcome (because ‘competition’ from the $(1, N)$ -firm prevents monopoly-pricing) than the acquirer in $\{R; \emptyset\}$. Therefore, $\{R; \emptyset\}$ dominates $\{(1, N), (2, R); \emptyset\}$.)

The general conclusion from the preceding implementation of the GADR for $\mu < \text{RHS}(6)$ is that the A-equilibrium dominates the G-equilibrium. Of course, this is intuitively appealing because for $\mu < \text{RHS}(6)$ the A-equilibrium is a monopoly equilibrium. However, we isolated two notable exceptions. First, for $t \cong 0$ and c ‘sufficiently large’ some (low) I -values exist where $\{(1, R), (1, R); \emptyset\}$ dominates $\{R; \emptyset\}$ for some interior p -values. However, sufficiently large I is always associated with acquisition-FDI. Second (and more interestingly), for small μ $\{(1, N), (1, N); \emptyset\}$ dominates $\{N; \emptyset\}$ when t is sufficiently large to permit monopoly-pricing at the G-equilibrium.

A-equilibrium of $\{R; R\}$

Implementation of the GADR for $\mu > \text{RHS}(6)$ is unaffected by whether (A1) holds or fails (i.e. Figures A2.3 and A2.4 are identical for $\mu > \text{RHS}(6)$). For $t < 0.5 \text{ RHS}(15) > \text{RHS}(6)$ and therefore a μ -interval exists where the G-equilibrium is $\{(1, R), (1, R); \emptyset\}$. $\{R; R\}$ is selected over $\{(1, R), (1, R); \emptyset\}$ iff

$$I > 2 \cdot p \cdot (1-p) \cdot [R(0, c+t) + R(t, c) - R(0, c)] + 2 \cdot p^2 \cdot R(0, t) + 2 \cdot (1-p)^2 \cdot R(c, c+t) \quad (\text{A18})$$

However, $\mu > \text{RHS}(6)$ implies that $I < R(0, c) \cdot p \cdot (1-p)$, which is inconsistent with (A18) iff

$$2 \cdot p \cdot (1-p) \cdot [R(0, c+t) + R(t, c)] + 2 \cdot p^2 \cdot R(0, t) + 2 \cdot (1-p)^2 \cdot R(c, c+t) \geq 3 \cdot p \cdot (1-p) \cdot R(0, c) \quad (\text{A19})$$

where both LHS and RHS are strictly concave in p (from assumption (B) in the case of LHS), and $\text{LHS} > \text{RHS}$ at $p = 0, 1$. Given that $R(0, c+t) \geq R(0, c)$, two simple sufficient conditions for (A19) to hold are

$$\left. \begin{aligned} [R(0, c) - 2 \cdot R(t, c) + 2 \cdot R(0, t)] \cdot p &\geq R(0, c) - 2 \cdot R(t, c) \\ [R(0, c) - 2 \cdot R(t, c) + 2 \cdot R(c, c+t)] \cdot p &\leq 2 \cdot R(c, c+t) \end{aligned} \right\} \quad (\text{A20})$$

for all $p \neq 0, 1$. The upper (resp. lower) condition in (A20) is derived from (A19) by adding $2 \cdot (1-p) \cdot \{[R(0, c) - R(0, c+t)] \cdot p - (1-p) \cdot R(c, c+t)\} < 0$ (resp. $2 \cdot p \cdot \{(1-p) \cdot [R(0, c) - R(0, c+t)] - p \cdot R(0, t)\} < 0$) to the LHS, and simplifying. Both conditions in (A20) are linear in p , which makes them analytically tractable. Suppose that $R(0, c) > 2 \cdot R(t, c)$, which guarantees that $[\cdot] > 0$ in the LHS of both conditions in (A20). Therefore, the upper condition in (A20) defines a lower bound on p of $(R(0, c) - 2 \cdot R(t, c)) / (R(0, c) - 2 \cdot R(t, c) + 2 \cdot R(0, t))$, and the lower condition defines an upper bound on p of $2 \cdot R(c, c+t) / (R(0, c) - 2 \cdot R(t, c) + 2 \cdot R(c, c+t))$. Because $R(0, t) > R(c, c+t)$, the denominator of the lower bound is certainly larger than that of the upper bound (Proof: at $t = 0$, $R(c, c+t) = R(0, t) = 0$. Now consider progressive increases in t towards c . For $t < 0.5$ $\partial R(0, t) / \partial t = \mu \cdot (1 - 2 \cdot t)$, and $\partial R(c, c+t) / \partial t = 0$ ($R(c, c+t)$ is M) or $\mu \cdot (1 - c - 2 \cdot t)$ ($R(c, c+t)$ is U). Given either expression for

$\partial R(c, c+t)/\partial t$, $\partial R(0, t)/\partial t > \partial R(c, c+t)/\partial t$. For $t > 0.5$ $\partial R(0, t)/\partial t = \partial R(c, c+t)/\partial t = 0$. $R(0, t)$ is kinked at $t = 0.5$, so $\partial R(0, t)/\partial t$ is not defined.). Therefore, a sufficient condition for the upper bound to be greater than the lower bound (so that the two conditions in (A20) cover all p) is

$$2 \cdot [R(c, c+t) + R(t, c)] > R(0, c) \quad (\text{A21})$$

(i.e. that the numerator of the upper bound be greater than that of the lower bound). We use (A21) as a sufficient condition for (A19) to hold. (Note that (A21) was derived under the assumption that $R(0, c) > 2 \cdot R(t, c)$. However, if $2 \cdot R(t, c) > R(0, c)$, which is more restrictive than (A21) and thus implies that (A21) will hold, then both conditions in (A20) hold for all p : rewrite the upper condition in (A20) as $2 \cdot R(0, t) \cdot p \geq (1-p) \cdot [R(0, c) - 2 \cdot R(t, c)]$ and the lower as $2 \cdot (1-p) \cdot R(c, c+t) \geq [R(0, c) - 2 \cdot R(t, c)] \cdot p$, where in both cases LHS $> 0 >$ RHS, to verify this.)

Given that $t < 0.5$, which is necessary for the G-equilibrium of $\{(1, R), (1, R); \emptyset\}$ to coincide with the A-equilibrium of $\{R; R\}$, there are seven regions in Figure A1 to consider when investigating the explicit forms of (A21). For $c \in (0, 1/3]$, (A21) holds for all $t \in (0, c)$ (regions I and II of Figure A2.1). For $c \in [1/3, 0.5]$, (A21) holds iff $t < (1/4) \cdot (1+c)$, where RHS = $1/3$ at $c = 1/3$ and increases to $3/8$ at $c = 1/2$ (in region III of Figure A2.1). For $c \in [0.5, 1 - (\sqrt{10}/10) \cong 0.684]$, (A21) holds iff $t < [2 \cdot (1-c) \cdot (1+3 \cdot c) - 1] / [8 \cdot (1-c)]$, where RHS = 0.375 at $c = 0.5$ and 0.368 at $c = 0.684$ (in region V of Figure A2.1). Finally, for $c \in [0.684, 1)$, (A21) holds iff $t < 1 - \sqrt{0.5 - (1-c)^2}$, where RHS = 0.368 at $c = 0.684$ and decreases to 0.293 at $c = 1$ (in region VIII of Figure A2.1). Therefore, our analysis of the sufficient condition (A21) shows that (A21) is satisfied for all t, c under assumption (A) if $c \leq 1/3$, and that for $c \geq 1/3$ (A21) holds iff the gap $(c - t)$ is 'sufficiently large'. Of course, (A21) is a *sufficient* condition, so we cannot conclude that (A19) fails whenever (A21) fails. Note, however, that if $t = 0.5$ and $c \geq t$, then $R(0, c+t) = R(0, t) = R(0, c) = \mu/4$; $R(c, c+t) = (\mu/4) \cdot (1-c)^2$

because $c + 0.5 > x^M(c)$; $R(t, c) = \mu/16$ (resp. $\mu \cdot (1 - c) \cdot (c - 0.5)$) for $c >$ (resp. $<$) 0.75 ; and that (A19) reduces to

$$0.5 \cdot (1 - c)^2 + [(1 - c) \cdot (3 \cdot c - 2) - 0.25] \cdot p - [0.5 \cdot (5 \cdot c - 3) \cdot (1 - c) - 0.75] \cdot p^2 > 0$$

for $c \in (0.5, 0.75]$

and

$$0.5 \cdot (1 - c)^2 - [0.125 + (1 - c)^2] \cdot p + [0.125 + 0.5 \cdot (1 - c)^2] \cdot p^2 > 0 \text{ for } c \in [0.75, 1)$$

where the coefficients on p and p^2 are strictly negative and strictly positive respectively. Both quadratics are strictly decreasing at $p = 0$ and strictly increasing at $p = 1$ and so have global minima on $(0, 1)$. Evaluating the quadratics at their global minima reveals that the minimum is strictly positive for $c \in (0.5, 0.75]$ but strictly negative for $c \in [0.75, 1)$. Therefore, it appears that (A19) holds for ‘most’ relevant (c, t) -pairs (as defined by assumption (B) and $t < 0.5$).

For $\mu \in (\text{RHS}(15), \min\{\text{RHS}(17), \text{RHS}(16)\})$ (i.e. region VI of Figure 2.3) the G-equilibrium is either $\{(1, R), (1, R); R\}$ or $\{(1, R), (2, R); \emptyset\}$, depending on whether entry-accommodation or –deterrence is selected (i.e. on whether condition (22) from the main text holds). The counterpart A-equilibrium is $\{R; R\}$. If the G-equilibrium of $\{(1, R), (1, R); R\}$ is selected, then the A subgame is played iff

$$I > 2 \cdot p \cdot (1 - p)^2 \cdot R(t, c) - 2 \cdot p^2 \cdot (1 - p) \cdot [R(0, c) - R(0, t)] \quad (\text{A22})$$

If the G-equilibrium of $\{(1, R), (2, R); \emptyset\}$ is selected, then the A subgame is played iff

$$I > p \cdot (1 - p) \cdot [R(0, c + t) + R(t, c)] + p^2 \cdot R(0, t) + (1 - p)^2 \cdot R(c, c + t) - G \quad (\text{A23})$$

Both RHS(A22) and RHS(A23) set lower bounds on I because selection of the A-equilibrium halves the incumbents’ sunk investments in R&D. Furthermore, $d\text{RHS}(A23)/dG < 0$ so that ceteris paribus a rise in G makes the selection of the A-equilibrium over $\{(1, R), (2, R); \emptyset\}$ ‘more likely’. This is a straightforward ‘substitution effect’ between the alternative forms of FDI.

Region VI is such that

$$\mu > \text{RHS}(15) \Rightarrow I < R(0, c) \cdot p \cdot (1 - p)^2 + R(0, t) \cdot p^2 \cdot (1 - p) \quad (\text{A24})$$

$$\mu < \text{RHS}(16) \Rightarrow G > [R(0,c) - R(t,c)] \cdot p \cdot (1-p) \quad (\text{A25})$$

$$\mu < \text{RHS}(17) \Rightarrow I > R(0,c) \cdot p \cdot (1-p)^2 + \frac{1}{2} \cdot R(0,t) \cdot p^2 \cdot (1-p) \quad (\text{A26})$$

Because assumption (C) imposes $G \geq I > 0$, (A25) binds iff $\text{RHS}(\text{A25}) > \text{RHS}(\text{A26})$, i.e. iff

$$R(t,c) + p \cdot \left[\frac{1}{2} \cdot R(0,t) - R(0,c) \right] < 0 \quad (\text{A27})$$

for $p \neq 0, 1$. (A27) certainly fails for small p ; however, for large p (A27) requires $2 \cdot R(0,c) - 2 \cdot R(t,c) - R(0,t) > 0$, which holds. (Proof: When $t = 0$, $\text{LHS} = 0$. Now consider progressive rises in t from 0 to c . $\partial \text{LHS} / \partial t > 0$ requires $-2 \cdot (\partial R(t,c) / \partial t) > \partial R(0,t) / \partial t$. For $t \leq 0.5$, $R(0,t) = \mu \cdot (1-t) \cdot t$ and $R(t,c) = \mu \cdot (1-c) \cdot (c-t)$ for $x^M(t) \geq c$ and $R^M(t)$ for $x^M(t) \leq c$. Given either functional form for $R(t, c)$, $\partial \text{LHS} / \partial t > 0$. (Note that $\partial \text{LHS} / \partial t > 0$ when $R(t,c) = \mu \cdot (1-c) \cdot (c-t)$ iff $t > c - 0.5$, which is implied by $x^M(t) \geq c$ for $t > 0$.) For $t \geq 0.5$, $R(0,t) = R^M(0)$, so $\partial R(0,t) / \partial t = 0$ and therefore $\partial \text{LHS} / \partial t > 0$.) If (A25) binds (i.e. $\text{RHS}(\text{A25}) > \text{RHS}(\text{A26})$), we will still have $\text{RHS}(\text{A24}) > \text{RHS}(\text{A25})$. (Proof: for $p \neq 0, 1$ $\text{RHS}(\text{A24}) > \text{RHS}(\text{A25})$ requires $R(t,c) + p \cdot [R(0,t) - R(0,c)] > 0$, which certainly holds at $p = 0$ and holds at $p = 1$ iff $R(t,c) + R(0,t) - R(0,c) > 0$. For $t \geq 0.5$, $\text{LHS} = R(t, c)$; furthermore, $\text{LHS} = 0$ at $t = 0, c$, so a sufficient condition for $\text{LHS} > 0$ is LHS concave in t for $c \in (0, 1)$, $t \in (0, \min\{c, 0.5\})$, which comprises two cases: (a) in regions I to V of Figure A2.1 $R(t,c) + R(0,t) = \mu \cdot \{c \cdot (1-c) + t \cdot c - t^2\}$; and (b) in regions VII and VIII of Figure A2.1 $R(t,c) + R(0,t) = \mu \cdot \left\{ \frac{1}{4} + \frac{1}{2} \cdot t - \frac{3}{4} \cdot t^2 \right\}$.) Therefore, region VI of Figure 2.3, as defined by (A24), (A25) and (A26), takes two distinct forms in (G, I) -space, depending on whether p is 'small' or 'large'.

Figure A2.5 examines the G/A choice in region VI when p is small and (A25) is made irrelevant by assumption (C).

[FIGURE A2.5 IS OVERLEAF]

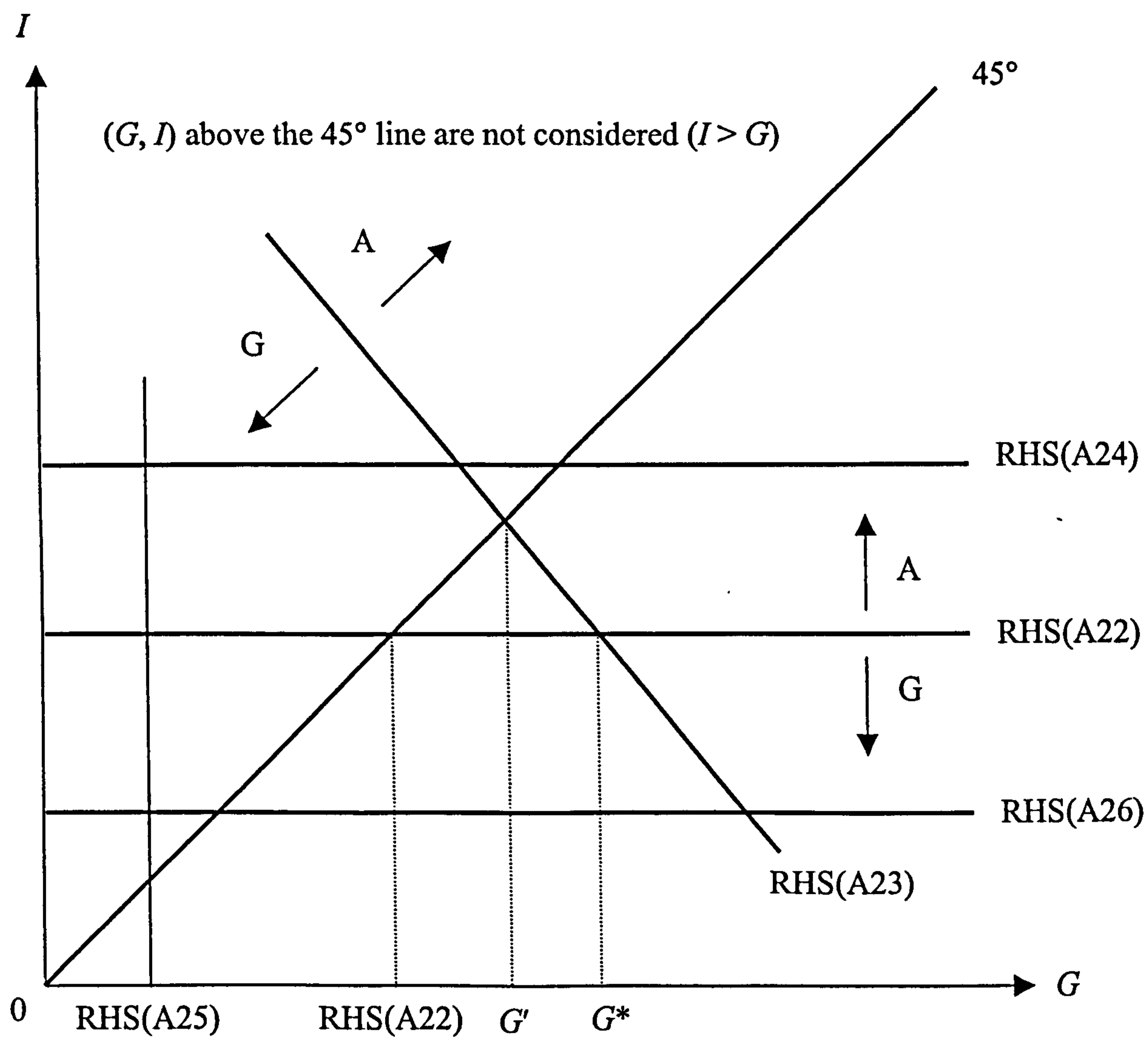


Figure A2.5: The G/A choice in region VI of Figure 3 for small p

The A (resp. G) subgame is chosen above (resp. below) $RHS(A22)$ and $RHS(A23)$.

If the entry-accommodating G-equilibrium of $\{(1, R), (1, R); R\}$ is selected, then the A subgame is played for all G, I in region VI iff $\text{RHS(A26)} > \text{RHS(A22)}$, i.e. iff

$$R(0, c) - 2 \cdot R(t, c) + p \cdot \left[R(0, c) + 2 \cdot R(t, c) - \frac{3}{2} \cdot R(0, t) \right] > 0 \quad (\text{A28})$$

for $p \neq 0, 1$. (A28) holds for $p \cong 0$ if t is sufficiently large. (Note that $\text{LHS(A28)} > 0$ at $p \cong 1$, so if $R(0, c) > 2 \cdot R(t, c)$ then (A28) holds for all p ; alternatively, if $R(0, c) < 2 \cdot R(t, c)$ then (A28) holds for sufficiently large p .) The A subgame is played for no G, I in region VI iff $\text{RHS(A22)} > \text{RHS(A24)}$, i.e. iff

$$2 \cdot R(t, c) - R(0, c) + p \cdot [R(0, t) - R(0, c) - 2 \cdot R(t, c)] > 0 \quad (\text{A29})$$

for $p \neq 0, 1$. (A29) holds for $p \cong 0$ if (A28) fails for $p \cong 0$. Therefore, for small p the G/A choice depends on t : for large (resp. small) t , $\{R; R\}$ (resp. $\{(1, R), (1, R); R\}$) is played for all G, I in region VI. (Note that $\text{LHS(A29)} < 0$ at $p \cong 1$, so if $2 \cdot R(t, c) > R(0, c)$ then (A29) only holds for sufficiently small p .)

If the entry-detering G-equilibrium of $\{(1, R), (2, R); \emptyset\}$ is selected, then the G/A choice is determined by the position of RHS(A23) relative to RHS(A24) and RHS(A26) . Two observations follow. First, because RHS(A23) is downward-sloping whereas RHS(A22) is horizontal, for sufficiently large G in region VI the I -interval where $\{(1, R), (1, R); R\}$ (resp. $\{R; R\}$) is chosen over $\{R; R\}$ (resp. $\{(1, R), (1, R); R\}$) is weakly larger (resp. smaller) than that where $\{(1, R), (2, R); \emptyset\}$ (resp. $\{R; R\}$) is chosen over $\{R; R\}$ (resp. $\{(1, R), (2, R); \emptyset\}$). Strictness requires $\text{RHS(A22)} > \text{RHS(A26)}$. (Note, however, that rises in G ceteris paribus make the selection of the entry-detering G-equilibrium 'less likely', see Proposition G3(i), so for large G RHS(A22) determines the G/A choice.) For sufficiently small G in region VI the I -interval where $\{(1, R), (2, R); \emptyset\}$ (resp. $\{R; R\}$) is chosen over $\{R; R\}$ (resp. $\{(1, R), (2, R); \emptyset\}$) is weakly larger (resp. smaller) than that where $\{(1, R), (1, R); R\}$ (resp. $\{R; R\}$) is chosen over $\{R; R\}$ (resp. $\{(1, R), (1, R); R\}$) iff $G^* > \text{RHS(A22)}$ (as in Figure A2.5). In addition, strictness requires $G' > \text{RHS(A26)}$ and $\text{RHS(A24)} > \text{RHS(A22)}$, so that the triangle formed by RHS(A22) , RHS(A23) and the 45° line when $G^* > \text{RHS(A22)}$ lies at least partly between RHS(A24) and RHS(A26) . $G^* > \text{RHS(A22)}$ iff

$$\begin{aligned}
& p \cdot (1-p) \cdot [R(0, c+t) + R(t, c)] + p^2 \cdot R(0, t) + (1-p)^2 \cdot R(c, c+t) \\
& > 4 \cdot p \cdot (1-p)^2 \cdot R(t, c) - 4 \cdot p^2 \cdot (1-p) \cdot [R(0, c) - R(0, t)]
\end{aligned} \tag{A30}$$

Solving (A30) requires manipulation of a cubic in p , a complicated analytical task. However, (A30) certainly holds for $p \cong 0, 1$, where LHS $\cong R(c, c+t), R(0, t)$ and RHS $\cong 0$. Further insight can be obtained by noting that a sufficient condition for (A30) to hold is $p \cdot (1-p) \cdot [R(0, c+t) + R(t, c)] > \text{RHS(A30)}$, which for $p \neq 0, 1$ becomes

$$R(0, c+t) + R(t, c) > 4 \cdot \{R(t, c) - p \cdot [R(t, c) + R(0, c) - R(0, t)]\} \tag{A31}$$

(A31) certainly holds at $p \cong 1$ where RHS ≤ 0 . (A31) holds for all $p \in (0, 1)$ iff $R(0, c+t) > 3 \cdot R(t, c)$, which requires t ‘sufficiently large’. (For example, if $t >$

0.5 then $R(0, c+t) = \frac{\mu}{4}$ and $R(0, c+t) > 3 \cdot R(t, c)$ becomes (a) $\frac{1}{3} > (1-t)^2$ if

$R(t, c) = R^M(t)$; or (b) $t > c - \frac{1}{12 \cdot (1-c)}$, both of which hold.)

The immediately-preceding analysis formally establishes an important result. For $p \cong 0$ (i.e. ‘small p ’), we have $G^* > \text{RHS(A22)}$; furthermore, the ‘strictness conditions’ $G' > \text{RHS(A26)}$ and $\text{RHS(A24)} > \text{RHS(A22)}$ both hold. (Proof: at $p \cong 0$ $G' > \text{RHS(A26)}$ because $G' \cong \frac{1}{2} \cdot R(c, c+t)$ and $\text{RHS(A26)} \cong 0$; $\text{RHS(A24)} > \text{RHS(A22)}$ for sufficiently large t from (A29).) Therefore, for $p \cong 0$ and t ‘sufficiently large’ there exists a triangle on the 45° line in (G, I) -space, lying (at least partly) between RHS(A24) and RHS(A26) , where $\{(1, R), (2, R); \emptyset\}$ dominates $\{R; R\}$ dominates $\{(1, R), (1, R); R\}$ from the GADR; this is the triangle bordered by RHS(A22) , RHS(A23) and the 45° line in Figure A2.5. Finally, from Proposition G2(iii) in the main text we know that $\{(1, R), (2, R); \emptyset\}$ is selected over $\{(1, R), (1, R); R\}$ within the G subgame for sufficiently large t and $G \cong I$. Therefore, within the $\text{RHS(A22)}/\text{RHS(A23)}/45^\circ$ line triangle in Figure A2.5 the G-equilibrium is $\{(1, R), (2, R); \emptyset\}$, which dominates $\{R; R\}$; however, if greenfield-FDI strategies were excluded from the G subgame, the G-equilibrium would be $\{(1, R), (1, R); R\}$, which is dominated by $\{R; R\}$, and so analysis would (mistakenly) predict acquisition-FDI in equilibrium. The intuition

for this result concerns the entry-detering effects of a sunk investment in greenfield-FDI, which by bolstering the G-incumbents' profits makes acquisition-FDI (which implies entry) unprofitable.

Figure A2.6 below examines the G/A choice in region VI of Figure 2.3 when p is large and (A25) binds.

[FIGURE A2.6 IS OVERLEAF]

The rightwards shift in RHS(A25) does not affect the choice between $\{(1, R), (1, R); R\}$ and $\{R; R\}$. Because (A28) holds at $p \cong 1$, we conclude that $\{R; R\}$ is selected over $\{(1, R), (1, R); R\}$ for all G, I in region VI at $p \cong 1$. Therefore, for sufficiently large G in region VI $\{R; R\}$ arises in equilibrium irrespective of equilibrium selection in the G subgame (because RHS(A23) is downward-sloping).

If $\{(1, R), (2, R); \emptyset\}$ is selected in the G subgame, then our first observation from the small- p case (i.e. that the selection of $\{R; R\}$ over $\{(1, R), (2, R); \emptyset\}$ becomes 'more likely' than the selection of $\{R; R\}$ over $\{(1, R), (1, R); R\}$ as G rises), which relies on RHS(A23) being downward-sloping, carries over to large p . The second observation from the small- p case, which gives conditions for the selection of $\{(1, R), (2, R); \emptyset\}$ over $\{R; R\}$ to be 'more likely' than the selection of $\{(1, R), (1, R); R\}$ over $\{R; R\}$, requires modification for large p . $G^* > \text{RHS(A22)}$ from the small- p case is replaced by $G^* > \max\{\text{RHS(A25)}, \text{RHS(A22)}\}$ to ensure the existence of a space in region VI where $\text{RHS(A23)} > \text{RHS(A22)}$. The 'strictness conditions', $G' > \text{RHS(A26)}$ and $\text{RHS(A24)} > \text{RHS(A22)}$, carry over directly to large p . For $p \cong 1$, $G^* > \max\{\text{RHS(A25)}, \text{RHS(A22)}\}$ holds because

$$G^* \equiv p \cdot (1-p) \cdot [R(0, c+t) + R(t, c)] + p^2 \cdot R(0, t) + (1-p)^2 \cdot R(c, c+t) - 2 \cdot p \cdot (1-p)^2 \cdot R(t, c) + 2 \cdot p^2 \cdot (1-p) \cdot [R(0, c) - R(0, t)] \cong R(0, t)$$

and $\text{RHS(A25)}, \text{RHS(A22)} \cong 0$; $G' > \text{RHS(A26)}$ holds because

$$G' \equiv \frac{1}{2} \cdot \{p \cdot (1-p) \cdot [R(0, c+t) + R(t, c)] + p^2 \cdot R(0, t) + (1-p)^2 \cdot R(c, c+t)\} \cong \frac{1}{2} \cdot R(0, t)$$

and $\text{RHS(A26)} \cong 0$; and $\text{RHS(A24)} > \text{RHS(A22)}$ holds because $\text{RHS(A26)} >$

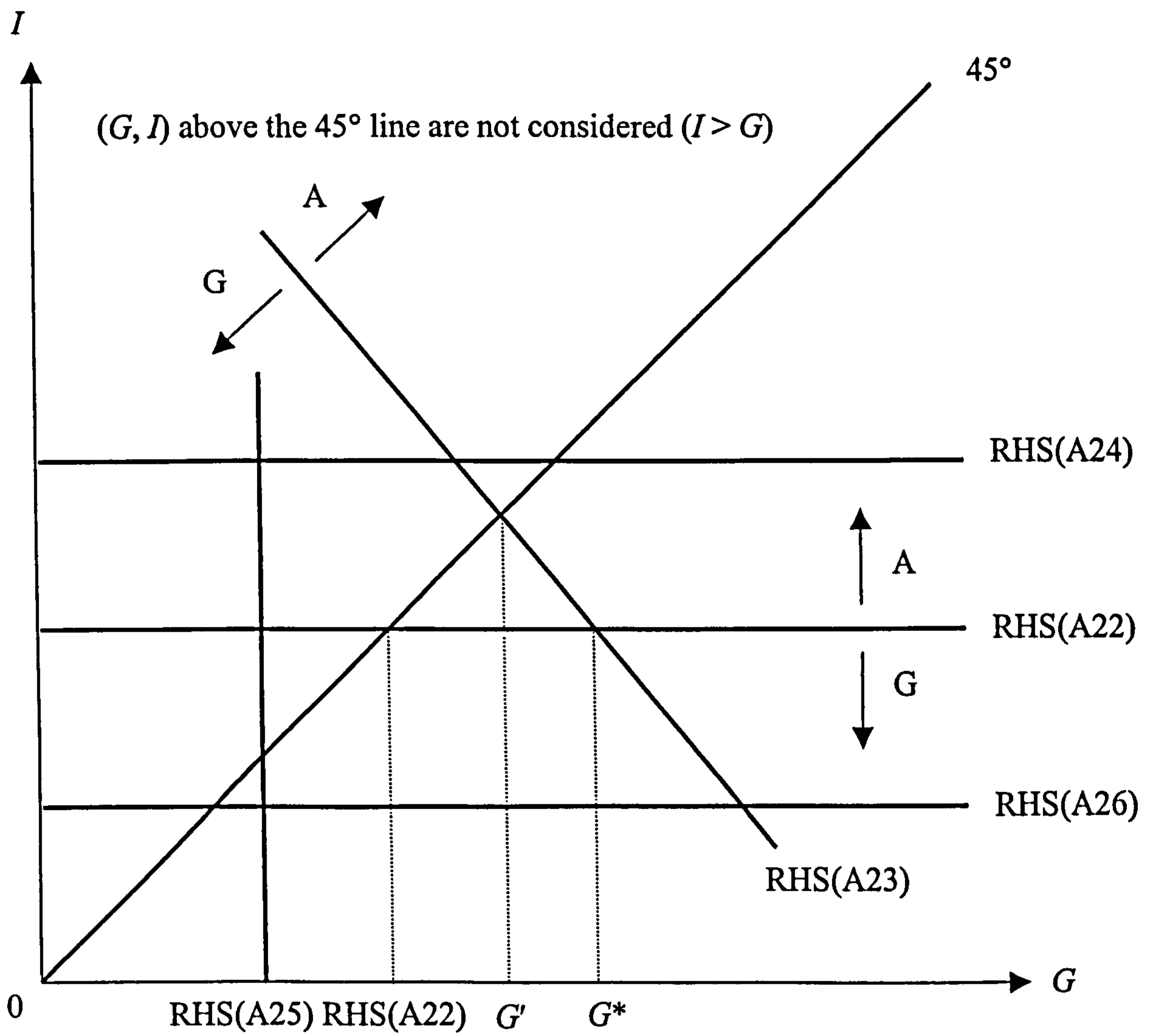


Figure A2.6: The G/A choice in region VI of Figure 3 for large p

The A (resp. G) subgame is chosen above (resp. below) RHS(A22) and RHS(A23).

RHS(A22). Therefore, the second observation from the small- p case (together with its implications) carries over to large p .

For $\mu \in (\text{RHS}(17), \text{RHS}(19))$ there is a G-equilibrium of $\{(1, R), (1, R); R\}$, and the counterpart A-equilibrium is $\{R; R\}$. (For the moment we ignore equilibrium selection within the G subgame in region VIII.) The A subgame is played iff (A22) holds. $\mu \in (\text{RHS}(17), \text{RHS}(19))$ implies that

$$I < \text{RHS}(A26)$$

and

$$G > p \cdot (1-p)^2 \cdot [R(0, c) - R(t, c)] \quad (\text{A32})$$

The G/A choice depends on RHS(A22) relative to RHS(A26). For all $G > \text{RHS}(A32)$ there exists an I -interval where the A subgame is played iff $\text{RHS}(A26) > \text{RHS}(A22)$, i.e. iff (A28) holds. Recall that (A28) certainly holds for $p \cong 1$, and it holds for all $p \in (0, 1)$ iff $R(0, c) > 2 \cdot R(t, c)$, which requires t 'sufficiently large'. Therefore, for small t and small p $\text{RHS}(A22) > \text{RHS}(A26)$ and $\{(1, R), (1, R); R\}$ is selected over $\{R; R\}$ for all G, I in regions VIII and IX; otherwise, $\{R; R\}$ is selected for some (sufficiently large) I . For $\text{RHS}(A22) < 0$ $\{R; R\}$ is selected over $\{(1, R), (1, R); R\}$ for all G, I in regions VIII and IX; for $p \neq 0, 1$ $\text{RHS}(A22) < 0$ iff $p > R(t, c) / [R(0, c) - R(0, t) + R(t, c)]$ (i.e. p 'sufficiently large'; although note that for $t \geq 0.5$ $\text{RHS}(A22) > 0$ for all $p \in (0, 1)$).

For $\mu \in (\text{RHS}(16), \text{RHS}(18))$ there is a G-equilibrium of $\{(2, R), (2, R); \emptyset\}$ and the counterpart A-equilibrium is $\{R; R\}$. The A subgame is played iff

$$I > 2 \cdot p \cdot (1-p) \cdot R(0, c) - 2 \cdot G \quad (\text{A33})$$

and G, I are such that

$$\mu > \text{RHS}(16) \Rightarrow G < \text{RHS}(A25)$$

$$\mu < \text{RHS}(18) \Rightarrow I > R(0, c) \cdot p \cdot (1-p)^2$$

which, given assumption (C), define a non-empty set of (G, I) -pairs iff $\text{RHS}(A25) > R(0, c) \cdot p \cdot (1-p)^2$, i.e. iff $p > R(t, c) / R(0, c)$ (< 1) for $p \neq 0, 1$.

Given $p > R(t, c) / R(0, c)$, the G/A choice is illustrated in Figure A2.7.

[FIGURE A2.7 IS OVERLEAF]

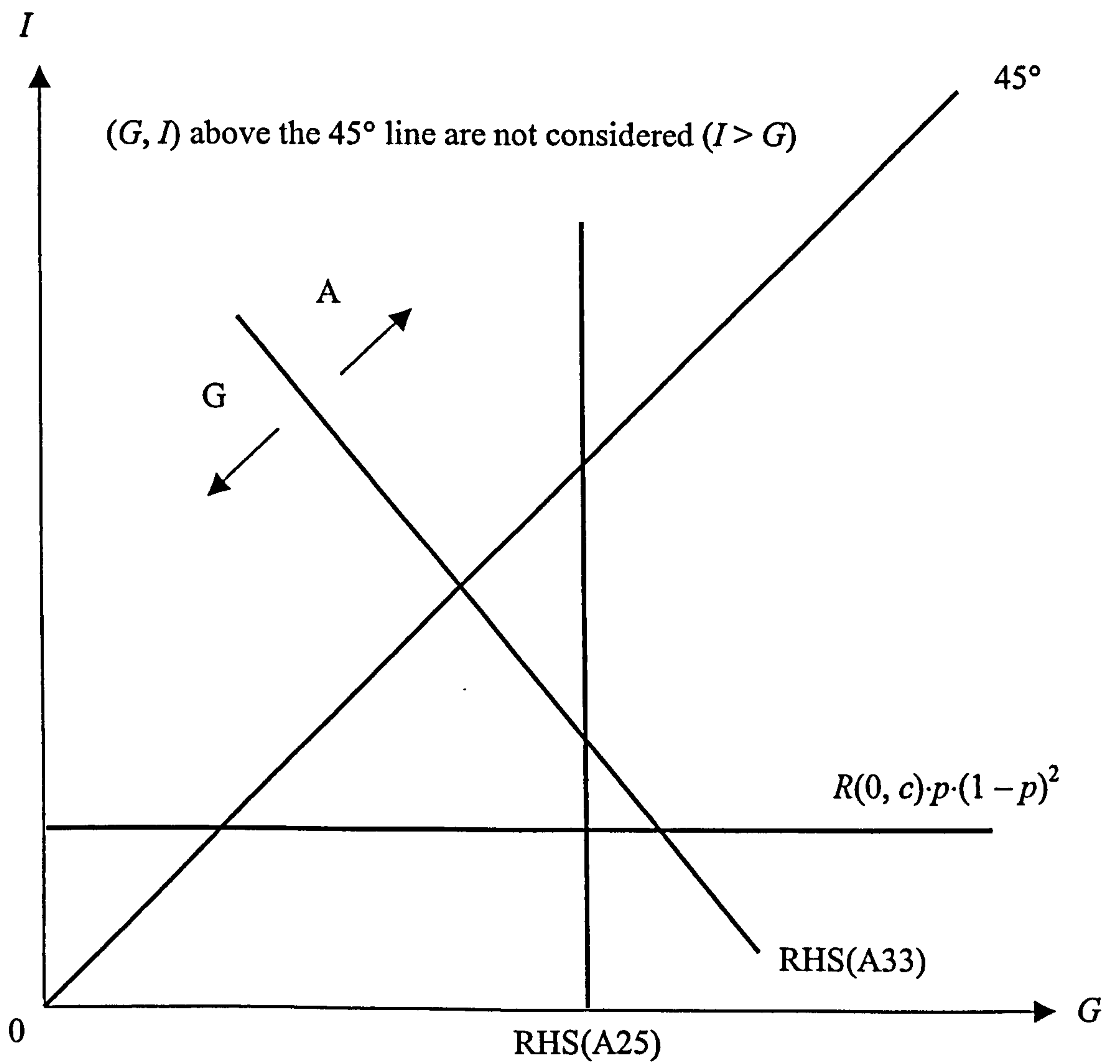


Figure A2.7: The G/A choice for $\mu \in (\text{RHS}(16), \text{RHS}(18))$ in Figure 3

The A (resp. G) subgame is chosen above (resp. below) $\text{RHS}(A33)$.

Two interesting cases emerge from Figure A2.7. First, $\{R; R\}$ is selected for all G, I iff $R(0, c) \cdot p \cdot (1 - p)^2 > \text{RHS(A33)}$ at $G = R(0, c) \cdot p \cdot (1 - p)^2$; this requires $p < \frac{1}{3}$ for $p \neq 0, 1$. Second, $\{(2, R), (2, R); \emptyset\}$ is selected for all G, I iff $\text{RHS(A25)} < \text{RHS(A33)}$ at $G = \text{RHS(A25)}$; this requires $3 \cdot R(t, c) > R(0, c)$ for $p \neq 0, 1$, which is satisfied for ‘sufficiently small’ t . Suppose that $R(0, c) > 3 \cdot R(t, c)$, so that $\frac{1}{3} > R(t, c)/R(0, c)$: therefore, on $p \in \left(R(t, c)/R(0, c), \frac{1}{3} \right)$ $\{R; R\}$ is selected for all G, I ; and on $p \in \left(\frac{1}{3}, 1 \right)$ either $\{R; R\}$ or $\{(2, R), (2, R); \emptyset\}$ can be selected, depending on G, I (the smaller are G, I , the ‘more likely’ is $\{(2, R), (2, R); \emptyset\}$ to be chosen; moreover, $\{R; R\}$ will always be chosen for sufficiently large G, I). Alternatively, if $3 \cdot R(t, c) > R(0, c)$ then $R(t, c)/R(0, c) > \frac{1}{3}$, and $\{(2, R), (2, R); \emptyset\}$ is selected for all G, I on $p \in (R(t, c)/R(0, c), 1)$.

For $\mu > \text{RHS(19)}$ the G- and A-equilibria are $\{(2, R), (2, R); R\}$ are $\{R; R\}$ respectively. $\{R; R\}$ is selected iff

$$I > 2 \cdot p \cdot (1 - p) \cdot (1 - 2 \cdot p) \cdot R(0, c) - 2 \cdot G \quad (\text{A34})$$

where RHS(A34) is downward-sloping in (G, I) -space. $\mu > \text{RHS(19)}$ implies that

$$G < \text{RHS(A32)}$$

Because $(1 - p) \cdot (1 - 2 \cdot p) = 0$ at $p = 0.5, 1$ and is strictly convex in p , for $p \in [0.5, 1)$ all G, I in region X satisfy (A34). Therefore, for $p \in [0.5, 1)$ $\{R; R\}$ is selected for all G, I in region X. For $p \in (0, 0.5)$ $p \cdot (1 - p) \cdot (1 - 2 \cdot p) > 0$, so $\{(2, R), (2, R); R\}$ is selected for some G, I in region X. Two cases are noteworthy. First, for all G in region X there exists some sufficiently small I such that $\{(2, R), (2, R); R\}$ is selected iff $\text{RHS(A34)} > 0$ at $G = \text{RHS(A32)}$; this requires $p < R(t, c)/[R(t, c) + R(0, c)] (< 0.5)$. Second, $\{(2, R), (2, R); R\}$ is selected for all G, I in region X iff $\text{RHS(A34)} > \text{RHS(A32)}$ at $G = \text{RHS(A32)}$; this requires $p < [3 \cdot R(t, c) - R(0, c)]/[3 \cdot R(t, c) + R(0, c)] (< R(t, c)/[R(t, c) + R(0, c)])$, where $\text{RHS} > 0$ iff t is ‘sufficiently small’.

Chapter 3

Inter- and Intra-Firm Technology Transfer in an International Oligopoly

3.1. Introduction.

This chapter aims to provide a theoretical analysis of the sources of foreign-owned firms' widely-documented 'productivity advantages' over domestic firms. For the UK this 'productivity gap' has been documented by Davies and Lyons (1991), Griffith (1999), and Oulton (2001). In particular, Oulton's study concludes that the labour productivity of foreign-owned firms, measured by value-added output per employee, has been continuously around 40 per cent higher than in UK-owned firms (a result derived from the respective shares of the two groups of firms in output and employment). Our analysis will focus on two specific features of this strand of empirical literature. First, it appears that this 'productivity advantage' is not entirely due to a concentration of foreign-owned firms in sectors with particularly high physical and human capital intensities (i.e. ratios of physical capital to labour and of skilled to unskilled workers). For example, Oulton found that US-owned plants in the UK enjoyed a significant additional advantage, over and above that due to higher (physical and human)

capital intensities, which was equivalent to 40 per cent of their overall 'productivity advantage'. One of Oulton's conjectures on the cause of this additional US advantage is 'better process technology' (Oulton, 2001, p. 132), and we develop this line of enquiry. Second, it appears that the 'productivity advantage' of foreign-owned firms is not a peculiar characteristic of the UK economy. Globerman, Ries and Vertinsky (1994) found a similar 'productivity advantage' among foreign-owned firms in Canada, and in their study of US manufacturing Doms and Jensen (1998) found that the significant difference – in terms of 'productivity gaps' – is between multinational enterprises (MNEs) and non-MNEs, not between foreign- and domestically-owned firms. Both of these studies suggest that 'nationality effects' are not central to explaining foreign-owned firms' 'productivity advantages'.

We model the relationships between foreign direct investment (FDI) inflows and outflows and national 'productivity distributions' across firms (plants) in an international oligopoly. Industrial structure is determined endogenously (as a subgame perfect Nash equilibrium of a four-stage game) in the manner of Horstmann and Markusen (1992) and Rowthorn (1992). The world comprises two countries with identical (linear) demand functions for a homogeneous good. There are three firms: two incumbents (M and T), who initially each own one plant in different countries; and one potential de novo entrant (E), who initially owns no plants. In the early stages of our game the firms choose how to serve the two national product markets: exporting, greenfield-FDI ('greenfield investment'), or acquisition-FDI (cross-border mergers and acquisitions, M&As). Although both greenfield-FDI and acquisition-FDI entail sunk costs (the price of

a new plant, or 'field', for the former and an acquisition price for the latter), an incentive to undertake FDI is provided by the existence of a strictly positive per-unit trade cost: undertaking FDI allows the trade cost to be 'jumped'.

In our model no firm will ever optimally operate more than one plant in either country (because marginal production costs are constant and there is a strictly positive set-up cost for additional plants), so when examining a national 'productivity distribution' the mapping from plants to firms is one-to-one. Fixed (and sunk) costs are incurred only for greenfield-FDI, and 'productivity' differences across firms are associated with differences in (constant) marginal production costs (i.e. with differences in process technologies). Under reasonable (and conventional) assumptions, the marginal production cost is inversely proportional to 'labour productivity' as measured in the empirical studies.¹ Two process technologies exist for production of the homogeneous good, and given our assumption that technology is unidimensional (i.e. affects only the marginal production cost) they can be unambiguously ranked in 'productivity' terms. One of the incumbents initially owns the 'more productive' (i.e. lower marginal production cost) technology, and the potential entrant and rival incumbent initially own the 'less productive' technology.

There are three ways in which firms' FDI decisions interact with a national 'productivity distribution' in the industry modelled. First, undertaking (either form of) FDI can lead to *inter-firm technology transfer* between the MNE's newly-established branch plant abroad and rival firms located in the host country. Inter-firm technology transfer is identical to what are sometimes labelled

'spillovers'. In our model spillovers can flow in both directions between a foreign branch plant and local rivals: for example, a technological laggard may undertake FDI in an attempt to 'source' technology via spillovers *from* (technologically superior) local firms. The relationship between FDI decisions and spillovers is two-way: if a foreign technological leader undertakes inward FDI, the productivity of local firms may be raised via spillovers (obviously, this cannot occur if the inward investor is a technological laggard); however, the technological leader will consider the potential for spillovers (and the dissipation of its advantage) when choosing between exporting and (both forms of) FDI. FDI inflows thus potentially affect national 'productivity distributions' in two ways: *directly* through the addition of a new plant (only in the case of greenfield-FDI), and *indirectly* through spillovers (both forms of FDI). It is also the case that outward FDI flows may affect the source country's national 'productivity distribution'. We assume that technology is a public good within the firm, so if the foreign branch plant of a technological laggard receives a spillover, the technological improvement can be costlessly applied to its domestic production (i.e. 'brought home') too. (Doing so risks that local firms in the home country may receive the technological improvement via 'second-hand' spillovers, but within our specific modelling structure this is a risk that a technologically-lagging MNE that receives spillovers abroad would always be willing to take.)

The second way in which firms' FDI decisions interact with national 'productivity distributions' relates specifically to acquisition-FDI. Our modelling structure allows the high-productivity incumbent to purchase the low-productivity incumbent abroad. Following this flow of acquisition-FDI, *intra-*

firm technology transfer occurs: the high-productivity purchaser is able costlessly to install its (superior) technology in the acquired plant abroad. The concept of intra-firm technology transfer is identical to that employed by Van Long and Vousden (1995) in their model of cross-border mergers, who assume that every plant in a merged firm operates at the minimum marginal cost of its constituent plants before the merger. Although we did not use this terminology in the previous paragraph, intra-firm technology transfer also occurs when a firm 'brings home' a spillover received abroad by its foreign branch plant.

Third, FDI decisions interact with national 'productivity distributions' through the relationship between the greenfield-FDI/ acquisition-FDI choice (i.e. which form of FDI to choose) and the potential entrant's decision. As we show below, greenfield- and acquisition-FDI result – when the potential entrant comes to make her choice – in different industrial structures (duopoly vs. monopoly), and thus different entry 'incentives'. (In terms of *post-entry* industrial structures, greenfield- and acquisition-FDI result in triopoly and duopoly respectively.) Furthermore, a reverse relationship exists (from the likelihood of subsequent *de novo* entry to the greenfield-FDI/ acquisition-FDI choice): for example, if entry never occurs following greenfield-FDI, then the 'incentive' to undertake acquisition-FDI will be weaker if it is accompanied by subsequent entry than if it is not.

It is clear from the three broad observations above that two characteristics of the national 'productivity distributions' (across plants) in the industry considered are endogenously determined in our model: first, plants can be either high- or low-

productivity (there are two technologies), depending on which types of 'technology transfer' occur; and, second, the number of plants is endogenously determined at equilibrium (a single potential-entrant firm exists). In both of these respects the number of degrees of freedom afforded by our model is limited. However, our analysis makes several novel contributions to the related theoretical literature. Both Fosfuri and Motta (1999) and Siotis (1999) present two-country, two-firm models of the choice between greenfield-FDI and exporting in the context of spillovers. Our analysis extends this work by admitting an alternative (and empirically important) form of FDI, acquisition-FDI, and by allowing for potential entry. Mattoo, Olarreaga and Saggi (2001) examine how the equilibrium market structure of a single host country depends on a foreign MNE's choice between greenfield- and acquisition-FDI (exporting is excluded) in the presence of intra-firm technology transfer; spillovers, potential entry, and influences on the (global) equilibrium industrial structure through firms' actions in the MNE's home country (i.e. the *international* aspects of the equilibrium) are excluded. In terms of this (admittedly selective) literature review our model offers a 'richer' (i.e. 'more general'; additional, intuitively-important strategic effects are accommodated) framework within which to consider how firms' FDI choices interact with national 'productivity distributions'.

The remainder of the chapter is organised as follows. Section 3.2 describes the model and our equilibrium concepts formally and derives some useful results on Cournot equilibria when firms' marginal costs differ. Section 3.3 derives the model's equilibrium industrial structures and examines their comparative-statics

properties. Section 3.4 discusses the broader implications of our results for the sources of foreign-owned firms' observed 'productivity advantages'. We also contrast our findings on the sources of MNEs' 'productivity advantages' with those which (it is claimed) are implicit in Dunning's famous (1977) OLI paradigm. Finally, Section 3.5 concludes. Some of our more interesting results are highlighted, and a number of suggestions for future research are made.

3.2. The Modelling Structure.

3.2.1. Sequence of Moves and Corporate Structure Choices.

There are two countries in the world, H ('home') and F ('foreign'), and two incumbent firms, one in each country: at the start of the game firm M (the potential MNE via acquisition-FDI) owns a plant in H and firm T (the potential acquisition target) owns a plant in F . The firms in our model produce homogeneous goods for sale on the identical national product markets of H and F , which are perfectly segmented (i.e. consumers are immobile internationally, so well-defined 'national' demand curves exist, although international trade can occur at a per-unit trade cost of t). Market demand in either country is

$$Q_d = 1 - p \tag{1}$$

In (1) Q_d and p are the national quantity demanded and price respectively; Q_d is independent of the product price abroad because of our assumption of perfectly segmented national product markets.

There are two distinct technologies for producing the homogeneous product, both of which exhibit constant marginal (= average variable) costs. Technology is assumed to be a public good (non-rival) within the firm and intra-firm technology transfer is costless, so firms always use their ‘most productive’ (lowest marginal production cost) technology in all their plants. Firm M ’s initial technology has a marginal production cost of c_M , and firm T ’s initial technology has a marginal production cost of c_T . We assume that labour is the only variable productive input and that money wages are constant across both locations and firms so that any difference between c_M and c_T is due entirely to differences in labour productivity between the two technologies. In this Section and the next we maintain the following assumption on c_M, c_T :

$$(A) \quad 0 < c_M < c_T < 1$$

Assumption (A) implies that M ’s initial technology is ‘more productive’ than T ’s. It is quite conventional in the literature to assume that acquiring MNEs possess ‘productivity advantages’ over their targets (e.g. Mattoo, Olarreaga and Saggi, 2001). In Section 3.4 we discuss the reasons behind this conventional assumption, and we explore the implications of relaxing assumption (A) to allow for $c_M > c_T$. For the moment, however, invoking assumption (A) greatly simplifies the exposition.

Given the initial conditions of our model described above, Figure 3.1 illustrates the extensive form of our four-stage game. In stage one M chooses its corporate structure from a strategy space of $\{X, G, A\}$, where each element represents a different method of serving the product market in country F . X is M ’s *exporting option*: M builds no additional plants (to its initial plant in H), and it serves H ’s

product market with local production at a marginal cost of c_M and F 's product market via international trade at a marginal cost of $c_M + t$. G represents *greenfield-FDI*: M builds an additional plant in F at a sunk cost of G and serves both countries' product markets from local production at a marginal cost of c_M . A represents *acquisition-FDI*: M makes T a take-it-or-leave-it offer of a take-over price. If T accepts M 's offer, M transfers its superior technology to T 's plant (*forward* intra-firm technology transfer) and serves both countries' product markets from local production at a marginal cost of c_M ; thereafter, we skip stage two (T 's corporate structure choice). If T rejects M 's take-over offer, then M must choose between X and G . We show below (in Section 3.2.3) that these assumptions on the structure of moves uniquely determine the equilibrium take-over price, which equals T 's expected profits under M 's next-best strategy (X or G), and imply that M captures the entire surplus created by the take-over (i.e. the surplus of M 's expected profits under A over the combined expected profits of M and T under M 's next-best strategy). However, although these implications may appear restrictive, we show in Section 3.4 that the equilibrium industrial structures we derive are consistent with a much more general formulation of the bargaining process preceding the take-over. Our current assumptions on bargaining merely help to fix ideas.

[FIGURE 3.1 IS OVERLEAF]

In stage two, which only arises if M chooses X or G in stage one, T chooses its corporate structure from a strategy space of $\{X, G\}$, where the elements are analogous to those in A 's strategy space. The key difference is that T 's initial

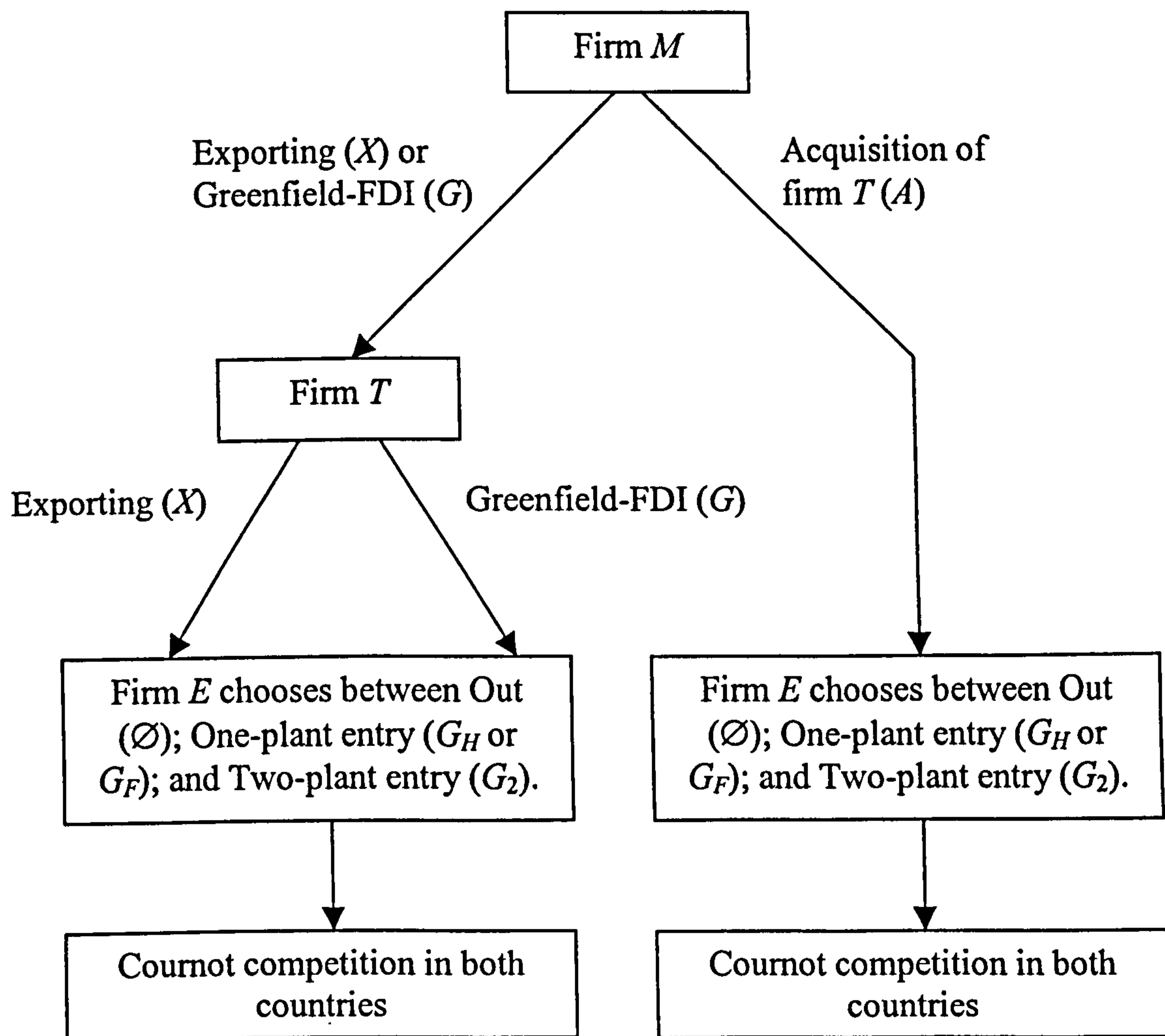


Figure 3.1: Game Tree

technology has a marginal production cost of $c_T > c_M$. To secure a marginal production cost of c_M T must rely on inter-firm technology transfers (spillovers), which are described below.

In stage three a single potential entrant (firm E) decides whether to enter the industry at a global level. E 's stage-three strategy space is $\{\emptyset, G_H, G_F, G_2\}$, whose elements represent: stay out (\emptyset); greenfield-FDI in country H (G_H); greenfield-FDI in country F (G_F); and greenfield-FDI in both countries (G_2). E 's initial marginal production cost is c_T , so M possesses a 'productivity advantage' over both its rivals under assumption (A), and E incurs sunk costs of G under G_H or G_F and $2 \cdot G$ under G_2 . Like T , E must rely on inter-firm technology transfers to obtain a marginal production cost of c_M .

Stage four is the market stage: at the end of stage four all firms in the industry compete à la Cournot to serve both national product markets.² Inter-firm technology transfers (spillovers) occur at the start of stage four before the production of outputs. With probability $\theta \in [0, 1]$ the 'most productive' (lowest marginal production cost) technology used in a country spills over to *all* the rival plants within that country (i.e. becomes common knowledge within that country). Therefore, spillovers are *localized*. We assume that the rival plants can absorb spillovers costlessly. If a technological laggard with two plants (firm T under G or firm E under G_2) benefits from a spillover in one country, it can costlessly apply its new technology to production in both countries (intra-firm technology transfer is costless). We assume that the probability of spillovers is identical and independent across countries. After spillovers have occurred, firms produce

outputs. We assume that marginal production costs are common knowledge (i.e. firms know the *characteristics* of their rivals' technologies even if they fail to obtain the *blueprints* via spillovers).

In Section 3.4 we discuss some of the *mechanisms* through which localized spillovers might occur and how the characteristics of those mechanisms affect θ . We also discuss for several spillover mechanisms the strategies that technological leaders (laggards) could use to try to minimize (maximize) θ . There are three obvious advantages to our method of modelling spillovers. First, it implies (*ceteris paribus*) a simple game structure relative to that where the spillover mechanism is explicitly modelled (e.g. Fosfuri, Motta and Rønde, 2001). In turn, this allows us to extend the game structure in other directions while retaining tractability. For example, Fosfuri, Motta and Rønde (2001) restrict their attention to market equilibria in a single host country for greenfield-FDI. By contrast, our model comprises two host countries for FDI and two types of FDI. Furthermore, note that leaving the spillover mechanism as a 'black box' is quite familiar in the R&D literature (e.g. d'Aspremont and Jacquemin, 1988). Second, our modelling of spillovers abstracts from patterns of technology flows between specific pairs of rival plants, which quickly become very complex when we move beyond the conventional duopoly case. For example, if there are three rival plants in a location, then there are three distinct pairs of plants that technology can flow between; this contrasts with only one pair in the duopoly case.³ Third, our method of modelling spillovers, while simple, does permit the investigation of some interesting strategic effects. For example, it is possible for a laggard to receive (indirectly) a spillover from M even if its plant is not in the

same country as M 's. Assume that M , T and E choose strategies of X , G and G_F respectively (the same point applies to choices of X , X and G_2 respectively). T 's probability of receiving a spillover from M , which it applies in both its plants, is θ . Therefore, if spillovers occur in *both* countries with probability θ^2 , E (located in F) will receive a spillover from M via T . The underlying message is intuitively appealing: it is not necessary to locate near a high-productivity firm's plant to receive spillovers of its technology; locating near a third firm's plant (and relying on indirect spillovers) may be sufficient if that third firm has another plant near the high-productivity firm. A related observation concerns the impact of spillovers on firms' 'incentives' to undertake greenfield-FDI, which might strengthen or weaken the 'tariff-jumping' motive for greenfield-FDI. Assume that the model's structural parameters are such that T and E will choose X and \emptyset respectively. M 's choice between X and G will clearly reflect the conventional tariff-jumping motivation for greenfield-FDI (i.e. M is 'more likely' to choose G , the higher is t and the lower is the sunk cost of additional plants). However, a disincentive for M to choose G is provided by the probability that its technology may spill over to T . Conversely, if M has chosen X and (the model's structural parameters are such that) E will choose \emptyset , an additional (to tariff-jumping) incentive for T to choose G is provided by the probability that it will receive spillovers from M .

3.2.2. Market Equilibria in an Asymmetric Cournot Oligopoly

In this Section we report standard results for a Cournot oligopoly whose firms are asymmetric in terms of their cost structures. These results will later be used

to describe market equilibria in both countries. We emphasise the implications for Cournot equilibria of marginal cost differences across firms, both because these variations are central to our analysis and because most textbook treatments downplay them, concentrating instead on the symmetric case.

Consider a homogeneous-good Cournot oligopoly, operating in a market with demand given by (1). There are N firms, each with constant (but possibly different) marginal costs; and for the moment we assume away fixed costs. The marginal cost of representative firm $i \in \{1, 2, \dots, N\}$ is c_i , and the labelling of firms with i -indices ensures that elements of the industry's set of marginal costs $\{c_i\}_1^N$ are increasing in i : $0 \leq c_1 \leq c_2 \leq \dots \leq c_N$. (The reason for this indexing procedure will become clear below.) The profits of firm i are given by $\pi_i \equiv (p - c_i) \cdot q_i$, and at i 's optimum the following two conditions hold with complementary slackness:⁴

$$\text{First-order condition: } \frac{\partial \pi_i}{\partial q_i} = q_i \cdot \frac{\partial p}{\partial Q} + p - c_i \leq 0 \quad (2)$$

$$\text{Non-negativity constraint: } q_i \geq 0 \quad (3)$$

Underlying the first-order condition (2) is the fact that i uses the Cournot conjecture when setting q_i : i behaves as if $\frac{\partial p}{\partial q_i} = \frac{\partial p}{\partial Q}$ because it takes its rivals'

outputs as data (i.e. $\frac{\partial Q}{\partial q_i} = 1$), which is conventionally justified by assuming that

firms set their outputs simultaneously (and therefore independently) in a Cournot

oligopoly. Using (1) to give the slope of the inverse demand curve as $\frac{\partial p}{\partial Q} = -1$,

(2) and (3) can be combined to give i 's best-response function:

$$q_i = \max \left\{ 0, \frac{1}{2} \cdot (1 - c_i) - \frac{1}{2} \cdot q_{-i} \right\} \quad (4)$$

where, as conventional, $Q \equiv q_i + q_{-i}$ is total industry output and $q_{-i} \equiv \sum_{j \neq i} q_j$ is the combined output of i 's $N - 1$ rivals.

We are now in a position to explore the impact of marginal cost asymmetries on Cournot equilibria. In any asymmetric Cournot equilibrium there will generally be a mixture of 'active' and 'inactive' firms. Active firms are ones for whom the first-order condition (2) binds and the non-negativity constraint (3) is generally slack (although there is the limiting case where (2) holds with equality at $q_i = 0$). Inactive firms are ones for whom the first-order condition (2) is slack and the non-negativity constraint (3) binds. Let $M \leq N$ be the number of active firms in equilibrium, so $N - M$ is the number of inactive firms. We will demonstrate below, in Lemma 1, that the lower a firm's marginal cost, the 'more likely' it is to be active in equilibrium. Therefore, equilibria where high-cost firms are active but low-cost ones inactive are impossible. This observation explains our ordering of $\{c_i\}_1^N$: in any Cournot equilibrium, the active firms will be those with $i \in \{1, 2, \dots, M\}$, and the inactive firms will have $i \in \{M + 1, M + 2, \dots, N\}$. Therefore, industry output in equilibrium is given by

$$Q \equiv \sum_1^M q_i + \sum_{M+1}^N q_i \equiv \sum_1^M q_i \quad (5)$$

where use is made of the fact that an inactive firm's output is zero by definition:

$q_i \equiv 0$ for all $i \in \{M + 1, M + 2, \dots, N\}$, so $\sum_{M+1}^N q_i \equiv 0$. Rearranging the best-

response function (4), an active firm's output is $q_i = 1 - c_i - Q$, and summing

across all M active firms this gives

$$Q = \frac{1}{M+1} \cdot \left(M - \sum_1^M c_i \right) \quad (6)$$

and, therefore, at Cournot equilibrium:

$$q_i = \begin{cases} \frac{1}{M+1} \cdot (1 - M \cdot c_i + c_{-i}) & \forall i \in \{1, 2, \dots, M\} \\ 0 & \forall i \in \{M+1, M+2, \dots, N\} \end{cases} \quad (7)$$

Note that in (7) we set $c_{-i} \equiv \sum_1^M c_j - c_i$. This definition is idiosyncratic, and it is meaningful only for active firms: for an active firm, c_{-i} gives the sum of its active rivals' marginal costs.

(6) and (7) provide a complete description of industry equilibrium given the number of active firms, M . The next task is to determine M itself. For a symmetric oligopoly, this procedure is simple: if every firm's marginal cost is c ,

(7) gives $q_i = \frac{1}{M+1} \cdot (1 - c)$ or $q_i = 0$ for all i . Thus, all firms are active iff $c \leq 1$

(the reservation price), and M equals 0 or N . This is the 'textbook' case. To determine M for an asymmetric oligopoly, we use the intuitively-appealing result in Lemma 1.

Lemma 1. *Of all the active firms in an asymmetric-cost Cournot equilibrium, the firm with the highest marginal cost will produce the lowest output.*

Proof. From our ordering of $\{c_i\}_1^N$, $c_M \equiv \max\{c_i\}_1^M$, although c_M may not be a

unique maximum. Therefore, $c_{-M} \equiv \min\{c_{-i}\}_1^M$. From the upper line of (7),

$\partial q_i / \partial c_i < 0$ and $\partial q_i / \partial c_{-i} > 0$. Therefore, $q_M = \min\{q_i\}_1^M$, which

establishes the Lemma. QED.

The equilibrium value of M in an asymmetric-cost Cournot oligopoly is such that

$$1 - M \cdot c_M + \sum_1^{M-1} c_i \geq 0 \quad (8)$$

and

$$1 - (M + 1) \cdot c_{M+1} - \sum_1^M c_i < 0 \quad (9)$$

Using Lemma 1, we can verify that the M -value that satisfies (8) and (9) is associated with all N firms playing best-responses in outputs (i.e. a Cournot-Nash equilibrium). Take (8) first. (8) gives a necessary-and-sufficient condition for firm M 's first-order condition to bind in equilibrium (so M is active), given that (a) firms 1, 2, ..., $M - 1$ also have binding first-order conditions; and (b) firms $M + 1, M + 2, \dots, N$ have binding non-negativity constraints. Furthermore, we know from Lemma 1 that if firm M is active in equilibrium, then all the lower-cost firms 1, 2, ..., $M - 1$ will also be active in equilibrium. Therefore, (8) can be interpreted as a necessary-and-sufficient condition for firms 1, 2, ..., M to be playing best-responses given that firms $M + 1, M + 2, \dots, N$ produce zero output.

(9) gives a necessary-and-sufficient condition for firm $M + 1$'s first-order condition to be slack (so $M + 1$ is inactive) in a hypothetical equilibrium constructed on the assumption that it would be active (i.e. a contradiction). Put slightly differently, if (9) holds, then firm $M + 1$ will optimally produce zero output in equilibrium, given that (a) firms 1, 2, ..., M are active; and (b) firms $M + 2, M + 3, \dots, N$ also produce zero. Furthermore, we know from Lemma 1 that if firm $M + 1$ is inactive in equilibrium, then all the higher-cost firms $M + 2, M + 3, \dots, N$ will also be inactive. Therefore, (9) can be interpreted as a necessary-and-

sufficient condition for firms $M + 1, M + 2, \dots, N$ to be playing best-responses given that firms $1, 2, \dots, M$ are active.

If (8) and (9) hold simultaneously, then all the firms in the industry are playing best-responses (and therefore have no incentive to deviate), so M must be in equilibrium. (8) and (9) both have useful economic meanings. Note from (1) and (6) that the equilibrium market price in terms of the number of active firms is

$$p = \frac{1 + \sum_{i=1}^M c_i}{M + 1} \quad (10)$$

Furthermore, (8) and (9) can be rearranged to give, respectively:

$$(8) \Rightarrow \frac{1 + \sum_{i=1}^{M-1} c_i}{M} \geq c_M \quad (11)$$

$$(9) \Rightarrow \frac{1 + \sum_{i=1}^M c_i}{M + 1} < c_{M+1} \quad (12)$$

where the LHS of (11) is the market price with $M - 1$ active firms, and the LHS of (12) is the market price with M active firms. From (11) it is clear that (8) that firm M will be active in equilibrium because, if it is not, the market price will exceed c_M . Therefore, taking the combined outputs of firms $1, 2, \dots, M - 1, M + 1, \dots, N$ as given, firm M can supply the product market with some $q_M > 0$ and still make a positive profit, because although production will depress the market price, it will still exceed c_M . (12), derived from (9), states that firm $M + 1$ will find *any* production unprofitable when firms $1, 2, \dots, M$ are active but firms $M + 2, M + 3, \dots, N$ inactive: the market price with M active firms is strictly less than c_{M+1} , and any production by firm $M + 1$ will merely depress the price further.⁵

We now apply these general results to the specific framework of this chapter. Consider a Cournot triopoly, where (as above) we index firms so that the set of marginal costs $\{c_i\}_1^3 = \{c_1, c_2, c_3\}$ has $0 \leq c_1 \leq c_2 \leq c_3$. We use (8) and (9) to derive the following results on the equilibrium M -value:

$$\left. \begin{aligned} M = 1 & \text{ iff } c_1 \leq 1 \text{ and } c_2 > \frac{1+c_1}{2} \\ M = 2 & \text{ iff } c_2 \leq \frac{1+c_1}{2} \text{ and } c_3 > \frac{1+c_1+c_2}{3} \\ M = 3 & \text{ iff } c_3 \leq \frac{1+c_1+c_2}{3} \end{aligned} \right\} \quad (13)$$

where $\frac{1+c_1}{2}$ and $\frac{1+c_1+c_2}{3}$ are (respectively) 1's monopoly price and the equilibrium price in a Cournot duopoly comprising firms 1 and 2. Of course, the number of active firms has implications for all three firms' net revenues (i.e. revenue minus variable costs).⁶ In general, the net revenues of firm i at Cournot equilibrium are (from (7) and (10))

$$(p - c_i) \cdot q_i = \begin{cases} \left(\frac{1 - M \cdot c_i + c_{-i}}{M + 1} \right)^2 & \forall i \in \{1, 2, \dots, M\} \\ 0 & \forall i \in \{M + 1, M + 2, \dots, N\} \end{cases}$$

Two specific cases will be of interest in our analysis. First, if firm 3 quits the market entirely, then

$$\text{Firm 1 earns } R^D(c_1, c_2) = \begin{cases} R^M(c_1) \equiv \left(\frac{1 - c_1}{2} \right)^2 & \text{iff } c_2 > \frac{1 + c_1}{2} \\ \left(\frac{1 - 2 \cdot c_1 + c_2}{3} \right)^2 & \text{iff } c_2 \leq \frac{1 + c_1}{2} \end{cases}$$

and

$$\text{Firm 2 earns } R^D(c_2, c_1) = \begin{cases} 0 & \text{iff } c_2 > \frac{1+c_1}{2} \\ \left(\frac{1-2 \cdot c_2 + c_1}{3}\right)^2 & \text{iff } c_2 \leq \frac{1+c_1}{2} \end{cases}$$

where $R^M(c_i)$ is i 's monopoly net revenue and $R^D(c_i, c_j)$ is i 's net revenue in a Cournot duopoly with firm j . Second, with firm 3 in the market we have

$$\text{Firm 1 earns } R^T(c_1, c_2, c_3) = \begin{cases} R^D(c_1, c_2) & \text{iff } c_3 > \frac{1+c_1+c_2}{3} \\ \left(\frac{1-3 \cdot c_1 + c_2 + c_3}{4}\right)^2 & \text{iff } c_3 \leq \frac{1+c_1+c_2}{3} \end{cases}$$

$$\text{Firm 2 earns } R^T(c_2, c_1, c_3) = \begin{cases} R^D(c_2, c_1) & \text{iff } c_3 > \frac{1+c_1+c_2}{3} \\ \left(\frac{1-3 \cdot c_2 + c_1 + c_3}{4}\right)^2 & \text{iff } c_3 \leq \frac{1+c_1+c_2}{3} \end{cases}$$

and

$$\text{Firm 3 earns } R^T(c_3, c_1, c_2) = \begin{cases} 0 & \text{iff } c_3 > \frac{1+c_1+c_2}{3} \\ \left(\frac{1-3 \cdot c_3 + c_1 + c_2}{4}\right)^2 & \text{iff } c_3 \leq \frac{1+c_1+c_2}{3} \end{cases}$$

where $R^T(c_i, c_j, c_k)$ with $c_k \geq c_j$ is i 's net revenue in a Cournot triopoly with firms j and k . (Although only the sum $(c_j + c_k)$ is relevant for i 's net revenue if i is active in equilibrium, the distribution of marginal costs across firms determines *whether* i is active in equilibrium. Therefore, we do not adopt the tempting notation $R^T(c_i, c_j + c_k)$ when describing the general forms of the $R(\cdot)$ functions.)

3.2.3. Equilibrium Industrial Structures.

We solve the game in Figure 1 by backwards induction. Definitions 1 and 2 formally characterise the game's subgame perfect Nash equilibria (in pure strategies) for a given choice by M . (Definition 1 applies if M chooses A , and Definition 2 applies if M chooses from $\{X, G\}$.) Definition 3 gives the equilibrium take-over price if A chooses M , and Definition 4 uses this result to state M 's decision rule between A and $\{X, G\}$.

Definition 1. If M 's strategy space is restricted to A , then the *equilibrium*

industrial structure is $\{A; S_E^*\}$ where

$$S_E^* \equiv \arg \max_{S_E} E\pi_E(A; S_E)$$

for all $S_E \in \{\emptyset, G_H, G_F, G_2\}$.

If M chooses A , then the equilibrium industrial structure is determined by the straightforward requirement that E play its best response to A .

Definition 2. If M 's strategy space is restricted to $\{X, G\}$, then the *equilibrium*

industrial structure is $\{S_A^*; S_T^*; S_E^*\}$ where

$$S_A^* \equiv \arg \max_{S_A} E\pi_A(S_A; S_T^{BR}(S_A); S_E^{BR}(S_A; S_T^{BR}(S_A)));$$

$$S_T^* \equiv S_T^{BR}(S_A^*); \text{ and } S_E^* \equiv S_E^{BR}(S_A^*; S_T^*)$$

and the $S^{BR}(\cdot)$ functions

$$S_T^{BR}(S_A) = \arg \max_{S_T} E\pi_T(S_A; S_T; S_E^{BR}(S_A; S_T))$$

$$S_E^{BR}(S_A; S_T) = \arg \max_{S_E} E\pi_E(S_A; S_T; S_E)$$

for all $S_A \in \{X, G\}$; $S_T \in \{X, G\}$; and $S_E \in \{\emptyset, G_H, G_F, G_2\}$

give the best responses of T and E to their (upstream) rivals' choices.

E 's equilibrium choice is (in the penultimate stage of the game) is determined by the requirement that E play its best response to S_A^* , S_T^* (which E takes as given). However, firm T must consider the knock-on effects of its choice of S_T on E 's optimal choice; therefore, S_E^{BR} is endogenized within S_T^{BR} . Likewise, firm M (the first-mover) must consider the implications of its choice of S_M for T and E 's optimal choices; therefore, the only independent variable in A 's objective function is S_A .

Definition 3. If M chooses A in the equilibrium industrial structure, then the

equilibrium take-over price is $E\pi_T(S_A^*; S_T^*; S_E^*)$, where S_A^* , S_T^* , S_E^* are

determined in Definition 2.

Given that M makes T a take-it-or-leave-it offer, the minimal take-over price that T will accept is (just above) T 's expected profits in equilibrium if M chooses from $\{X, G\}$. This is a standard result (see, e.g., Gilbert and Newbery, 1992).

Definition 4. M chooses A in the equilibrium industrial structure iff

$$E\pi_M(A; S_E^*) - E\pi_T(S_A^*; S_T^*; S_E^*) > E\pi_M(S_A^*; S_T^*; S_E^*) \quad (14)$$

where $E\pi_M(\cdot; \cdot)$ is determined in Definition 1, and $E\pi_T(\cdot; \cdot; \cdot)$, $E\pi_M(\cdot; \cdot; \cdot)$ are determined in Definition 2.

Definition 4 ultimately ties down the equilibrium industrial structure of the game in Figure 3.1. Condition (14) is straightforward: the LHS gives M 's expected payoff if acquisition-FDI occurs in equilibrium, and the RHS gives M 's expected payoff if acquisition-FDI does not occur in equilibrium. An implication of condition (14), which is clear on rearrangement, is that acquisition-FDI occurs in equilibrium iff M 's expected profits following acquisition-FDI are (strictly) greater than the combined expected profits of M and T if acquisition-FDI does not occur. Therefore, the decision rule for acquisition-FDI in our model is formally equivalent to the familiar co-operative decision rule for mergers of Salant, Switzer and Reynolds (1983), and our assumptions on the bargaining process *do not* restrict equilibrium behaviour. However, the assumption that M makes T a take-it-or-leave-it offer *does* restrict equilibrium payoffs following acquisition-FDI (i.e. T receives none of the 'surplus' from acquisition-FDI; see Definition 3), which are indeterminate under the co-operative decision rule. This restriction on equilibrium payoffs would primarily be a problem if we planned to undertake welfare comparisons across industrial structures, which we do not. We shall make use of the formal equivalence between condition (14) and the co-operative decision rule in Section 3.4 below.

When solving the model we place restrictions on c_M , c_T , t so that the functional forms of $R^D(\cdot, \cdot)$ and $R^T(\cdot, \cdot, \cdot)$ are independent of their arguments. This enables us to avoid extensive (and unrewarding) taxonomy. Specifically, we assume that all firms in the industry will be active in both countries in product market equilibrium. This assumption is additional to our maintained assumption (A) on c_M , c_T . Therefore, for example, for given c_M and c_T , t is constrained not to be so large that M can monopoly-price in its home market when T chooses X and E chooses \emptyset or G_F . The key implication of this assumption is that all firms always earn strictly positive net revenue in both countries in product market equilibrium (although, of course, low-marginal cost firms earn more than high-marginal cost ones). If E chooses \emptyset , then the net revenues of M and T in product market equilibrium are described by the duopoly net revenue function, $R^D(\cdot, \cdot)$. The necessary-and-sufficient condition for $R^D(\cdot, \cdot) > 0$ for every possible permutation of arguments is $R^D(c_T + t, c_M) > 0$, because $c_T + t$ is the maximum possible value of a firm's own marginal cost and c_M is the minimum possible value for its rival's marginal cost (and $\partial R^D(c_i, c_j) / \partial c_i \leq 0$, $\partial R^D(c_i, c_j) / \partial c_j \geq 0$). $R^D(c_T + t, c_M) > 0$ requires $c_T < (1 - 2 \cdot t + c_M) / 2$ (i.e. the monopoly price associated with c_M is strictly greater than $c_T + t$). The necessary-and-sufficient condition for $R^T(\cdot, \cdot, \cdot) > 0$ for every possible permutation of arguments is $R^T(c_T + t, c_M, c_M) > 0$, because the equilibrium price in a Cournot duopoly is lowest when both firms have marginal costs of c_M . $R^T(c_T + t, c_M, c_M) > 0$ requires $c_T < (1 - 3 \cdot t + 2 \cdot c_M) / 3$ (i.e. the equilibrium price in Cournot duopoly when both firms have marginal costs of c_M is strictly greater than $c_T + t$). Given

that $c_T > c_M$ from assumption (A), $c_T < (1 - 3 \cdot t + 2 \cdot c_M) / 3$ is more restrictive than $c_T < (1 - 2 \cdot t + c_M) / 2$ (which is intuitive because for a constant marginal cost across firms of c_M the monopoly price is strictly greater than the duopoly price). Therefore, our assumption that all firms are active in both countries in product market equilibrium translates into

$$(B) \quad t \in \left(0, \frac{1}{3}\right); \quad c_M \in (0, 1 - 3 \cdot t); \quad c_T \in \left(c_M, \frac{1 - 3 \cdot t + 2 \cdot c_M}{3}\right)$$

Given the assumptions on marginal costs in (B), we are able to derive some of the equilibrium properties of our model analytically (specifically, we solve backwards to *stage 2* – inclusive – analytically). However, as will be shown in the next Section, deriving the model's equilibrium industrial structures analytically is complicated by the model's mathematical intractability. Therefore, we solve for M 's stage-one choice numerically for three sets of the marginal cost parameters; these are

$$(S1) \quad t = 0.05; \quad c_M = 0.2; \quad c_T = 0.25$$

$$(S2) \quad t = 0.05; \quad c_M = 0.2; \quad c_T = 0.4$$

$$(S3) \quad t = 0.15; \quad c_M = 0.2; \quad c_T = 0.25$$

(S1) is the benchmark case. If wages are constant across both countries and firms, then M 's labour productivity is 25% higher than T 's in (S1). Compared to (S1), (S2) represents a widening of the (labour) productivity gap between M and T ; in (S2) M 's labour productivity is double T 's. Compared to (S1), (S3) represents a trebling of trade costs. (Note that all of (S1), (S2), (S3) are consistent with assumption (B).)

3.3. Analysis.

3.3.1. E 's optimal choice (stage three).

In stage three E chooses a corporate structure from $\{\emptyset, G_H, G_F, G_2\}$ (see Figure 1). We deal first with the (relatively simple) case where M 's prior corporate structure choice was A (and thus T does not exist as an independent entity).

Clearly $E\pi_E(A; \emptyset) = 0$. We also have

$$E\pi_E(A; G_H) = E\pi_E(A; G_F) = \theta \cdot [R^D(c_M, c_M) + R^D(c_M + t, c_M)] \\ + (1 - \theta) \cdot [R^D(c_T, c_M) + R^D(c_T + t, c_M)] - G$$

and

$$E\pi_E(A; G_2) = 2 \cdot [\theta + (1 - \theta) \cdot \theta] \cdot R^D(c_M, c_M) + 2 \cdot (1 - \theta)^2 \cdot R^D(c_T, c_M) - 2 \cdot G$$

$E\pi_E(A; G_H) = E\pi_E(A; G_F)$ (and hence E is indifferent between G_H and G_F following A) because following acquisition-FDI the two countries are identical, both containing one plant (in common ownership) with a marginal production cost of c_M . (We adopt two conventions throughout when writing down $E\pi_E(\cdot)$. First, if E has only one plant, we write *local* net revenue as the first term in square brackets and net revenue from *exports* as the second. Second, if E has two plants, we write net revenue in H before net revenue in F .) $E\pi_E(A; G_H)$ is linear and strictly increasing in θ , which makes intuitive sense because spillovers reduce E 's marginal production cost. In the expression for $E\pi_E(A; G_2)$ $\theta + (1 - \theta) \cdot \theta$ measures the probability that a spillover occurs in *at least* one country (note that $(1 - \theta) \cdot \theta$ is the probability of spillovers in a country given that none occur

abroad) and $(1 - \theta)^2$ measures the probability that spillovers occur in *neither* country. $E\pi_E(A;G_2)$ is increasing and strictly concave in θ on $[0, 1]$, which is again intuitive because $d^2[\theta + (1 - \theta)\cdot\theta]/d\theta^2 < 0$ so increases in θ have progressively smaller impacts on the *overall* probability of receiving spillovers.

As noted above, E has $G_H \sim G_F$ in response to A . Furthermore, in response to A

$$E \text{ has } \begin{cases} G_H, G_F \succ \emptyset & \text{iff } ER_E(A;G_H) > G \\ G_2 \succ \emptyset & \text{iff } \frac{1}{2} \cdot ER_E(A;G_2) > G \\ G_2 \succ G_H, G_F & \text{iff } ER_E(A;G_2) - ER_E(A;G_H) > G \end{cases} \quad (15)$$

where $ER_E(\cdot)$ denotes E 's expected net revenues in a given industrial structure.

Iff

$$2 \cdot ER_E(A;G_H) > ER_E(A;G_2) \quad (16)$$

then the plot of E 's best responses to A in (θ, G) -space resembles Figure 3.2. Condition (16) holds in all of (S1), (S2), (S3). The sufficiency of (16) for Figure 3.2 is obvious from inspection; its necessity is made clear by considering E 's best responses to A if (16) fails. (If $ER_E(A;G_2) \geq 2 \cdot ER_E(A;G_H)$, then E would never optimally choose G_H, G_F in response to A ; the best response to A would be G_2 (resp. \emptyset) iff $ER_E(A;G_2) >$ (resp. $<$) $2 \cdot G$. Therefore, an alternative interpretation of (16) is that it ensures that the region where G_H or G_F is E 's best response is non-empty.) Necessary-and-sufficient conditions akin to (16), which states that twice the net revenue from exporting (from a single plant) must strictly exceed the net revenue from undertaking (additional) greenfield-FDI (and establishing a second plant), will occur repeatedly in our analysis of E 's best responses. Those familiar

with the literature on tariff-jumping greenfield-FDI might find it difficult to conceive of circumstances where (16) fails since, if a foreign market can be served via exporting, undertaking greenfield-FDI will typically increase *but not double* total net revenues.⁷ Consider, however, E 's expected net revenues in $\{A; G_H\}$ and $\{A; G_2\}$ when t is so large that no international trade occurs in product-market equilibrium. In this case $ER_E(A; G_H) = \theta R^D(c_M, c_M) + (1 - \theta) \cdot R^D(c_T, c_M)$ because $R^D(c_M + t, c_M) = R^D(c_T + t, c_M) = 0$, and straightforward but tedious algebra shows that (16) fails for all $\theta \in [0, 1]$ (since $c_T > c_M$).⁸ The intuition for this (surprising) result (i.e. that adding a second plant *more* than doubles E 's global expected net revenues) is that only local producers serve product markets in equilibrium if t is 'very large' so (i) *all* of E 's variable profits abroad under greenfield-FDI represent a net increase in its global variable profits, and (ii) because E 'meets' M in two markets rather than one, adding a second plant increases E 's probability of receiving spillovers.

[FIGURE 3.2 IS OVERLEAF]

The effects of changing G in Figure 3.2 are entirely intuitive: increases in G decrease E 's optimal number of plants. The effects of changing θ are more complex, however, because it is *not* the case that increasing θ always increases E 's equilibrium number of plants. Where $ER_E(A; G_2) - ER_E(A; G_H)$ is downward-sloping, an increase in θ (for given G) can reduce E 's equilibrium number of plants from two to one: this occurs because increases in θ raise $ER_E(A; G_H)$ more than $ER_E(A; G_2)$ for large θ , so the gain in expected net revenue from choosing two plants over one, $ER_E(A; G_2) - ER_E(A; G_H)$, falls.⁹

Sunk cost of
greenfield-FDI, G

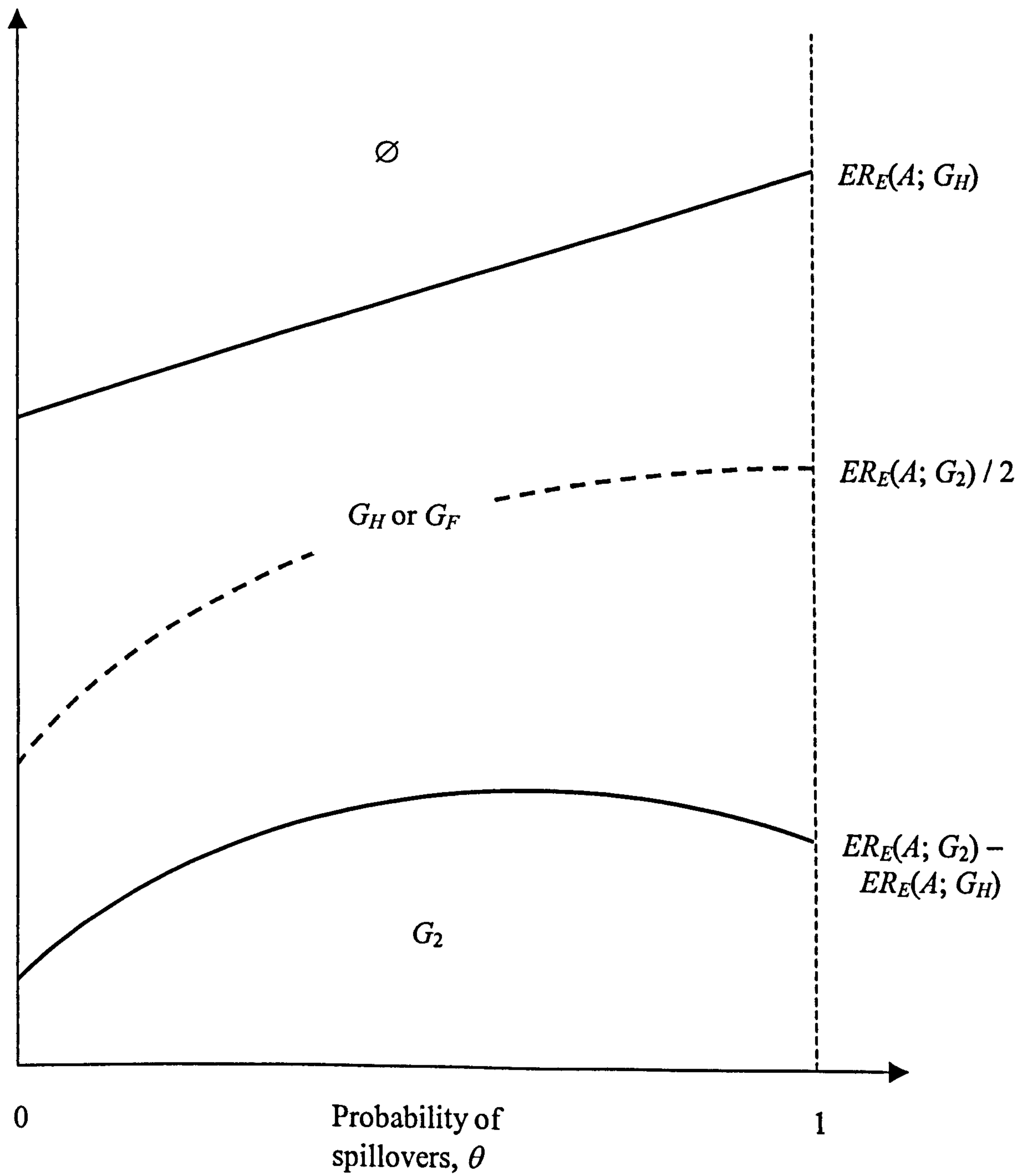


Figure 3.2: E 's best responses if M chooses A

We can also examine the comparative-statics effects of changing the marginal cost parameters c_M , c_T , t in Figure 3.2. Increasing t reduces $ER_E(A;G_H)$ as net revenues from abroad fall, but $ER_E(A;G_2)$ is unaffected because no international trade occurs in $\{A; G_2\}$ (A and E produce locally in both countries). Therefore, the top (\emptyset) and bottom (G_2) regions in Figure 3.2 both increase in size, and the middle (G_H or G_F) region is squeezed from both directions. (This is the case in (S3) relative to (S1).) Intuitively, an increase in t strengthens both E 's preference for zero plants over one (i.e. $ER_E(A;G_H)$ falls) and E 's preference for two plants over one (i.e. $ER_E(A;G_2) - ER_E(A;G_H)$ rises, an enhanced 'tariff-jumping' motive); thus the regions where \emptyset and G_2 are best responses grow at the expense of that where G_H or G_F is optimal.

We next consider the effects of raising c_T on Figure 3.2. (This is the case in (S2) relative to (S1).) Note first that both inter-regional boundaries in Figure 3.2 are independent of c_T at $\theta = 1$. This is because neither firm will have a marginal production cost in the product-market competition stage of c_T if spillovers are certain, so c_T becomes irrelevant. $ER_E(A;G_H)$, the upper inter-regional boundary in Figure 3.2, shifts downwards for all $\theta \in [0, 1)$ when c_T rises, because E 's preference for zero plants over one strengthens (if spillovers do not occur, higher c_T reduces E 's net revenues under G_H or G_F). $ER_E(A;G_2) - ER_E(A;G_H)$, the lower inter-regional boundary in Figure 3.2, shifts downwards for small θ but upwards for large (but <1) θ when c_T rises, reflecting the fact that a two-plant entrant has a higher probability of receiving spillovers than a one-plant entrant and so is less harmed by rises in c_T .¹⁰ Therefore, increasing c_T can strengthen E 's preference

for G_2 over G_H or G_F , implying that the bottom region in Figure 3.2 expands at the expense of the middle one.

Finally, we consider the effects on Figure 3.2 of varying c_M , which are more complex than the effects of varying t , c_T . Reducing c_M shifts $ER_E(A;G_H)$ downwards at $\theta = 0$ but upwards at $\theta = 1$ (in the linear Cournot duopoly considered here a common cut in both firms' marginal costs increases both firms' net revenues because the 'own' effect outweighs the 'cross' effect). Therefore, for appropriate G and small θ (e.g. just below the upper inter-regional boundary in Figure 3.2) a cut in c_M shifts E 's best response to A from G_H or G_F to \emptyset : entry is discouraged because M becomes a tougher competitor. However, for appropriate G and large θ (i.e. just above the upper inter-regional boundary in Figure 3.2) a cut in c_M shifts E 's best response to A in the opposite direction, from \emptyset to G_H or G_F : despite the tougher competition from M , entry is on balance encouraged by the desire to receive spillovers of its (now more valuable) technology. Turning to the lower inter-regional boundary in Figure 3.2, $ER_E(A;G_2) - ER_E(A;G_H)$ shifts in the same direction as $ER_E(A;G_H)$ near and at its end-points ($\theta \approx 0, 1$); however, further analysis is excessively complex given the illustrative comparative-statics exercise at hand.¹¹

If M and E do not choose A and \emptyset respectively, then both national product markets will be served by Cournot triopolies in stage four. Firm i 's net revenue in a Cournot triopoly with firms j and k was described by the function $R^T(c_i, c_j, c_k)$ in Section 3.2.2. However, if the Cournot first-order condition (2) binds (which is guaranteed by assumption (B)), then firm i 's best-response output

depends only on the *sum* of its rivals' marginal costs, $c_i + c_k$. Therefore, to lighten notation we write i 's net revenue function in a Cournot triopoly as $R^T(c_i, c_j + c_k)$ given assumption (B).

We next consider E 's best responses to $\{G; G\}$, $\{G; X\}$, $\{X; G\}$ and $\{X; X\}$. E 's expected profit functions for each case are presented in the Appendix; some commentary on them is also provided, and the more mechanical (i.e. less economically interesting) aspects of E 's best responses are derived. In each of these four cases we can state a necessary-and-sufficient condition analogous to (16) for E 's best responses in (θ, G) -space to resemble Figure 3.2. ('Resemble' is used here loosely to mean that each plot would have three distinct regions, which are ordered identically to those in Figure 3.2. Inter-regional boundaries may be shaped differently to those in Figure 3.2.) The relevant necessary-and-sufficient conditions are

For E 's best responses to $\{G; G\}$:

$$2 \cdot ER_E(G; G; G_H) > ER_E(G; G; G_2) \quad (17)$$

For E 's best responses to $\{G; X\}$:

$$2 \cdot ER_E(G; X; G_H) > ER_E(G; X; G_2) \quad (18)$$

For E 's best responses to $\{X; G\}$:

$$2 \cdot \max \{ER_E(X; G; G_H), ER_E(X; G; G_F)\} > ER_E(X; G; G_2) \quad (19)$$

For E 's best responses to $\{X; X\}$:

$$2 \cdot ER_E(X; X; G_H) > ER_E(X; X; G_2) \quad (20)$$

(17) – (20) hold in all of (S1), (S2), (S3) (and they are unconnected to assumption (B)¹²). Note that (17) – (20) share the same structure as (16): all five conditions state that twice the expected net revenue from establishing one plant must (strictly) exceed the expected net revenue from establishing two plants. (17) – (20) have two other characteristics in common with (16): first, if (17) – (20) fail, then E will never establish a single plant as a best response; second, (17) – (18) fail if t is so large that no international trade occurs in product-market equilibrium because in that case establishing a second plant (and thus meeting M in an additional product market) *more* than doubles E 's expected net revenues (E 's probability of receiving spillovers rises).¹³ Even if (16) – (20) all hold, E 's best responses will differ across cases in one noteworthy aspect: namely, E 's optimal choice of *where* to locate a single plant when E 's best response is one plant. In response to A , E is indifferent between G_H and G_F ; this is also so in response to $\{G; G\}$. In response to both $\{G; X\}$ and $\{X; X\}$ G_H strictly dominates G_F for all parameter values. E 's optimal one-plant choice in response to $\{X; G\}$ is more complex: in the region where E optimally chooses a single plant G_F is certainly (strictly) preferred to G_H for extreme θ -values (i.e. $\theta \approx 0, 1$). However, E 's choice between G_H and G_F at more central θ -values depends crucially on the marginal cost parameters c_M, c_T, t . For example, in (S1) and (S2) E strictly prefers G_H to G_F in response to $\{X; G\}$ for central θ -values, whereas in (S3) E strictly prefers G_F to G_H in response to $\{X; G\}$ for all $\theta \in [0, 1]$.¹⁴ We do not explore in any detail *how* the marginal cost parameters affect E 's choice between G_H and G_F in the one-plant region because for our purposes the fact that E

chooses one plant is much more significant than its location. However, we can provide some simple intuition on why E 's best response to $\{X; G\}$ might be G_H for central θ -values but G_F at the extremes. In $\{X; G; G_H\}$ E 's probability of receiving a spillover is θ , whereas in $\{X; G; G_F\}$ it is θ^2 . Clearly these probabilities are equal at $\theta = 0, 1$; but for $\theta \in (0, 1)$ E is strictly more likely to receive a spillover if it chooses G_H . Therefore, a desire to maximize the chance of receiving spillovers could (intuitively) explain a preference by E for G_H over G_F central θ -values in response to $\{X; G\}$.

In Figure 3.3 and 3.4 we plot, respectively, E 's best responses if M chooses G and X in (θ, G) -space. Both Figures cover both of T 's possible choices (X and G) and so allow us to investigate, for a given choice by M , E 's best response to a *change* in T 's choice. In the Appendix we show that the necessary-and-sufficient condition for the construction of Figure 3.3 is

$$ER_E(G; G; G_H) + ER_E(G; X; G_H) > ER_E(G; X; G_2) \quad (21)$$

which holds in all of (S1), (S2), (S3). Note that (21) is more restrictive than (17) and (18) (see the Appendix for proof).¹⁵

[FIGURE 3.3 IS OVERLEAF]

Sunk cost of
greenfield-FDI, G

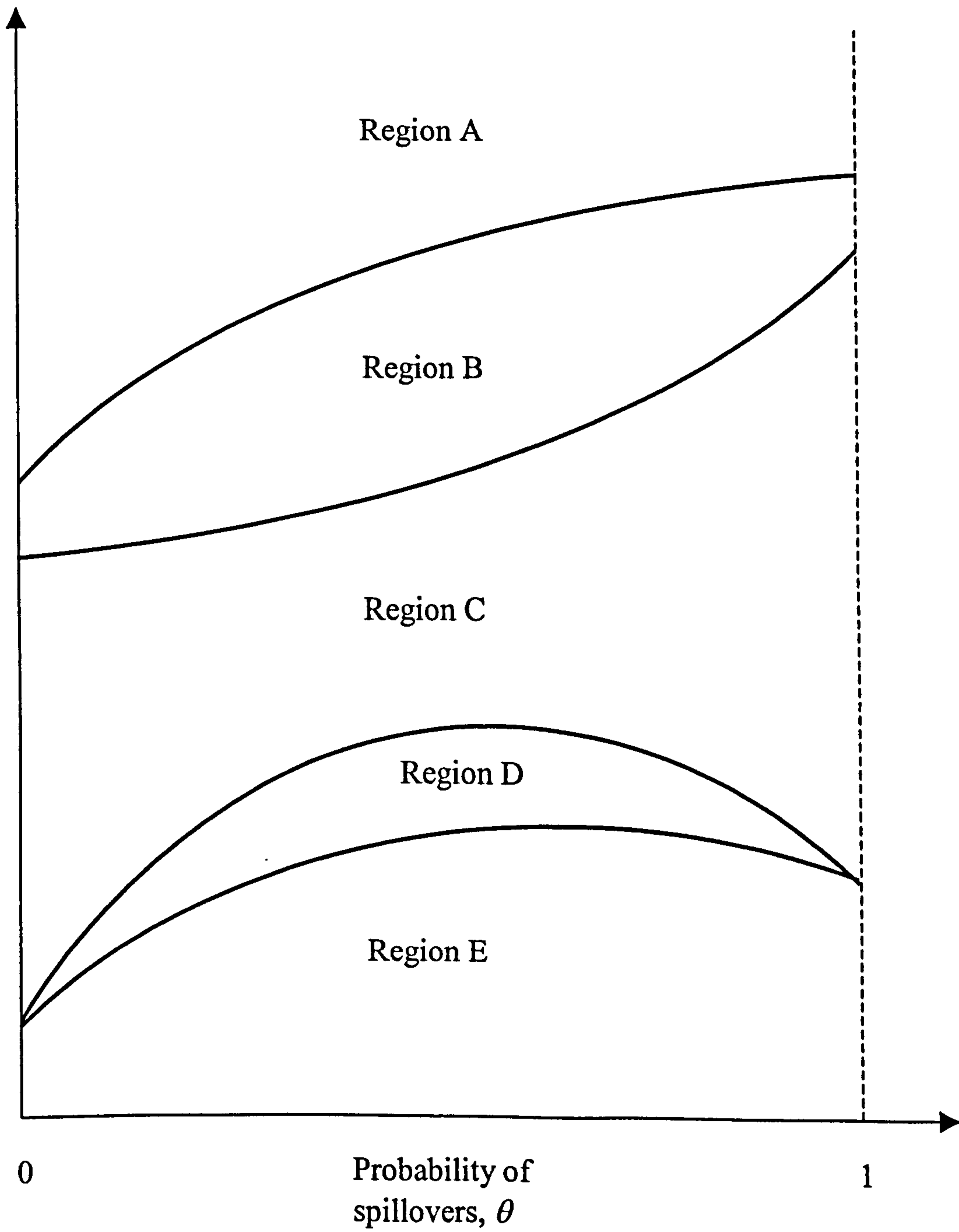


Figure 3.3: E 's best responses if M chooses G

Inter-regional boundaries. A/B: $ER_E(G; X; G_H)$; B/C: $ER_E(G; G; G_H \text{ or } G_F)$; C/D: $ER_E(G; X; G_2) - ER_E(G; X; G_H)$; D/E: $ER_E(G; G; G_2) - ER_E(G; G; G_H \text{ or } G_F)$.

Key to Figure 3.3

E 's BR to $\{G; G\}$	E 's best response (BR) to $\{G; X\}$		
↓	\emptyset	G_H	G_2
\emptyset	region A	region B	
G_H or G_F^*		region C	region D
G_2			region E

Note (*): In regions C and D, E is indifferent between G_H and G_F in response to $\{G; G\}$.

In Figure 3.3 increases in G reduce E 's optimal number of plants. Note that the critical G -values where E optimally switches from two plants to one and from one plant to zero are both higher if T chooses X (horizontal movements between cells in the key to Figure 3.3) than if T chooses G (vertical movements). This implies that two distinct (and mutually exclusive) cases exist in Figure 3.3. First, E 's optimal number of plants if M chooses G may be independent of T 's intervening choice (the diagonal cells in the key to Figure 3.3). Second, E 's optimal number of plants if T chooses X may be one greater than if T chooses G (the off-diagonal cells). However, it is *never* the case that E optimally chooses (strictly) more plants if T chooses G than if T chooses X . To provide some intuition for the existence of the second case above, note that (ceteris paribus) total expected net revenues ('rents') in product-market equilibrium will be lower if T chooses G over X , because (a) 'competition' in H is more intense since the trade cost does not enter T 's marginal cost; and (b) T has a higher probability of receiving spillovers from M since T and M 'meet' in two countries rather than

one. Therefore, it is possible to imagine situations where there is 'room' in the industry for an additional E -plant if T chooses X but not if T chooses G .

Figure 3.4 shows E 's best responses if M chooses X for either of T 's possible choices. In the Appendix we show that the necessary-and-sufficient conditions for the construction of Figure 3.4 are

c_T 'sufficiently larger' than c_M

$$2 \cdot \max \{ ER_E(X; G; G_H), ER_E(X; G; G_F) \} > ER_E(X; G; G_2) \quad (19) \text{ repeated}$$

$$\max \{ ER_E(X; G; G_H), ER_E(X; G; G_F) \} + ER_E(X; X; G_H) > ER_E(X; X; G_2) \quad (22)$$

all of which hold in (S1), (S2), (S3). It is unclear from inspection which of (19), (22) is the more restrictive: we have both $LHS(22) > LHS(19)$ and $RHS(22) > RHS(19)$. However, from Figure 3.4 it is clear that for small θ (22) is the more restrictive, whereas (19) is more restrictive for large θ . (This follows from how the inter-regional boundaries in the lower part of Figure 3.4 intersect.) A final, brief technical point worth making is that, although the *form* of Figure 3.4 is robust to all of (S1), (S2), (S3), the B/C, C/D and E/F inter-regional boundaries need not be kinked: in (S3) they will all be smooth.

[FIGURE 3.4 IS OVERLEAF]

Sunk cost of
greenfield-FDI, G

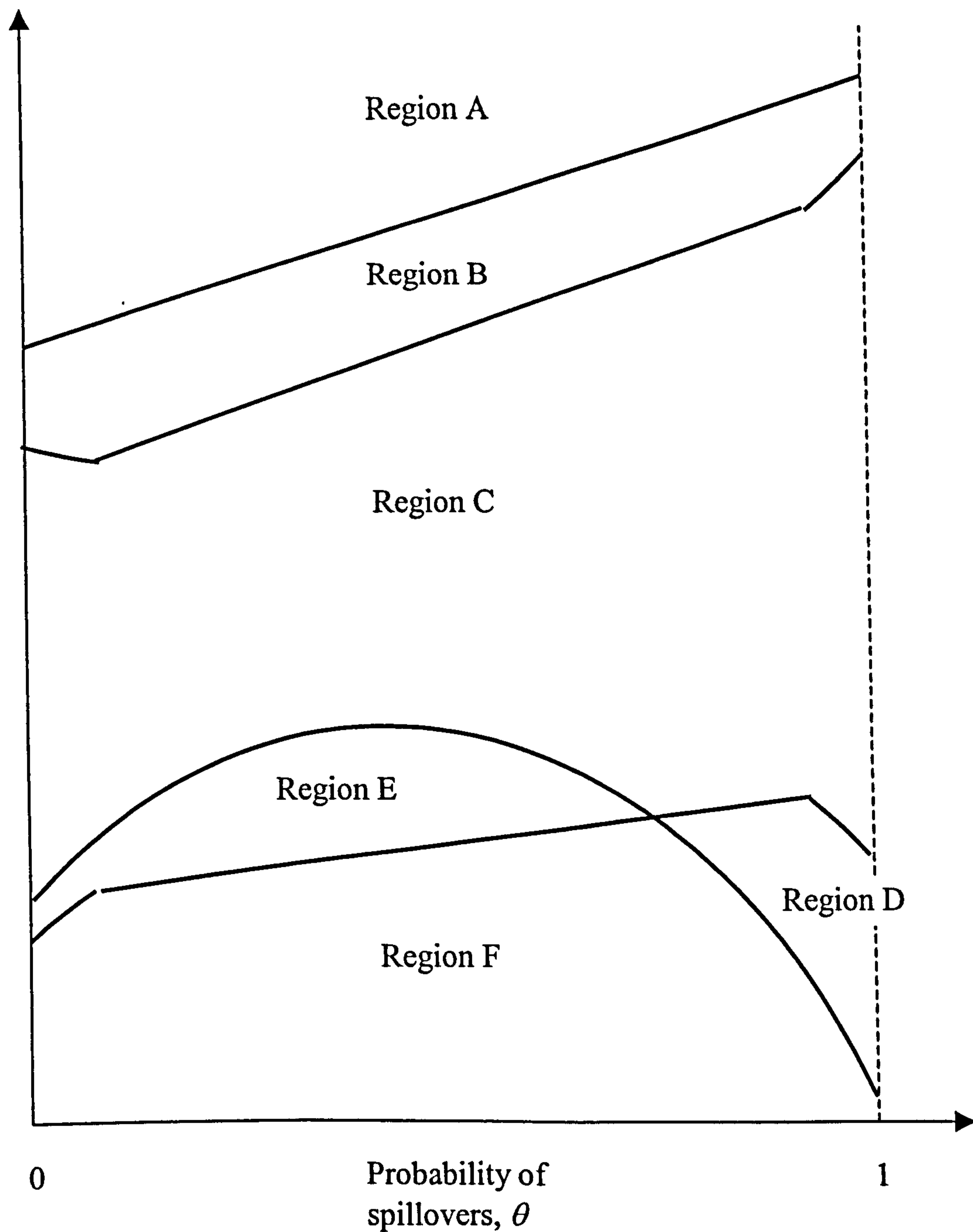


Figure 3.4: E 's best responses if M chooses X

Inter-regional boundaries. A/B: $ER_E(X; X; G_H)$; B/C: $\max\{ER_E(X; G; G_H), ER_E(X; G; G_F)\}$; C/D and E/F: $ER_E(X; G; G_2) - \max\{ER_E(X; G; G_H), ER_E(X; G; G_F)\}$; C/E and D/F: $ER_E(X; X; G_2) - ER_E(X; X; G_H)$.

Note that we do not locate the maximum θ -value in region E relative to the kink in the E/F inter-regional boundary. Therefore, although E will always choose one plant in region E, it may not always be in the same location. Furthermore, region F may not extend entirely to $\theta = 1$.

Key to Figure 3.4

E 's BR to $\{X; G\}$	E 's best response (BR) to $\{X; X\}$		
↓	\emptyset	G_H	G_2
\emptyset	region A	region B	
G_H or G_F^*		region C	region E
G_2		region D	region F

Note (*): In regions C and E, E is *not* indifferent between G_H and G_F in response to $\{X; G\}$. Rather, *one* of $\{G_H, G_F\}$ will be chosen by E in response to $\{X; G\}$ with *strict preference*.

Figure 3.4 shares several comparative-statics properties with Figure 3.3: in both, E 's optimal number of plants falls for a given choice by T as G rises. However, it is no longer true that E 's optimal number of plants is always (weakly) greater if T chooses X over G ; that is, the argument that there is more 'room' for entry by E (and thus E chooses more plants in equilibrium) if T chooses X , which was invoked to rationalise the structure of Figure 3.3, does not (universally) hold in Figure 3.4. The exception occurs in region D, where E chooses two plants in response to $\{X; G\}$ but only one plant in H in response to $\{X; X\}$. The explanation for this lies in the fact that region D does not exist for small θ . If the probability of spillovers is significantly greater than zero (as in D), then by choosing G_2 in response to $\{X; X\}$ E runs a significant risk (probability θ^2) of providing a channel for T to receive M 's technology (which would make T a more aggressive competitor). However, this risk is not present if M has previously chosen G . Therefore, for large θ E 's gain in expected net revenues from choosing two plants over one is greater following $\{X; G\}$ than $\{X; X\}$. Note

that for small θ the counterpart region to D is region E where the intuitive ‘room’ argument *does* hold: E chooses two plants in response to $\{X; X\}$ but only one in response to $\{X; G\}$ because the risk of indirectly providing T with M ’s technology is considered insignificant. It can easily be shown that the existence of region D crucially depends on c_T being ‘sufficiently larger’ than c_M .¹⁶ This makes intuitive sense: if $c_T \approx c_M$, then the cost to E in $\{X; X; G_2\}$ of providing T with spillovers of M ’s technology will be negligible (despite the fact that the associated probability, θ^2 , may be large).

3.3.2. M and T ’s optimal choices (stages one and two).

We begin by examining T ’s optimal choice in stage two, which itself exists only if M chooses X or G in stage one (see Figure 3.1). In stage two T chooses a corporate structure from $\{X, G\}$, taking account of E ’s subsequent best response in stage three. T ’s expected profit functions in every possible industrial structure are presented for reference in the Appendix. A key feature of them for our purposes is that $E\pi_T(\cdot)$ is generally strictly decreasing in the number of plants chosen by E for given choices by M, T .¹⁷ This makes intuitive sense because additional entry by E (i.e. adding an extra E -plant) will typically increase ‘competition’ in both host-country markets (i.e. E ’s marginal cost of supplying a market will fall if it establishes a local plant because trade costs are eliminated and E ’s probability of receiving spillovers typically rises). Therefore, we can describe how T ’s incentive to undertake greenfield-FDI changes as we move between cells in the keys to Figures 3.3 and 3.4 (i.e. how E ’s subsequent location choice affects T ’s decision *ceteris paribus*). First, a *rightwards* movement

between cells in either key generally *strengthens* T 's incentive to undertake greenfield-FDI because T 's expected net revenues from exporting fall but those from greenfield-FDI are unchanged so the gain to undertaking greenfield-FDI rises. The exception to this rule occurs in the key to Figure 3.4 when E 's best response to $\{X; X\}$ changes from G_H to G_2 : because we can have $ER_T(X; X; G_2) > ER_T(X; X; G_H)$ (see end-note 16), a rightwards move from the middle to the righthand column can *weaken* T 's incentive to undertake greenfield-FDI. Second, a *downwards* movement between cells in either key always *weakens* T 's incentive to undertake greenfield-FDI because T 's expected net revenues from greenfield-FDI fall but those from exporting are unchanged. These two points can be illustrated by considering the critical G -value, G^* , that governs T 's choice between greenfield-FDI and exporting for any given cell in the key to either Figure 3.3 or Figure 3.4. G^* equals T 's gain in expected net revenues from choosing greenfield-FDI over exporting, and it depends on the marginal cost parameters and θ in a form determined by the corporate structure choices of M , E . Clearly, T optimally chooses greenfield-FDI iff $G < G^*$ and exporting iff $G > G^*$ (by definition T is indifferent iff $G = G^*$). The first point above implies that G^* rises if we move rightwards between cells in either key, and the second implies that G^* falls if we move downwards between cells.¹⁸

Figure 3.5 plots the optimal corporate structure choices of T and E if M chooses G in (S1), (S2) and (S3). Because the inter-regional boundaries in Figure 3.5 are identical to those in Figure 3.3, it would be straightforward to derive the general necessary-and-sufficient conditions on θ and the marginal cost parameters underlying Figure 3.5; however, we do not do so here because the remainder of

our analysis will be concerned with the parameter values in (S1), (S2) and (S3).¹⁹ One point to note is that the pattern of optimal choices by T depicted in Figure 3.5 is consistent with (and explainable by) our analysis above of the effects of E 's subsequent choices on T 's incentives. For example, G^* (the critical G -value where T switches between greenfield-FDI and exporting, which reflects T 's 'incentive' to undertake greenfield-FDI) is higher for region B in Figure 3.3 than for region A because entry by E is strategically deterred if T chooses G in region B whereas in region A entry is blockaded. Given our parameter restrictions, we find that the A/B inter-regional boundary lies between these two values for G^* .²⁰

[FIGURE 3.5 IS OVERLEAF]

Key to Figure 3.5 (in the form {best response of T ; best response of E })

Region A: $\{X; \emptyset\}$; region B: $\{G; \emptyset\}$; region C: $\{X; G_H\}$; region D: $\{G; G_H$ or $G_F\}$ – E is indifferent between G_H and G_F ; region E: $\{G; G_2\}$.

Figure 3.6 plots the optimal corporate structure choices of T and E if M chooses X in (S1), (S2) and (S3). Again, we could straightforwardly derive the general necessary-and-sufficient conditions on θ and the marginal cost parameters underlying Figure 3.6 but for brevity do not do so.²¹ Three features that Figures 3.5 and 3.6 have in common are noteworthy. First, increases in the sunk cost of greenfield-FDI are associated with reductions in the number of plants that T and E , taken together, subsequently build. (If the sunk cost of greenfield-FDI is sufficiently small, then three plants are subsequently built following choices of both X and G by M . In both Figure 3.5 and Figure 3.6 increases in the sunk cost

Sunk cost of
greenfield-FDI, G

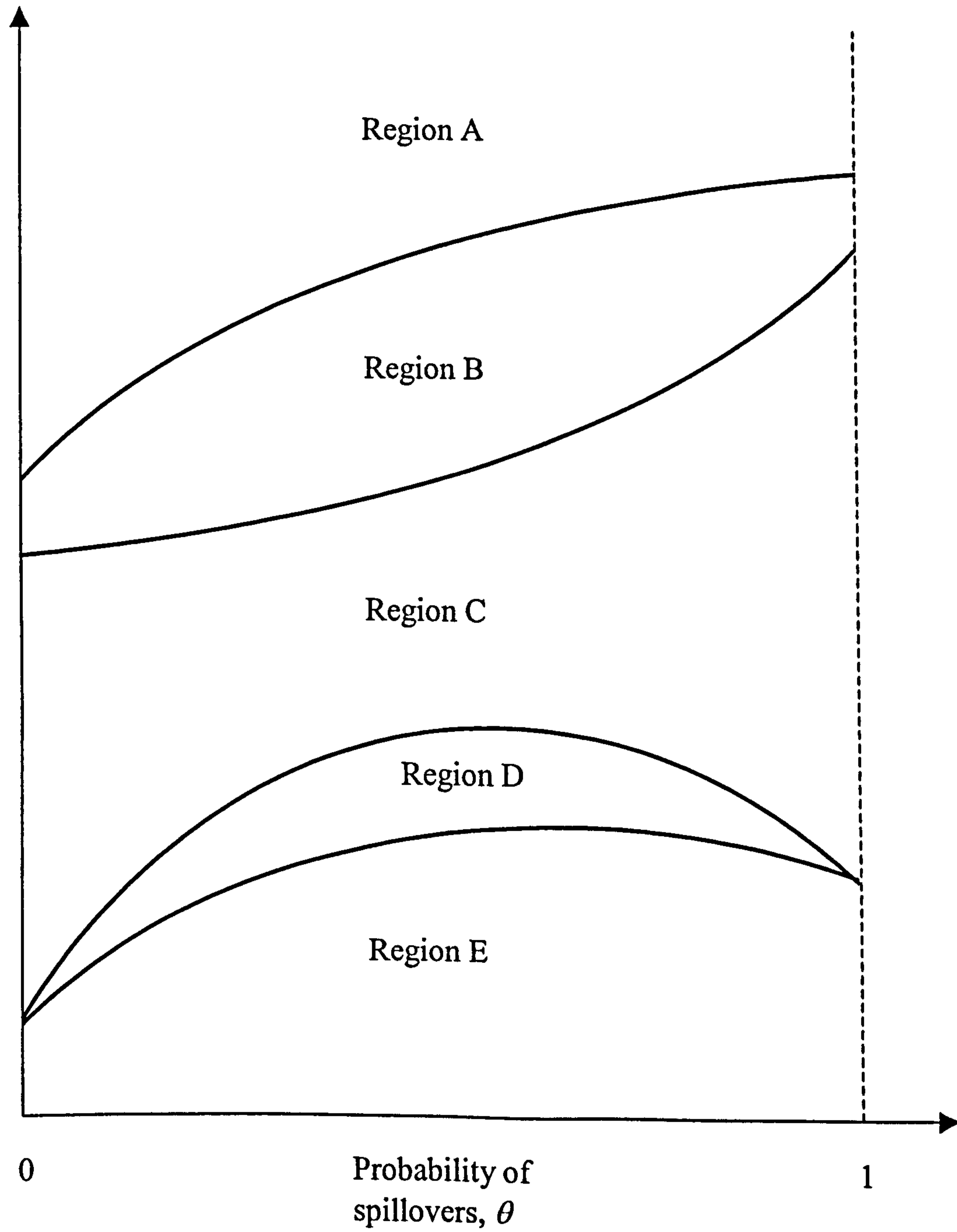


Figure 3.5: Best responses of T and E if M chooses G

Inter-regional boundaries (as in Figure 3). A/B: $ER_E(G; X; G_H)$; B/C: $ER_E(G; G; G_H$ or $G_F)$; C/D: $ER_E(G; X; G_2) - ER_E(G; X; G_H)$; D/E: $ER_E(G; G; G_2) - ER_E(G; G; G_H$ or $G_F)$.

of greenfield-FDI successively reduce the number of new-builds to two, then one, then zero.) Second, although the *total* number of subsequently-built plants is decreasing in the sunk cost of greenfield-FDI, the number built T individually is not.²² In region B of both Figure 3.5 and Figure 3.6 T switches, as the sunk cost of greenfield-FDI rises, from choosing X to G , before re-switching back to X in region A. The reason for this is that in region B T can strategically deter entry by E by undertaking greenfield-FDI, which is not possible in either region A or region C (in A entry is blockaded, and in C it is inevitable). Therefore, T 's incentive to undertake greenfield-FDI is greater in region B than in either region A or region C. Third, where the inter-regional boundaries in Figures 3.5 and 3.6 are upward-sloping, which is generally the case, increases in θ tend to increase the total number of subsequently-built plants. This reflects the strengthening of the motive for technology-sourcing greenfield-FDI (i.e. undertaking greenfield-FDI in the hope of benefitting from 'reverse' spillovers) as the probability of receiving spillovers rises.

[FIGURE 3.6 IS OVERLEAF]

Key to Figure 3.6 (in the form {best response of T ; best response of E })

Region A: $\{X; \emptyset\}$; region B: $\{G; \emptyset\}$; region C: $\{X; G_H\}$; region D: $\{G; G_H\}$ or $\{G; G_F\}$ – E is not indifferent between G_H and G_F ; region E: $\{G; G_2\}$.

We turn finally to consider firm M 's stage-one choice between $\{X, G, A\}$ and thus our game's equilibrium industrial structures. The analysis of M 's optimal choice occurs in two steps. First, we consider which of $\{X, G\}$ M prefers; by

Sunk cost of
greenfield-FDI, G

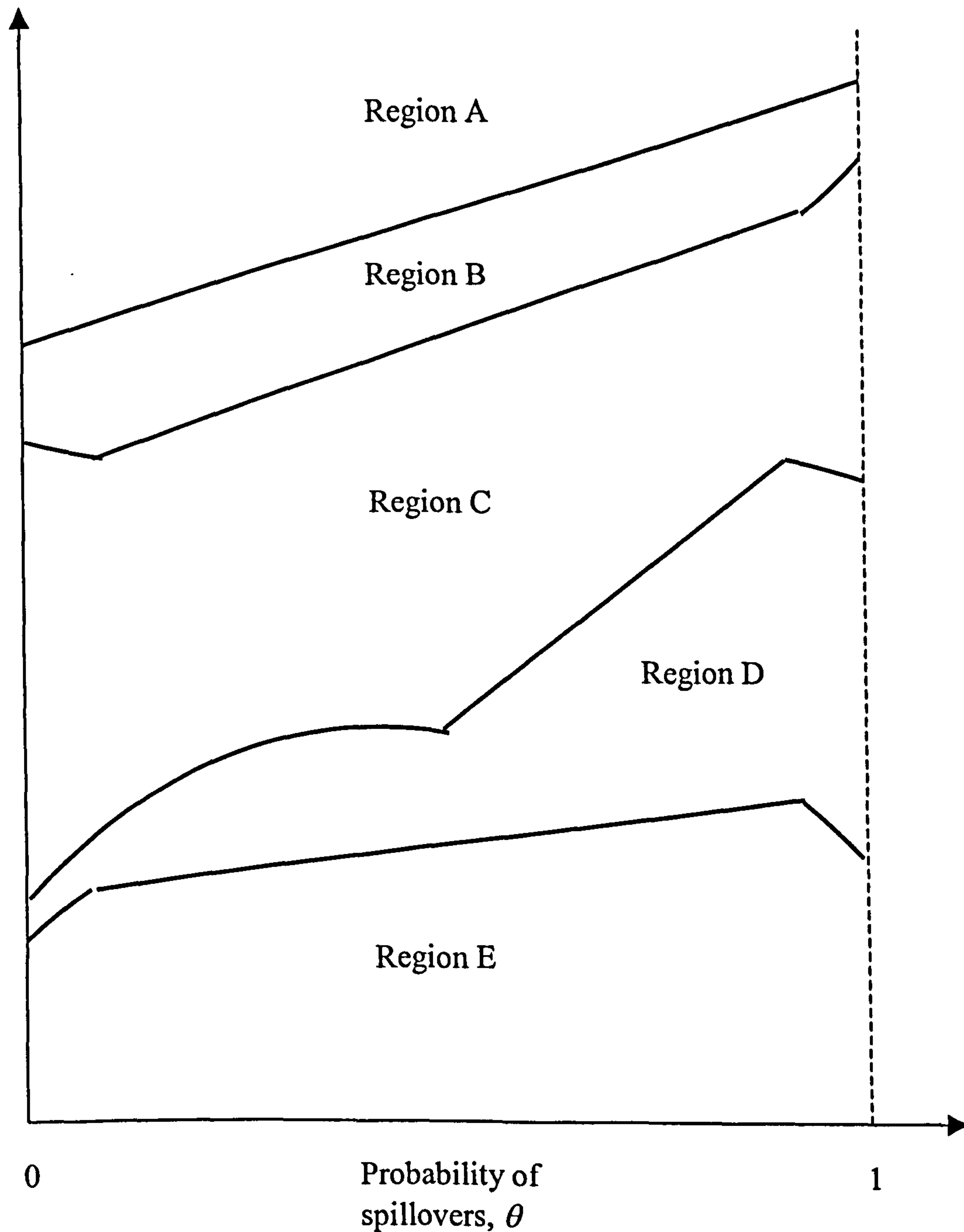


Figure 3.6: Best responses of T and E if M chooses X

Inter-regional boundaries. A/B: $ER_E(X; X; G_H)$; B/C: $\max\{ER_E(X; G; G_H), ER_E(X; G; G_F)\}$; C/D: $ER_E(X; X; G_2) - ER_E(X; X; G_H)$ for small θ , and $\min\{ER_T(X; G; G_H), ER_T(X; G; G_F)\} - ER_T(X; X; G_H)$ for large θ ; and D/E: $ER_E(X; G; G_2) - \max\{ER_E(X; G; G_H), ER_E(X; G; G_F)\}$.

Notes. In (S3) the B/C and D/E inter-regional boundaries will be smooth (by analogy with Figure 4). It is possible that region D may not exist continuously for all θ : for some parameter values a C/E inter-regional boundary may exist for a small interval of interior θ -values.

identifying M 's potential alternative strategy to A , this determines the acquisition price that M would have to pay for T . Second, we determine M 's choice between A and its preferred candidate from $\{X, G\}$ using the decision rule in (14).

The first step involves locating the inter-regional boundaries from Figure 3.5 and those from Figure 3.6 on the same diagram, and then calculating whether M prefers X or G in each distinct region (no inter-regional boundary is the same in both Figures, so the potential number of distinct regions thus created is large). Because of the complexity of the proposed analytical task, we solve stage one numerically. As will be demonstrated below, this still yields some useful suggestive insights. We work with three distinct numerical simulations: (S1), (S2) and (S3), where variation in the marginal cost parameters is allowed for. In each simulation we consider a 55-cell grid in (θ, G) -space: we consider θ -values belonging to $\{0, 0.25, 0.5, 0.75, 1\}$ and G -values (the sunk cost of greenfield-FDI) belonging to $\{0, 1, 2, \dots, 8, 10, 12\}$.²³

In Tables A3.1, A3.2 and A3.3 in the Appendix we report M 's preferred choice from $\{X, G\}$ in each of (S1), (S2) and (S3) respectively. Analytic representations of M 's expected profit functions are also given in the Appendix for reference. (In each Figure bold lines are used to group together cells where M makes the same optimal choice from $\{X, G\}$.) Here we report only some of the key features of those Figures, which relate to the determination of the acquisition price for T .²⁴ (AP stands for 'acquisition price', and each proposition holds 'other things' constant.)

AP1. If the sunk cost of greenfield-FDI rises, then the number of plants subsequently built by T and E (weakly) falls.

AP2. If θ rises, then the number of plants subsequently built by T and E (weakly) rises.

AP3. If M switches its choice from X to G , then the number of plants subsequently built by T and E (weakly) falls.

AP4. If M chooses X and c_T rises, then the number of plants subsequently built by T and E (weakly) falls for small θ but (weakly) rises for large θ . However, if M chooses G and c_T rises, then the number of plants subsequently built by T and E does not change.

AP5. If t rises, then the number of plants subsequently built by T and E (weakly) rises.

AP6. M is 'more likely' to choose G over X , the lower is the sunk cost of greenfield-FDI. If c_T rises, then M becomes 'less likely' to choose G over X . However, if t rises, then M becomes 'more likely' to choose G over X .

Note that propositions AP1 – AP6 only catalogue general properties of Figures A3.1 – A3.3: exceptions do exist, but the propositions are correct in the majority of cases (cells) considered. AP1 and AP2 summarise features of Figures 3.5 and 3.6 that were discussed in more detail above. The rationale for AP1 is a

straightforward substitution effect away from greenfield-FDI following a rise in the price of fields; that for AP2 is a strengthening of the technology-sourcing motive for greenfield-FDI as the probability of spillovers rises. AP3 illustrates how incumbents' undertaking greenfield-FDI can pre-empt de novo entry (Smith, 1987) by reducing the amount of 'room' in the industry for additional plants. (The mechanism here is that the incumbent's marginal cost of serving a host-country product market falls if it undertakes greenfield-FDI rather than exporting, thereby reducing a de novo entrant's expected net revenues.)

AP1 – AP3 were concerned with movements between or within cells *in a given Figure*. By contrast, AP4 and AP5 compare the same cell across different Figures. AP4 compares (S2) to (S1), i.e. Figure A3.2 to Figure A3.1, to gain insight into the effects of a rise in c_T . The results in AP4 are primarily driven by T 's behaviour, although E 's choices do play a role. (The rise in c_T makes 'entry' 'less likely', but – in particular – it appears primarily to affect E 's choice between one plant and none, rather than its choice between two plants and one. Furthermore, the effect of the rise in c_T on E 's behaviour is weaker, the larger is θ .) If M chooses X , then T can use greenfield-FDI to source technology from M to use in *both* its plants. The strength of this motive is increasing in both θ and c_T , which given the constancy of c_M reflects M 's technological lead. Therefore, if M chooses X , T becomes 'more likely' to choose G over X for large θ ($= 0.75, 1$), where the technology-sourcing motive is stronger than the straightforward profit-reducing effect of a rise in c_T if spillovers do not occur, but 'less likely' to choose G over X for small θ ($= 0, 0.25$), where the latter effect dominates.²⁵ However, if M chooses G , then the technology-sourcing motive for T also to choose G is

weakened (because T can receive spillovers from M without undertaking greenfield-FDI). In our reported numerical simulations this results in the rise in c_T having relatively little effect on T 's choice between G and X .

AP5 compares (S3) to (S1), i.e. Figure A3.3 to Figure A3.1, to gain insight into the effects of a rise in t . The effect of higher t on T 's behaviour is relatively straightforward to interpret: higher t encourages 'tariff-jumping' (or trade cost-jumping) greenfield-FDI, thus making a choice of G by T 'more likely'. The effect of higher t on E 's behaviour is more complex: 'initial' entry by E (i.e. one plant vs. none) is discouraged because its viability relies on net revenues from exporting, but 'expansion' by E (i.e. two plants vs. one) is encouraged via the same 'tariff-jumping' effects that influence T . Therefore, if t rises, the region where E optimally chooses one plant is squeezed – both from below (by the two-plant region) and from above (by the zero-plant region).²⁶

Finally, we consider AP6, which describes M 's optimal decision between X and G both within and between Figures A3.1 – A3.3. In each of Figures A3.1 – A3.3 a bold line groups together cells where M makes the same optimal choice. The first observation in AP6 says that M optimally chooses G *below* the bold lines in each Figure. This is not surprising: a rise in the sunk cost of greenfield-FDI causes a substitution effect away from greenfield-FDI. The second observation in AP6, which compares Figure A3.2 to Figure A3.1, captures the fact that a rise in c_T (i.e. in M 's technological lead given constant c_M) reduces M 's incentive to undertake greenfield-FDI because M 's technological lead might be dissipated through spillovers to local rivals in the host country following greenfield-FDI;

and obviously this loss is more costly to M , the greater is M 's technological lead. (This effect is stronger, the larger is θ , e.g. $\theta = 0.5, 0.75$. At $\theta = 1$ T and E 's subsequent location of plants in H (for sufficiently small sunk costs of greenfield-FDI) implies that the probability that M loses its technological lead is *independent* ($= 1$) of M 's choice between X and G , and M 's initial – rather than equilibrium – technological lead, $c_T - c_M$, is irrelevant to M 's choice between X and G . Therefore, M continues optimally to choose G for sufficiently small sunk costs of greenfield-FDI at $\theta = 1$ when c_T rises.) In the next Section we compare this finding to the contrasting conclusion of Dunning's (1977) OLI paradigm. The third observation in AP6, which compares Figure A3.3 to Figure A3.1, records how M 's incentive to undertake 'tariff-jumping' greenfield-FDI rises as t rises, an intuitive result.

We now turn to the second (and final) step in the determination of the game's equilibrium industrial structures: the comparison of M 's expected profits under acquisition-FDI (A) with the combined expected profits of M and T at the 'threat point' (i.e. if M chooses between X and G). From (14), acquisition-FDI occurs in equilibrium in stage one of the game if and only if M 's post-acquisition profits can (more than) cover M and T 's combined profits if the acquisition does not occur. In Tables 3.1 – 3.3 we report the game's equilibrium industrial structures in (S1), (S2) and (S3) respectively. In each Table bold lines are used to group together cells where M makes the same optimal choice between A and $\{X, G\}$. Some noteworthy features of the Tables are summarised in the following propositions (where EIS stands for 'equilibrium industrial structure' and – as above – 'other things' are held constant).

EIS1. As the sunk cost of greenfield-FDI rises from 0, the sequence of M 's equilibrium choices is $\{X, G\}, A, \{X, G\}, A$. (The bold lines divide each of Table 3.1 to Table 3.3 into four regions to reflect this sequence.²⁷) Rises in the sunk cost of greenfield-FDI also reduce the number of plants built by T and E in equilibrium.

EIS2. (A weaker property than EIS1.) For intermediate sunk costs of greenfield-FDI, rises in θ shift M 's equilibrium choice from A to $\{X, G\}$ if θ is initially small but from $\{X, G\}$ to A if θ is initially large.

EIS3. Where M chooses from $\{X, G\}$ in equilibrium, an increase in c_T makes M 'less likely' to choose G but T 'more likely' to choose G . An increase in c_T also shifts all four regions defined in EIS1 downwards (especially for small θ).

EIS4. Where M chooses from $\{X, G\}$ in equilibrium, an increase in t makes both M and T 'more likely' to choose G . Where M chooses A in equilibrium, an increase in t makes E 'more likely' to choose G_2 over G_H or G_F . An increase in t also shifts all four regions defined in EIS1 downwards.

Sunk cost of greenfield-FDI, G ($\times 100$)

12	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{X; X; \emptyset }
10	{A; \emptyset }	{X; X; \emptyset }	{X; X; \emptyset }	{X; X; \emptyset }	{X; X; \emptyset }
8	{X; X; \emptyset }	{X; X; \emptyset }	{X; X; \emptyset }	{X; X; \emptyset }	{X; G; \emptyset }
7	{X; X; \emptyset }	{X; X; \emptyset }	{X; G; \emptyset }	{X; G; \emptyset }	{A; G_H/G_F }
6	{X; X; \emptyset }	{X; G; \emptyset }	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }
5	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }
4	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }
3	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }	{A; G_H/G_F }
2	{A; G_H/G_F }	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_H/G_F }
1	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_2 }
0	{G; G; G_2 }	{G; G; G_2 }	{G; G; G_2 }	{G; G; G_2 }	{G; G; G_2 }
	0	0.25	0.5	0.75	1

Probability of spillovers, θ

Table 3.1: Equilibrium industrial structures in (S1) ($t = 0.05$; $c_M = 0.2$;

$c_T = 0.25$)

Sunk cost of greenfield-FDI, G ($\times 100$)

12	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{X; X; \emptyset }
10	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{X; X; \emptyset }	{X; G; \emptyset }
8	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{X; G; \emptyset }	{X; G; \emptyset }
7	{A; \emptyset }	{A; \emptyset }	{X; X; \emptyset }	{X; G; \emptyset }	{A; G_H/G_F }
6	{A; \emptyset }	{A; \emptyset }	{X; G; \emptyset }	{X; G; \emptyset }	{A; G_H/G_F }
5	{A; \emptyset }	{X; X; \emptyset }	{X; G; \emptyset }	{A; G_H/G_F }	{A; G_H/G_F }
4	{A; \emptyset }	{A; G_H/G_F }	{G; G; \emptyset }	{A; G_H/G_F }	{A; G_H/G_F }
3	{A; \emptyset }	{X; G; \emptyset }	{A; G_2 }	{A; G_2 }	{A; G_H/G_F }
2	{G; X; \emptyset }	{A; G_2 }	{A; G_2 }	{X; G; G_H }	{A; G_H/G_F }
1	{A; G_H/G_F }	{A; G_2 }	{A; G_2 }	{X; G; G_2 }	{A; G_2 }
0	{A; G_2 }	{A; G_2 }	{X; G; G_2 }	{X; G; G_2 }	{G; G; G_2 }
	0	0.25	0.5	0.75	1
	Probability of spillovers, θ				

Table 3.2: Equilibrium industrial structures in (S2) ($t = 0.05$; $c_M = 0.2$;

$c_T = 0.4$)

Sunk cost of greenfield-FDI, G ($\times 100$)

12	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }
10	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }	{A; \emptyset }
8	{A; \emptyset }	{A; \emptyset }	{X; X; \emptyset }	{X; X; \emptyset }	{X; G; \emptyset }
7	{X; X; \emptyset }	{X; X; \emptyset }	{X; X; \emptyset }	{G; X; \emptyset }	{G; X; \emptyset }
6	{X; X; \emptyset }	{G; X; \emptyset }	{G; X; \emptyset }	{X; G; \emptyset }	{A; G_H/G_F }
5	{G; X; \emptyset }	{X; G; \emptyset }	{A; G_H/G_F }	{G; G; \emptyset }	{G; G; \emptyset }
4	{A; G_H/G_F }	{G; G; \emptyset }	{G; G; \emptyset }	{A; G_2 }	{A; G_2 }
3	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_2 }
2	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_2 }
1	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_2 }	{A; G_2 }
0	{G; G; G_2 }	{G; G; G_2 }	{G; G; G_2 }	{G; G; G_2 }	{G; G; G_2 }
	0	0.25	0.5	0.75	1

Probability of spillovers, θ

Table 3.3: Equilibrium industrial structures in (S3) ($t = 0.15$; $c_M = 0.2$;

$c_T = 0.25$)

EIS1 to EIS4 describe the comparative-statics effects on industrial structure of exogenous changes in the (sunk and marginal) cost parameters of our game and θ . They are derived from inspection of Tables 3.1 to 3.3, which show our game's equilibrium industrial structures in each of our three numerical simulations. EIS1 and EIS2 list the effects of changes in the sunk cost of greenfield-FDI and θ respectively and, therefore, catalogue properties of each Table considered individually. The key to understanding the sequence of equilibria described in EIS1 is to consider the effects of changes in the sunk cost of greenfield-FDI on E 's decision if M chooses A or $\{X, G\}$. The basic distinction between choices of A and $\{X, G\}$ by M is that, when contemplating de novo entry, E faces a monopoly (at a global level) following A but a duopoly following $\{X, G\}$. Therefore, following de novo entry by E , the global industry will be a duopoly following A but a triopoly following $\{X, G\}$ (conduct is always Cournot), so that subsequent 'entry' is 'more likely' (i.e. occurs for a larger set of parameter values) following A than $\{X, G\}$. (I write 'entry' because it encompasses any choice on $\{G_H, G_F, G_2\}$ by E . We have seen in Figure 3.2, which – as discussed in the Appendix – extends readily to all possible pre-entry industrial structures, that E 's optimal number of plants switches from two to one to none as the sunk cost of greenfield-FDI rises. By claiming that 'entry' is 'more likely' following A than $\{X, G\}$, I mean that the inter-regional boundaries in Figure 3.2 are higher than the analogous inter-regional boundaries when E faces $\{G; G\}$, $\{G; X\}$, $\{X; G\}$ or $\{X; X\}$. Put another way, compared to the four alternative pre-entry industrial structures, E will always optimally choose as many (and sometimes more) plants following a choice by M of A .)

Applying this insight to EIS1, in the bottom two regions in Tables 3.1 to 3.3 E optimally chooses from $\{G_H, G_F, G_2\}$ (i.e. some form of ‘entry’) regardless of whether M has previously chosen A or one of $\{X, G\}$. From the point of view of M ’s decision, ‘entry’ (broadly construed) is *inevitable*: choosing A will result in a global duopoly in equilibrium, whereas choosing one of $\{X, G\}$ will produce a global triopoly. Therefore, M ’s preference for A in the higher of the bottom two regions in Tables 3.1 to 3.3 reflects a substitution of acquisition-FDI for the combined greenfield-FDI investments of M and T at the threat-point equilibrium as the sunk cost of greenfield-FDI rises. In the top region of Tables 3.1 to 3.3, where the equilibrium industrial structure is $\{A; \emptyset\}$, entry is *blockaded*: E optimally chooses \emptyset regardless of M ’s prior choice. Therefore, the occurrence of acquisition-FDI in equilibrium at the top of Tables 3.1 to 3.3 reflects the fact that industry profits are maximised under a low marginal cost (i.e. c_M) monopolist. Finally, we consider the second-from-top region in Tables 3.1 to 3.3, where (in general) M chooses from $\{X, G\}$ in equilibrium. Here the fact that ‘entry’ is ‘more likely’ following A than $\{X, G\}$ is crucial. In the second-from-top region ‘entry’ is *conditional* on M ’s prior choice: if M chooses A , then E optimally chooses from $\{G_H, G_F, G_2\}$; whereas if M chooses from $\{X, G\}$, then E optimally chooses \emptyset . Therefore, regardless of M ’s decision, the global industry is always a duopoly in equilibrium, and the non-occurrence of acquisition-FDI in equilibrium reflects the (generic) fact that *industry* profits in a Cournot duopoly are larger than either *firm*’s profits in a ‘similar’ Cournot duopoly.

The non-monotonic relationship in EIS1 between (the occurrence of) acquisition-FDI and the sunk cost of greenfield-FDI contrasts with the finding of Gilbert and

Newbery (1992, Proposition 1 and pp. 138-9) that a rise in the sunk cost of new plants will always make a single 'outside' firm 'more likely' to choose acquisition ('buying') over de novo entry ('building'). The contrast arises because the Gilbert/Newbery model does not allow for *subsequent* de novo entry following a firm's buy/build choice, whereas in our game (see Figure 3.1) firm E chooses whether to build plants in the industry at stage three following M 's choice between acquisition-FDI, greenfield-FDI and exporting at stage one. Because a choice by M of acquisition-FDI (A) rather than greenfield-FDI (G) or exporting (X) alters the industry's 'concentration' (i.e. replaces a duopoly with a monopoly), E 's 'entry incentive' is stronger following acquisition-FDI. In the second-from-top region of Tables 3.1 to 3.3 the sunk cost of greenfield-FDI is such that E chooses (some form of) 'entry' following acquisition-FDI but \emptyset (inactivity) if M selects greenfield-FDI or exporting: there is 'room' for additional plants only if E faces a monopoly. Firm M takes E 's subsequent best responses into account when making its own choice and optimally selects from $\{X, G\}$ in order to deter subsequent rent-dissipating de novo entry. This contrasts with M 's choice in the second-from-bottom region of Tables 3.1 to 3.3 where E always 'enters' and M chooses acquisition-FDI to economize on the sunk costs of greenfield-FDI.

EIS2 is (like EIS1) rationalised by considering E 's decision in stage three. EIS2 exploits the upward slopes of the (bold) inter-regional boundaries between the top three regions in each of Tables 3.1 to 3.3. Because, in each Table, the top two inter-regional boundaries are upward-sloping, a rise in θ from a low level can be associated (for an appropriately-selected sunk cost of greenfield-FDI) with a

switch in M 's equilibrium choice from A to X , but a rise in θ from a high level can be associated (again, for an appropriately-selected sunk cost of greenfield-FDI) with a 're-switch' in M 's equilibrium choice from one of $\{X, G\}$ back to A . For example, starting at the point (0.25, 6) in Table 3.2, where the equilibrium industrial structure is $\{A; \emptyset\}$, an increase in θ to 0.5 or 0.75 shifts the equilibrium industrial structure to $\{X; G; \emptyset\}$; however, a further increase in θ to 1 shifts equilibrium industrial structure to $\{A; G_H/ G_F\}$. The intuitive reason why the (top two) inter-regional boundaries in Tables 3.1 to 3.3 are upward-sloping is that 'entry' by E is 'more likely', the larger is θ (because the probability of access to a marginal production cost of c_M via spillovers is higher). Therefore, recalling our earlier result that 'entry' is 'more likely' following A than $\{X, G\}$, when increasing θ from a low level we are moving from a position of *blockaded* to *conditional* entry: the increase in θ makes 'entry' following A (but not $\{X, G\}$) profitable. Moreover, when increasing θ from a high level we are moving from a position of *conditional* to *inevitable* entry: the increase in θ makes 'entry' following both A and $\{X, G\}$ profitable.

EIS3 and EIS4 report the results of a comparison between Table 3.1, the benchmark case, and (respectively) Table 3.2 and Table 3.3. In the absence of spillovers we might reasonably expect a rise in c_T (relative to c_M) to make M 'more likely' to choose G but T 'less likely'. (For example, M 's gain in net revenue from choosing G over X if spillovers are assumed away and E chooses \emptyset is $R^D(c_M, c_T) - R^D(c_M + t, c_T)$, which will be increasing in c_T under the sort of linear Cournot model we are considering here because, although both terms are individually increasing in c_T , the scale of M 's output – and hence its ability to

benefit from industry price rises – is greater in the first term.) As we discuss in the next Section, these are the implications of the OLI paradigm; however, we find converse results. Comparing the bottom region of Table 3.1 to that of Table 3.2, we find M optimally switching from G to X as c_T rises – presumably to reduce the chance of its (now more valuable) technological lead being dissipated via spillovers. (In the second-from-top region in both Table 3.1 and Table 3.2 M generally chooses X , thus indicating little effect of a rise in c_T on M 's equilibrium behaviour.) On the contrary, if we compare T 's optimal behaviour in the second-from-top regions of Tables 3.1 and 3.2, we find T optimally switching from X to G as c_T rises: M 's greater technological lead makes technology-sourcing greenfield-FDI more worthwhile when c_T rises. (In the bottom regions of both Table 3.1 and Table 3.2 T always chooses G , so the rise in c_T has no effect on T 's equilibrium behaviour.)

If t rises (comparing Table 3.3 to Table 3.1), we find (a) both M and T 'more likely' to choose G over X in the second-from-top region, and (b) E 'more likely' to choose G_2 over G_H or G_F in the second-from-bottom region. These effects, which all boil down to a strengthened preference for two plants over one when t rises, can be rationalised in terms of greenfield-FDI's ability to 'jump' the trade cost. Finally, we find in EIS3 and EIS4 that increases in c_T and t both tend to push the four regions identified in each Table downwards. These effects share a common cause: rises in c_T and t both make 'entry' less profitable, so the spaces where entry is 'blockaded', 'conditional' and 'inevitable' (as defined above) all shift downwards in (θ, G) -space. A rise in c_T has relatively little effect for large θ

(and no discernable effect at $\theta = 1$) because the 'more likely' is E to receive M 's technology via spillovers, the less relevant is c_T for market equilibria.

3.4. Discussion.

In this Section I want to discuss some of the broader features and implications of our analysis. First, I shall consider some aspects of the spillover process (the θ -parameter); and second, I shall draw out some of the implications of our results for the sources of foreign-owned firms' 'productivity advantages'.

In our model θ , the 'probability of spillovers', is exogenous. We identify three factors that might be expected (partially) to determine θ in reality.²⁸ First, the degree of standardization (homogeneity) of products between foreign and local firms will be important: the 'more similar' are the products offered on the market by the two groups of firms, the 'more applicable' (useful) to their production processes will any spillovers received by local firms be. (Note that this point is independent of the direction in which spillovers are assumed to flow, and it could alternatively be stated as: 'absorptive capacity' is a decreasing function of the 'space' between products.) Second, to the extent that firms' 'productivity advantages' are embodied in their workers (via, e.g., on-the-job training), the level (or probability) of spillovers will increase in the degree of (intra-industry) worker mobility. Third, government policy can play a role in determining the probability of spillovers. Increases in the degree of 'patent protection' offered in law to new products would be expected (*ceteris paribus*) to reduce the probability of spillovers. (More precisely, spillovers might still occur – e.g. via

'demonstration effects' and reverse engineering – but the knowledge so gained could not lawfully be applied to the production process by the receiving firms.) Alternatively, government policy can attempt to raise the probability of spillovers: for example, by building 'business parks' where domestic and foreign firms are induced (by high-quality infrastructure) to locate side-by-side. If such a policy is successful, the probability of spillovers should rise (however, the UK evidence is not encouraging: see, e.g., Driffield, 2001).

Given the three mechanisms described above that affect θ (product differentiation, worker mobility, government policy), an interesting question (for extended work) is: How might the firms in our model use strategic behaviour to determine θ endogenously? After all, it seems reasonable to expect that the technological leader (firm M) will have a strong incentive (in an extended game with endogenous θ) to attempt to minimize θ , whereas firms T and E will have the converse incentive. From firm M 's perspective the following strategies may prove attractive: maximal (or, at least, increased) product differentiation; wage premia to prevent trained workers moving to local rivals (see Fosfuri, Motta and Rønde, 2001, for a neat analysis of this phenomenon); lobbying to strengthen 'patent protection'; and the choice of relatively (geographically) isolated locations for production plants, rather than locating in 'business parks'.²⁹

We turn now to consider our model's implications for the sources of foreign-owned firms' 'productivity advantages'. Before doing so, I want briefly to set out a reference point: Dunning's (1977) OLI (ownership-location-internalisation) paradigm. (Recent restatements of the OLI paradigm are given by Markusen,

1995, 1998.) The OLI paradigm starts from the assumption that an MNE establishing a production plant abroad via FDI incurs costs of co-ordinating business activities across national and cultural boundaries which are not incurred by local firms in the host country. Given this, the OLI paradigm identifies three conditions for FDI to occur, which taken together are necessary and sufficient: (a) the potential MNE must possess an 'ownership advantage' relative to its host-country rivals (e.g. a highly productive, proprietary process technology), the 'O'; (b) the foreign country must possess a 'location advantage' relative to others (e.g. low factor prices), the 'L'; and (c) FDI must possess an 'internalisation advantage' relative to licensing (e.g. because opportunistic use of blueprints by the licensee cannot be contracted against), the 'I'. In the context of our analysis of 'productivity advantages', the key element in the OLI paradigm is the necessity of 'ownership advantages' for multinational operations (a 'productivity advantage' is the only possible 'ownership advantage' in our model). It follows that, according to the OLI paradigm, the observed 'productivity advantages' of foreign-owned MNEs are *embodied* in their FDI inflows: either a (relatively) highly productive new plant is established via greenfield-FDI, or the technology in a pre-existing plant is upgraded (intra-firm technology transfer) following acquisition-FDI. (It is interesting to consider why the OLI paradigm predicts that MNEs require 'ownership advantages'. One possible explanation is that underlying OLI analysis is an implicit assumption that product markets are monopolistically competitive, so the 'representative' local firm in the foreign market earns only normal profits in long-run equilibrium. Given the cost disadvantage of operating internationally, MNEs would then require some

offsetting 'ownership advantage' – relative to the 'representative' local firm – to break even.³⁰)

We now compare the relationships of equilibrium national 'productivity distributions' to FDI inflows and outflows in our model to those predicted by the OLI paradigm (as reconstructed above). In Tables 3.1 to 3.3 we see that the role played by FDI inflows in shaping the equilibrium 'productivity distribution' in country F generally conforms to the OLI predictions. For example, in the equilibrium industrial structures of $\{G; G; G_2\}$ (all three Tables), $\{G; G; \emptyset\}$ (Tables 3.2 and 3.3) and $\{G; X; \emptyset\}$ (Tables 3.2 and 3.3), firm M 's inflow of greenfield-FDI into F directly adds a relatively productive new plant to F and indirectly raises the productivity of other plants in F via the probability of spillovers. Furthermore, in the equilibrium industrial structures of $\{A; \emptyset\}$, $\{A; G_H/ G_F\}$ and $\{A; G_2\}$ (all three Tables), firm M 's inflow of acquisition-FDI into F directly raises the productivity of the acquired (T -) plant (intra-firm technology transfer) and – in $\{A; G_F\}$ and $\{A; G_2\}$ – indirectly raises the productivity of the E -plant in F via the probability of spillovers.

However, there are three noticeable features of our model's equilibrium industrial structures that do not conform to the OLI predictions. First, in several equilibrium industrial structures (e.g. $\{G; G; G_2\}$, $\{X; G; \emptyset\}$, $\{G; G; \emptyset\}$ and $\{X; G; G_2\}$) firm T undertakes greenfield-FDI in country H . This occurs *despite* T 's 'ownership disadvantage' (i.e. technology c_T is 'less productive' than technology c_M). The reason why 'ownership advantages' are unnecessary for greenfield-FDI in our model is that the scale of potential entry is limited, so the 'representative

firm' can earn supernormal profits in equilibrium (there is also the important integer constraint on the number of firms). This is a replication of Fosfuri and Motta's (1999) 'multinationals without advantages' result. Indeed, stronger anti-OLI evidence in the same vein is provided in proposition EIS3 in the previous Section: if c_T rises relative to c_M (i.e. M 's 'ownership advantage' becomes greater), then M becomes 'less likely' to undertake greenfield-FDI but T 'more likely'. This result runs directly counter to the OLI predictions, and (as discussed in the previous Section) it is explained by M 's greater reluctance to risk losing its technological lead through spillovers when that lead lengthens.

The second equilibrium feature of our model that fails to conform to OLI predictions concerns acquisition-FDI. Although we set the model up by *assuming* that firm M is the potential acquirer, the decision rule for acquisition-FDI in (14) carries directly over to cases where the sequence of moves is modified so that (a) firm T is labelled the potential acquirer or (b) firms M and T are considered to merge.³¹ This is so because the decision rule is co-operative (i.e. the decision depends only on the *sum* of 'disagreement profits') and because the characteristics of the integrated firm are independent of the identity of the purchaser. Therefore, unless we assume a purchaser (as in our model), the *direction* (internationally) of acquisition-FDI flow in equilibrium in our modelling structure is indeterminate. It follows that whenever incentives for 'technology-injecting' acquisition-FDI exist in our model (i.e. the purchase of T by M), identical incentives for 'cherry-picking' acquisition-FDI (i.e. the purchase of M by T) will also exist. Therefore, our model gives no support to the OLI prediction that the purchaser in an acquisition-FDI transaction will be the

technological leader: indeed, there is no reason to suppose anything a priori about the relative technological strengths of acquirer and target.

The third aspect of our model that fails to conform to OLI predictions concerns its distinction between greenfield- and acquisition-FDI (the two forms of FDI are conflated in the OLI paradigm). Because of the limited scope for potential entry in our model, we found that M 's choice between A (acquisition-FDI) and $\{X, G\}$ (exporting or greenfield-FDI) frequently (i.e. for 'large' sets of parameter values) mattered for the equilibrium number of firms. Indeed, we used this feature of our model in explaining its 'pattern' of equilibrium industrial structures (see proposition EIS1 and the commentary on it in the previous Section). This suggests that more attention should perhaps be given to the distinction between greenfield- and acquisition-FDI (in shaping equilibrium industrial structures in industries without perfectly free entry or where integer constraints are important) than is afforded it in the OLI paradigm.

3.5. Concluding Comments.

In this chapter we have developed an equilibrium model of the relationship of FDI inflows and outflows to the national 'productivity distribution' across rival plants within an industry. We allowed for 'technology transfer' between plants in two forms: *inter-firm*, which represents 'spillovers'; and *intra-firm*, which reflects the 'public good' characteristic of technology within the firm. One of our key aims was to shed fresh (theoretical) light on the sources of foreign-owned firms' widely-documented 'productivity advantages'. Some of our principal

findings in the comparative-statics analysis of equilibrium industrial structures in Section 3.3 were

- Acquisition-FDI arises in equilibrium for two distinct sets of parameter values, medium-sized and very large sunk costs of greenfield-FDI; between them (i.e. large greenfield-FDI sunk costs) and for small greenfield-FDI sunk costs, firms optimally choose between exporting and greenfield-FDI in order to serve foreign product markets. The consequent ‘re-switching’ between greenfield- and acquisition-FDI that occurs as the sunk cost of greenfield-FDI rises is a typical feature of our model.
- Rises in the trade cost make the occurrence of greenfield-FDI (rather than exporting) in equilibrium ‘more likely’ in regions where acquisition-FDI does not occur. This is analogous to the ‘tariff-jumping’ greenfield-FDI observed in other models.
- Rises in the technological lead of an incumbent firm make that firm ‘less likely’ to undertake greenfield-FDI in equilibrium (because its technological lead could consequently be dissipated via localized spillovers in the host country), but they make foreign technological laggards ‘more likely’ to undertake (‘technology-sourcing’) greenfield-FDI in the leader’s home country.

The third property above contradicts the prediction of the popular OLI (ownership-location-internalisation) paradigm that the possession of ‘ownership advantages’ (highly productive, firm-specific assets) is necessary for (greenfield-)FDI. In addition, we found that the incentives for ‘technology-injecting’

acquisition-FDI (leader purchases laggard) are identical to those for 'cherry-picking' acquisition-FDI (laggard purchases leader), so the view that foreign MNEs' 'productivity advantages' are *necessarily* embodied in acquisition-FDI inflows is without theoretical support. There is some empirical support for this view. For example, Conyon, Girma, Thompson and Wright (2002) found that, over the period 1989 – 1994, UK firms acquired by foreign MNEs exhibited an increase in labour productivity of 13% (*ceteris paribus*). This contrasts with a (labour) 'productivity advantage' for foreign-owned firms in their dataset of nearly 30% over domestic firms (at the industry level), which suggests that, as well as raising the labour productivity of the plants they acquire, foreign MNEs choose to purchase plants with above-average productivity.

Our analysis leaves open a number of avenues for future research. Two seem immediately relevant to the types of questions we have been asking. First, inter-industry spillovers (i.e. 'vertical' spillovers to up- and downstream industries) could be modelled (our game contains only 'horizontal' or intra-industry spillovers). For example, a foreign MNE might demonstrate to indigenous firms in an upstream (input-supplying) industry better production techniques; indeed, to do so may well be in the MNE's private interest. Recent empirical work (Smarzynska, 2003) finds more support for 'backward' vertical spillovers than for horizontal spillovers. Second, we could consider some of the possible dynamic effects of FDI flows on national 'productivity distributions'. For example, inward FDI could – by increasing 'competition' (i.e. allowing the newly-created MNE to supply the host-country product market at a lower marginal cost) – promote skill and technology 'upgrading' within domestic firms

over time (e.g. increased training of workers and extra spending on R&D). It could also lead to the 'weeding out' (exit) of (technologically) inefficient domestic firms. These two topics (inter-industry and dynamic effects) will form the basis of future work.

3.6. Endnotes.

¹ Assume, first, that firms make no purchases of intermediate goods, so all gross output is value added (the acquisition price is the profits of the integrated firm that accrue to the owners of the target firm, and the sunk cost of greenfield-FDI is rent for the 'field'); second, that average variable cost is constant (= marginal production cost); and third, that firms are price-takers in factor markets and operate with a constant ratio of labour to (variable) capital. Then, if the two variable factors of production are labour (L) and capital (K), the marginal production cost is $L \cdot (w + r \cdot K/L) / Q$, where (\cdot) is constant by assumption. Both labour productivity (Q/L) and capital productivity (Q/K) are inversely proportional to the marginal production cost.

² We adopt Cournot competition, rather than Bertrand, as the solution concept because it allows variations in marginal costs (labour productivities) across active firms in equilibrium: a key aspect of our analysis.

³ To further illustrate this point, assume that three rival firms compete to serve a host-country product market (either via local production or via international trade) and that one is a clear technological leader over the other two, who both share the same inferior technology. This is the basic modelling structure of the current paper: assuming uni-dimensional technologies and imposing a simple pattern of technological leadership both restrict the number of possible inter-firm spillover flows. However, significant modelling complications remain. For example, if the spillover process is *deterministic* (e.g. a given share of the leader's marginal-cost advantage automatically spills over to the laggards), then the laggards' equilibrium marginal costs will vary continuously with the spillover-share parameter if they produce locally, and the number of active firms in market equilibrium will also potentially depend on the spillover-share parameter. Therefore, the analysis of the game's market stage becomes very burdensome (especially if one firm chooses to serve the market by international trade and a trade cost enters its marginal cost). Although expected marginal production costs are the same in our modelling of spillovers and the just-

described deterministic case, the expected profit functions differ because profits depend on *squared* marginal costs (Jensen's Inequality). If the spillover process is *random* (as in our model) but θ is defined as $\text{Prob}\{\text{technology flows between the leader and a given laggard}\}$, then if all three firms produce locally $\text{Prob}\{\text{a given laggard receives a spillover}\} = \theta + (1-\theta)\cdot\theta$. Because expected profits depend on *intersections* of events, e.g. $\text{Prob}\{\text{both laggards receive spillovers}\}$, the expected profit functions would contain high-powered terms in θ (making analytical manipulation difficult). The two examples above illustrate the difficulties in building deterministic spillovers and spillover flows between specific pairs of rival plants into even a relatively simple triopoly model.

⁴ Complementary slackness means that at most one of (2), (3) can be slack. Given the market demand curve in (1), the second-order condition is $\partial^2\pi_i/\partial q_i^2 = -2 < 0$, which ensures that π_i is globally strictly concave in q_i .

⁵ Lemma 1 proves that if firm M is active in Cournot equilibrium, then firms 1, 2, ..., $M - 1$ will also be active. However, it is not immediately clear that (11)

holding is incompatible with $c_j > \frac{1 + \sum_1^{j-1} c_i}{j}$ for some $j \in \{1, 2, \dots, M - 1\}$,

where the RHS is the equilibrium market price with only firms 1, 2, ..., $j - 1$

active. If $c_j > \frac{1 + \sum_1^{j-1} c_i}{j}$ for some $j < M$, then $1 + \sum_1^{j-1} c_i < j \cdot c_j$. (11) requires

$M \cdot c_M \leq 1 + \sum_1^{j-1} c_i + \sum_j^{M-1} c_i$, a sufficient condition for which to fail is

$M \cdot c_M > \max\{\text{RHS}\}$ (where $\max\{\text{RHS}\}$ is the maximum possible value that

$1 + \sum_1^{j-1} c_i + \sum_j^{M-1} c_i$ can assume). Using $1 + \sum_1^{j-1} c_i < j \cdot c_j$, we get

$\max\{\text{RHS}\} = j \cdot c_j - \varepsilon + (M - j) \cdot c_M$ where ε is strictly positive but arbitrarily

small. Therefore, the sufficient condition $M \cdot c_M > \max\{\text{RHS}\}$ becomes

$\varepsilon > j \cdot (c_j - c_M)$, which holds because $c_M \geq c_j$ so $\text{RHS} \leq 0$ but $\text{LHS} > 0$.

Therefore, if (11) holds, then $\frac{1 + \sum_1^{j-1} c_i}{j} \geq c_j$ for all $j < M$ and the equilibrium M from (11), (12) is *unique*.

To make the preceding algebra a little less abstract, assume a three-firm world (as in the current paper) with $c_3 \geq c_2 \geq c_1 \geq 0$. If $c_2 > (1 + c_1)/2$, then firms 2, 3 will be inactive in equilibrium. To see that it is impossible to have $1 + c_1 < 2 \cdot c_2$ (i.e. $c_2 > (1 + c_1)/2$) and $3 \cdot c_3 \leq 1 + c_1 + c_2$ (i.e. $c_3 \leq (1 + c_1 + c_2)/3$), note that $\max\{1 + c_1 + c_2\} = 3 \cdot c_2 - \varepsilon$ and $3 \cdot c_3 > 3 \cdot c_2 - \varepsilon$ because $c_3 \geq c_2$.

⁶ Net revenue is sometimes called ‘variable profit’.

⁷ Consider a world comprising two identical countries and a monopolistic firm in a given market who has a pre-existing plant in one country and is contemplating undertaking greenfield-FDI to establish a second plant abroad. Let $R^M(c)$ denote the monopolist’s net revenues (variable profits) in either national product market given a marginal production cost of c , and let t be the trade cost. Then the monopolist’s global net revenues from exporting are $NR_X = R^M(c) + R^M(c + t)$, and its global net revenues following greenfield-FDI are $NR_G = 2 \cdot R^M(c)$. Clearly, $NR_X < NR_G < 2 \cdot NR_X$ if $0 < R^M(c + t) < R^M(c)$ (as is conventionally assumed) because (intuitively) *the foreign product market is served under both exporting and greenfield-FDI*.

⁸ With very large t (16) becomes $\theta(1 - \theta) \cdot [R^D(c_T, c_M) - R^D(c_M, c_M)] > 0$. $[\cdot] < 0$ because $c_T > c_M$ and $\theta(1 - \theta) \geq 0$, which together imply that the strict inequality can never hold.

⁹ Whereas $dER_E(A; G_H)/d\theta > 0$ is constant, $dER_E(A; G_2)/d\theta = 4 \cdot (1 - \theta) \cdot [R^D(c_M, c_M) - R^D(c_T, c_M)] > 0$ tends to 0 as θ tends to 1.

¹⁰ $dER_E(A; G_H)/dc_T = (1 - \theta) \cdot d[R^D(c_T, c_M) + R^D(c_T + t, c_M)]/dc_T < 0$ for $\theta \in [0, 1)$, and the shift is larger, the smaller is θ . Because $dER_E(A; G_2)/dc_T = 2 \cdot (1 -$

$\theta^2 \cdot dR^D(c_T, c_M)/dc_T < 0$, the direction of shift in $ER_E(A;G_2) - ER_E(A;G_H)$ is given by $\text{sgn}[(1 - 2\theta) \cdot dR^D(c_T, c_M)/dc_T - dR^D(c_T + t, c_M)/dc_T]$, where $\text{sgn}[\cdot] = -$ implies that a rise in c_T shifts the lower inter-regional boundary in Figure 2 downwards. $[\cdot]$ is linear in θ , and $[\cdot] < (\text{resp. } >) 0$ at $\theta = 0$ (resp. 1). Note, however, that $[\cdot] = -dR^D(c_T + t, c_M)/dc_T > 0$ at $\theta = 0.5$, so $\theta \ll 0.5$ is necessary for 'low θ '.

¹¹ For $\theta \approx 0$ $ER_E(A;G_2) - ER_E(A;G_H)$ shifts downwards when c_M falls because $dR^D(c_T, c_M)/dc_M > dR^D(c_T + t, c_M)/dc_M$. For $\theta \approx 1$ $ER_E(A;G_2) - ER_E(A;G_H)$ shifts upwards when c_M falls because $dR^D(c_M + t, c_M)/dc_M > dR^D(c_M, c_M)/dc_M$. Both inequalities can be verified straightforwardly.

¹² In a strict, but rather limited, sense this may not be true. Under (B) we are able to place certain a priori restrictions on E 's choice between G_H and G_F (see the Appendix), which may not hold if (B) is abandoned. The necessary-and-sufficient condition on E 's best responses $\{G; G\}$, (17), is certainly independent of (B) because the two countries are identical at the point of entry irrespective of the marginal cost variables. However, in the other cases the necessary-and-sufficient condition may need to be expanded to take the form of (19). For example, it seems sensible to conjecture that E has G_F strictly preferred to G_H for small θ in response to $\{X; X\}$ if t is very large: given the low probability of receiving spillovers, E would rather produce in the protected F -market than face competition from M in H .

¹³ Note, of course, that M and E can only 'meet' in two markets if M chooses A or G : conditions (16), (17) and (18). With very large t , (17) and (18) become $\theta(1 - \theta) \cdot [R^T(c_T, 2 \cdot c_M) - R^T(c_M, 2 \cdot c_M)] > 0$ and $\theta(1 - \theta) \cdot [R^D(c_T, c_M) - R^D(c_M, c_M)] > 0$, both of which fail. If M chooses X , then conditions (19) and (20) apply to E 's best responses. With very large t , (19) becomes $\theta R^T(c_M, 2 \cdot c_M) + (1 - \theta) \cdot R^T(c_T, c_M + c_T) > \theta R^D(c_M, c_M) + (1 - \theta) \cdot R^D(c_T, c_T)$ if $\max\{\cdot\} = ER_E(X; G; G_H)$ and $2 \cdot (1 - \theta) \cdot R^D(c_T, c_T) + 2 \cdot \theta(1 - \theta) \cdot R^D(c_T, c_M) + 2 \cdot \theta^2 \cdot R^D(c_M, c_M) > \theta [R^T(c_M, 2 \cdot c_M) + R^D(c_M, c_M)] + (1 - \theta) \cdot [R^T(c_T, c_M + c_T) + R^D(c_T, c_T)]$ if $\max\{\cdot\} = ER_E(X; G; G_F)$. The former condition fails, but the latter certainly holds near its end-points, i.e. θ

$\approx 0, 1$. The intuition is that if E chooses two plants rather than one in response to $\{X; X\}$, then E risks passing spillovers (indirectly) from M to T . With very large t , (20) becomes $2 \cdot \theta \cdot R^D(c_M, c_M) + 2 \cdot (1 - \theta) \cdot R^D(c_T, c_M) > (1 - \theta) \cdot [R^D(c_T, c_M) + R^D(c_T, c_T)] + \theta(1 - \theta) \cdot [R^D(c_M, c_M) + R^D(c_M, c_T)] + 2 \cdot \theta^2 \cdot R^D(c_M, c_M)$, which fails. The reason for the appearance in the inequalities reported above of $R^D(\cdot, \cdot)$, which is absent from all the expected profit functions, is that very large t is incompatible with assumption (B) (which was invoked when writing down the E 's expected profit functions in the Appendix).

¹⁴ Note that in both (S1) and (S2) the intervals of θ -values where E chooses G_F are very small: in (S1) G_F is optimally chosen in the one-plant region following $\{X; G\}$ for $\theta \in [0, 0.039)$ and for $\theta \in (0.961, 1]$; and in (S2) the corresponding intervals are even smaller, $[0, 0.014)$ and $(0.986, 1]$.

¹⁵ A brief explanation of the role of assumption (B) (that all firms in the industry serve both national product markets in Cournot equilibrium) in deriving (21) is in order. Assumption (B) is invoked when deriving (21) in the Appendix, although we do not investigate formally whether this is necessary. (Our use of assumption (B) takes the form of assuming that a firm's net revenue in Cournot equilibrium depends on the *sum* of rivals' marginal costs but not on their distribution.) Furthermore, note that some c_M, c_T, t in (B) violate (21): for example, (21) fails for 'most' θ (except the extremes) when $c_M = 0, c_T = 0.03, t = 0.3$, values compatible with (B). Likewise, we invoke (B) when deriving the necessary-and-sufficient conditions that underlie Figure 3.4.

On the contrary, note that (B) is *not* invoked when deriving (16) – (20). However, some c_M, c_T, t in (B) do violate (16) – (21): for example, (17) fails for 'most' θ (except the extremes) when $c_M = 0, c_T = 0.03, t = 0.3$.

¹⁶ If $c_T = c_M$, then it is straightforward to show that $ER_E(X; G; G_2) - ER_E(X; G; G_H) = ER_E(X; X; G_2) - ER_E(X; X; G_H)$ at $\theta = 1$. Therefore, if $c_T = c_M$, region D in Figure 4 would be absorbed into region F, and region E in Figure 3.4 would exist for all θ .

¹⁷ In the $\{G; G\}$, $\{G; X\}$ and $\{X; G\}$ cases (where the first element indicates M 's choice and the second T 's) it is immediately obvious that additional entry by E (i.e. changing E 's choice from \emptyset to G_H or G_F , and from G_H or G_F to G_2) reduces T 's expected profits. This is because adding an extra E -plant makes E a tougher competitor in at least one market (by eliminating the trade cost from E 's marginal cost and perhaps increasing E 's probability of receiving spillovers) *but leaves T 's probability of receiving spillovers unchanged*. However, in the $\{X; X\}$ case comparisons are more complicated because by switching from G_H or G_F to G_2 , E increases T 's probability of receiving spillovers from 0 to θ^2 . Therefore, we might have $ER_T(X; X; G_2) > ER_T(X; X; G_H)$; in fact, it is straightforward to show that this holds for sufficiently large θ iff $R^T(c_M, 2 \cdot c_M + t) + R^T(c_M + t, 2 \cdot c_M) > R^T(c_T, 2 \cdot c_M + 2 \cdot t) + R^T(c_T + t, 2 \cdot c_M)$ (which ensures $ER_T(X; X; G_2) > ER_T(X; X; G_H)$ at $\theta = 1$; the inequality cannot hold at $\theta = 0$), which is satisfied in (S1), (S2), (S3).

¹⁸ Of course, the opposite effects occur if we move in the opposite directions.

¹⁹ For example, because T optimally chooses X throughout region A of Figure 3.3, one such necessary-and-sufficient condition would be $ER_E(G; X; G_H) > ER_T(G; G; \emptyset) - ER_T(G; X; \emptyset)$ for all θ , where the LHS is the lower boundary of region A and the RHS is T 's gain in expected net revenues from undertaking greenfield-FDI in A, i.e. the G^* in A. Furthermore, because T optimally chooses G throughout region D in Figure 3.3, another necessary-and-sufficient condition underlying Figure 3.5 would be $ER_T(G; G; G_H) - ER_T(G; X; G_2) > ER_E(G; X; G_2) - ER_E(G; X; G_H)$ for all θ (which simplifies to $ER_E(G; X; G_H) > ER_T(G; X; G_2)$ for all θ because $ER_T(G; G; G_H) \equiv ER_E(G; X; G_2)$, and always holds), where the LHS is the G^* in region D and the RHS is the upper boundary of region D. Therefore, we could state five necessary-and-sufficient conditions, one relating to each region in Figure 3.3. (Note, however, that the condition relating to region E would be trivial because $G^* \equiv$ upper boundary in E.)

We should finally note, although it will not affect our subsequent analysis, that the implicit necessary-and-sufficient condition underlying region B of Figure 3.5 is violated in (S1) and (S2) for $\theta \approx 1$ ($\theta > 0.975$ in (S1) and $\theta > 0.988$ in (S2)), where T optimally chooses X for some G near the A/B inter-regional boundary.

²⁰ Likewise, G^* is higher for region B in Figure 3.3 than for region C, where one-plant entry occurs regardless of T 's choice. This ranking of G^* is necessary (but insufficient) for the optimal choices by T depicted in regions B and C of Figure 3.5.

²¹ The derivation would follow the principles used in end-note 19 above. Note that T optimally chooses X throughout region A of Figure 3.4 and G throughout regions B, D, E and F of Figure 3.4. By comparing the relevant boundary of each of those five regions to the region's G^* , we can derive a necessary-and-sufficient condition for T to make the desired choice in that region of Figure 3.6. (Note also – as in end-note 19 – that the derived necessary-and-sufficient conditions can sometimes be usefully simplified. For example, $ER_E(X; G; G_2) - ER_E(X; G; G_F) \equiv ER_T(X; G; G_2) - ER_T(X; X; G_2)$, where the LHS is always (weakly) above the upper boundary of region F in Figure 3.4 and the RHS is T 's gain in expected net revenue from undertaking greenfield-FDI in that region (the G^*). Therefore, we are guaranteed that T will optimally choose G in region F of Figure 3.4. From this it follows that T optimally chooses G in region D of Figure 3.4 because the rightwards movement from cell D to cell F in the key to Figure 3.4 is associated with a weakening of T 's incentive to undertake (technology-sourcing) greenfield-FDI; see end-note 17.)

It is more difficult to derive a necessary-and-sufficient condition to apply to region C of Figure 3.4, where T 's optimal choice changes from G to X as the sunk cost of greenfield-FDI rises. A possible approach would be to restrict $ER_T(X; G; G_H) - ER_T(X; X; G_H)$, which measures T 's incentive to undertake greenfield-FDI in region C of Figure 3.4, to lying strictly below region C at $\theta = 0$ but strictly within region C at $\theta = 1$. However, we do not propose to explore this issue any further in the present chapter.

²² However, E 's optimal number of plants is decreasing in the sunk cost of greenfield-FDI, thus reflecting the aggregate (T plus E) pattern.

²³ For convenience we scale the sunk costs of greenfield-FDI upwards by a factor of 100 when reporting our results.

²⁴ When listing properties of the industrial structures where the acquisition price is determined, we adopt the organising principle of considering how a change in the environment affects the number of plants T and E , taken together, optimally choose to build. This organising principle is useful because it collapses T and E 's decisions into one another, thus allowing us to focus on aggregate effects.

Although the AP propositions (and the EIS propositions later) are framed in dynamic terms (e.g. 'if X rises, then Y will happen'), this is merely a convenient shorthand. Strictly, we are performing comparative-statics exercises on a one-shot game, and so we are comparing *alternative* equilibria rather than changes in an equilibrium over time.

²⁵ For illustrative purposes, assume that M and E choose X and \emptyset respectively. If $\theta \cong 1$, then the gain in expected net revenue to T from choosing G over X is approximately $R^D(c_M, c_M + t) + R^D(c_M, c_M) - [R^D(c_T, c_M + t) + R^D(c_T + t, c_M)]$, which is clearly increasing in c_T . This reflects a strong technology-sourcing motive for greenfield-FDI. However, if $\theta \cong 0$, then T 's gain is approximately $R^D(c_T, c_M) - R^D(c_T + t, c_M)$, which is decreasing in c_T because T 's output base in the former term is larger. This reflects the straightforward effect of a higher marginal cost on profits.

²⁶ A noteworthy point, consistent with these observations, is that the rise in t may sometimes alter the *composition* of a given number of subsequently-built plants. For example, $(X; G_H)$ sometimes switches to $\{G; \emptyset\}$, and in both cases one new plant is built by T and E , taken together.

²⁷ In Table 3.2 the $\{G; X; \emptyset\}$ cell at (0, 2) should be considered part of the second $\{X, G\}$ region.

²⁸ For a much more detailed discussion of the issues briefly considered here, see Blomström and Kokko (1998).

²⁹ The discussion here is intended to be suggestive rather than conclusive. For example, it is well known (see, e.g., d'Aspremont, Jaskold Gabszewicz and Thisse, 1979) that there are formidable analytical difficulties in endogenising the location choices of rival duopolists on the Hotelling line (when consumer transport costs are linear in distance). Therefore, we do not propose that a technological leader would choose maximal product differentiation in equilibrium, but rather that – *ceteris paribus* – a technological leader may reasonably be expected to have an incentive to differentiate its good more in order to reduce the probability of spillovers.

³⁰ Although monopolistic competition is rarely (if ever) explicitly mentioned in OLI analysis, it is consistent with OLI's emphasis on normal profits (necessitating 'ownership advantages) and product differentiation (as a source of 'ownership advantages'). Furthermore, formalizations of the OLI paradigm (e.g. Helpman, 1984; Ethier, 1986; Markusen and Venables, 1999) have tended to assume monopolistically competitive market structures. (Monopolistic competition also seems intuitively consistent with OLI's downplaying of the distinction between greenfield- and acquisition-FDI: for example, if firms are symmetric, then long-run free entry makes the buy/build choice irrelevant to equilibrium market structure.)

³¹ For example, in case (a), stage zero of the game would be firm T making a (take-it-or-leave-it) takeover to M . If the offer is accepted, we would move down the RHS of the game tree in Figure 3.1 to E 's decision. If the offer is rejected, firm M would choose between X and G and we would move down the LHS of the game tree.

3.7. Appendix.

Under the following four headings we present E 's expected profit functions (if M does not choose A) under assumption (B) (i.e. that all firms serve both national product markets in Cournot equilibrium). We also derive some of the basic properties of E 's best responses. In Section 3.7.5 we construct Figure 3.3, and in Section 3.7.6 we construct Figure 3.4.

3.7.1. E 's expected profits under $\{G; G\}$.

$$E\pi_E(G; G; \emptyset) = 0$$

$$E\pi_E(G; G; G_H) = E\pi_E(G; G; G_F) = \theta \cdot \left[R^T(c_M, 2 \cdot c_M) + R^T(c_M + t, 2 \cdot c_M) \right] \\ + \theta \cdot (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_T, 2 \cdot c_M) \\ + R^T(c_T + t, 2 \cdot c_M) \end{array} \right] + (1 - \theta)^2 \cdot \left[\begin{array}{l} R^T(c_T, c_M + c_T) \\ + R^T(c_T + t, c_M + c_T) \end{array} \right] - G$$

$$E\pi_E(G; G; G_2) = 2 \cdot \left[1 - (1 - \theta)^2 \right] \cdot R^T(c_M, 2 \cdot c_M) + 2 \cdot (1 - \theta)^2 \cdot R^T(c_T, c_M + c_T) - 2 \cdot G$$

In $E\pi_E(G; G; G_H)$ and $E\pi_E(G; G; G_F)$ the terms in θ reflect (successively) market equilibria if spillovers occur in the country where E locates; if spillovers occur in the country where E does *not* locate but not in E 's chosen country; and if spillovers occur in neither country. (In the middle case T , who owns two plants, benefits from spillovers but E does not.) $E\pi_E(G; G; G_H) = E\pi_E(G; G; G_F)$ (and hence E is indifferent between G_H and G_F in response to $\{G; G\}$) because the two countries are identical at the start of stage three, both containing an M -plant and a T -plant. In $E\pi_E(G; G; G_2)$ 1

– $(1 - \theta)^2$ is the probability that spillovers occur somewhere; because T and E both own two plants, both will receive spillovers that occur anywhere.

Iff

$$2 \cdot ER_E(G; G; G_H) > ER_E(G; G; G_2),$$

then E 's best responses to $\{G; G\}$ in (θ, G) -space can easily be shown to fall into three distinct regions, which are ordered identically to those in Figure 3.2. Analogously to Figure 3.2, the inter-regional boundaries are $ER_E(G; G; G_H)$ (upper) and $ER_E(G; G; G_2) - ER_E(G; G; G_H)$ (lower). $ER_E(G; G; G_H)$ is increasing and strictly convex in θ , and $ER_E(G; G; G_2) - ER_E(G; G; G_H)$ is hump-shaped (i.e. strictly concave with an interior maximum) because $ER_E(G; G; G_2)$ is increasing but strictly concave in θ and flat at $\theta = 1$.

3.7.2. E 's expected profits under $\{G; X\}$.

$$E\pi_E(G; X; \emptyset) = 0$$

$$E\pi_E(G; X; G_H) = \theta^2 \cdot \begin{bmatrix} R^T(c_M, 2 \cdot c_M + t) \\ +R^T(c_M + t, 2 \cdot c_M) \end{bmatrix} + \theta \cdot (1 - \theta) \cdot \begin{bmatrix} R^T(c_M, c_M + c_T + t) \\ +R^T(c_M + t, c_M + c_T) \end{bmatrix} \\ + \theta \cdot (1 - \theta) \cdot \begin{bmatrix} R^T(c_T, 2 \cdot c_M + t) \\ +R^T(c_T + t, 2 \cdot c_M) \end{bmatrix} + (1 - \theta)^2 \cdot \begin{bmatrix} R^T(c_T, c_M + c_T + t) \\ +R^T(c_T + t, c_M + c_T) \end{bmatrix} - G$$

$$E\pi_E(G; X; G_F) = \theta \cdot \begin{bmatrix} R^T(c_M, 2 \cdot c_M) \\ +R^T(c_M + t, 2 \cdot c_M + t) \end{bmatrix} + (1 - \theta) \cdot \begin{bmatrix} R^T(c_T, c_M + c_T) \\ +R^T(c_T + t, c_M + c_T + t) \end{bmatrix} - G$$

$$E\pi_E(G; X; G_2) = \theta \cdot \begin{bmatrix} R^T(c_M, 2 \cdot c_M + t) \\ + R^T(c_M, 2 \cdot c_M) \end{bmatrix} + \theta \cdot (1 - \theta) \cdot \begin{bmatrix} R^T(c_M, c_M + c_T + t) \\ + R^T(c_M, c_M + c_T) \end{bmatrix} \\ + (1 - \theta)^2 \cdot \begin{bmatrix} R^T(c_T, c_M + c_T + t) \\ + R^T(c_T, c_M + c_T) \end{bmatrix} - 2 \cdot G$$

In $E\pi_E(G; X; G_H)$ the terms in θ reflect (successively) market equilibria if spillovers occur in both countries; if spillovers occur in H but not in F ; if spillovers occur in F but not in H ; and if spillovers occur in neither country. $E\pi_E(G; X; G_F)$ is straightforward to interpret because only spillovers in F matter for market equilibria. In $E\pi_E(G; X; G_2)$ the terms in θ reflect (successively) market equilibria if spillovers occur in F ; if spillovers occur in H but not in F ; and if spillovers occur in neither country. An important simplification is provided by the fact that $E\pi_E(G; X; G_H) > E\pi_E(G; X; G_F)$ for all θ because $c_T > c_M$, which implies that G_H is strictly preferred to G_F .¹

Iff

$$2 \cdot ER_E(G; X; G_H) > ER_E(G; X; G_2),$$

then E 's best responses to $\{G; X\}$ in (θ, G) -space can easily be shown to fall into three distinct regions, which are ordered identically to those in Figure 3.2. Analogously to Figure 3.2, the inter-regional boundaries are $ER_E(G; X; G_H)$ (upper) and $ER_E(G; X; G_2) - ER_E(G; X; G_H)$ (lower). Both $ER_E(G; X; G_H)$ and $ER_E(G; X; G_2) - ER_E(G; X; G_H)$ are strictly concave in θ , and $ER_E(G; X; G_2) - ER_E(G; X; G_H)$ has an interior maximum. (The curvature of $ER_E(G; X; G_H)$ is proved in end-note 1 to this Appendix, and that of $ER_E(G; X; G_2) - ER_E(G; X; G_H)$ is proved indirectly during the construction of Figure 3.3 (see section 3.7.5): because $ER_E(G; X; G_2) - ER_E(G; X; G_H)$

$= ER_E(G; G; G_2) - ER_E(G; G; G_H)$ at $\theta = 0, 1$ and $ER_E(G; X; G_2) - ER_E(G; X; G_H) > ER_E(G; G; G_2) - ER_E(G; G; G_H)$ on $\theta \in (0, 1)$ (both proved below), and because $ER_E(G; G; G_2) - ER_E(G; G; G_H)$ is strictly concave in θ with an interior maximum, $ER_E(G; X; G_2) - ER_E(G; X; G_H)$ must have the same shape as $ER_E(G; G; G_2) - ER_E(G; G; G_H)$.)

3.7.3. E 's expected profits under $\{X; G\}$.

$$E\pi_E(X; G; \emptyset) = 0$$

$$E\pi_E(X; G; G_H) = \theta \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_M) \\ + R^T(c_M + t, 2 \cdot c_M + t) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_T, c_M + c_T) \\ + R^T(c_T + t, c_M + c_T + t) \end{array} \right] - G$$

$$E\pi_E(X; G; G_F) = (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_T, c_M + c_T + t) \\ + R^T(c_T + t, c_M + c_T) \end{array} \right] + \theta \cdot (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_T, 2 \cdot c_M + t) \\ + R^T(c_T + t, 2 \cdot c_M) \end{array} \right] \\ + \theta^2 \cdot \left[R^T(c_M, 2 \cdot c_M + t) + R^T(c_M + t, 2 \cdot c_M) \right] - G$$

$$E\pi_E(X; G; G_2) = \theta \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_M) \\ + R^T(c_M, 2 \cdot c_M + t) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_T, c_M + c_T) \\ + R^T(c_T, c_M + c_T + t) \end{array} \right] - 2 \cdot G$$

$E\pi_E(X; G; G_H)$ and $E\pi_E(X; G; G_2)$ are both straightforward to interpret because only spillovers in H matter for market equilibria. In $E\pi_E(X; G; G_F)$ the terms in θ reflect (successively) market equilibria if spillovers do not occur in H ; if spillovers occur in H but not in F ; and if spillovers occur in both countries.

Note that E 's best responses to $\{X; G\}$ are more complex than those to $\{G; G\}$ or $\{G; X\}$ because nothing can be said a priori about E 's choice between G_H and G_F (recall that – for all parameter values – E is indifferent between G_H and G_F in response to

$\{G; G\}$, whereas G_H strictly dominates G_F in response to $\{G; X\}$). Although $ER_E(X; G; G_F) > ER_E(X; G; G_H)$ at $\theta = 0, 1$, $ER_E(X; G; G_F)$ is strictly convex in θ whereas $ER_E(X; G; G_H)$ is linear.² Therefore, two mutually-exclusive and exhaustive possibilities arise: either (a) $ER_E(X; G; G_F) > ER_E(X; G; G_H)$ for all $\theta \in [0, 1]$; or (b) $ER_E(X; G; G_F) > ER_E(X; G; G_H)$ on $\theta \in [0, \theta_L)$ and $\theta \in (\theta^H, 1]$, and $ER_E(X; G; G_H) > ER_E(X; G; G_F)$ on $\theta \in (\theta_L, \theta^H)$, where $0 < \theta_L < \theta^H < 1$. In (a) G_F strictly dominates G_H , whereas in (b) E strictly prefers G_F to G_H for small and large θ -values but G_H to G_F for intermediate θ -values. (Case (a) applies in (S3) and (b) applies in (S1) and (S2). However, the distinction does not qualitatively affect our analysis of equilibrium behaviour because in both (a) and (b) there is considerable similarity between the sets of parameter values where E enters with one plant: the issue at stake is *where* that plant is located.)

Iff

$$2 \cdot \max\{ER_E(X; G; G_H), ER_E(X; G; G_F)\} > ER_E(X; G; G_2),$$

then E 's best responses to $\{X; G\}$ in (θ, G) -space can easily be shown to fall into three distinct regions, which are ordered identically to those in Figure 3.2. Analogously to Figure 3.2, the inter-regional boundaries are $\max\{ER_E(X; G; G_H), ER_E(X; G; G_F)\}$ (upper) and $ER_E(X; G; G_2) - \max\{ER_E(X; G; G_H), ER_E(X; G; G_F)\}$ (lower). The curvatures of $ER_E(X; G; G_H)$ and $ER_E(X; G; G_F)$ have been established above (see end-note 2 to this Appendix). Because $ER_E(X; G; G_2)$ is linear in θ , $ER_E(X; G; G_2) - ER_E(X; G; G_H)$ is also linear in θ but $ER_E(X; G; G_2) - ER_E(X; G; G_F)$ is strictly concave in θ .

3.7.4. E 's expected profits under $\{X; X\}$.

$$E\pi_E(X; X; \emptyset) = 0$$

$$E\pi_E(X; X; G_H) = \theta \cdot \left[\begin{array}{l} R^T(c_M, c_M + c_T + t) \\ + R^T(c_M + t, c_M + c_T + t) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_T, c_M + c_T + t) \\ + R^T(c_T + t, c_M + c_T + t) \end{array} \right] - G$$

$$E\pi_E(X; X; G_F) = R^T(c_T, c_M + c_T + t) + R^T(c_T + t, c_M + c_T + t) - G$$

$$E\pi_E(X; X; G_2) = 2 \cdot (1 - \theta) \cdot R^T(c_T, c_M + c_T + t) + 2 \cdot \theta \cdot (1 - \theta) \cdot R^T(c_M, c_M + c_T + t) \\ + \theta^2 \cdot R^T(c_M, 2 \cdot c_M + t) - 2 \cdot G$$

In $\{X; X; G_H\}$ only spillovers in H are relevant to E 's payoff, and in $\{X; X; G_F\}$ spillovers (anywhere) are irrelevant to E 's payoff. In $E\pi_E(X; X; G_2)$ the terms in θ reflect (successively) market equilibria if spillovers do not occur in H ; if spillovers occur in H but not in F ; and if spillovers occur in both countries. A useful simplification is provided by the fact that $E\pi_E(X; X; G_H) > E\pi_E(X; X; G_F)$ for all $\theta > 0$ (with equality at $\theta = 0$): regardless of where E locates its single plant, its rivals' marginal costs total $c_M + c_T + t$ in both countries; therefore, E 's location decision is driven solely by the possibility of receiving spillovers from M if it chooses H .

Iff

$$2 \cdot ER_E(X; X; G_H) > ER_E(X; X; G_2),$$

then E 's best responses to $\{X; X\}$ in (θ, G) -space can easily be shown to fall into three distinct regions, which are ordered identically to those in Figure 3.2. Analogously to Figure 3.2, the inter-regional boundaries are $ER_E(X; X; G_H)$ (upper), which is linear in θ , and $ER_E(X; X; G_2) - ER_E(X; X; G_H)$ (lower), which is strictly concave in θ (following $ER_E(X; X; G_2)$).

3.7.5. E 's best responses if M chooses G (Figure 3.3).

First, note that $ER_E(G; X; G_H) > ER_E(G; G; G_H)$ for all θ . This clearly holds at $\theta = 0$, because E faces less 'competition' in H under $\{G; X; G_H\}$. For $\theta > 0$ it is sufficient to have

$$\begin{aligned} \theta \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_M + t) \\ + R^T(c_M + t, 2 \cdot c_M) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_M, c_M + c_T + t) \\ + R^T(c_M + t, c_M + c_T) \end{array} \right], \\ > R^T(c_M, 2 \cdot c_M) + R^T(c_M + t, 2 \cdot c_M) \end{aligned}$$

which clearly holds at $\theta = 0, 1$ and therefore for all θ (because LHS is linear in θ).

Second, note that $ER_E(G; X; G_2) - ER_E(G; X; G_H) \geq ER_E(G; G; G_2) - ER_E(G; G; G_H)$ iff

$$\theta \cdot (1 - \theta) \cdot \left[\begin{array}{l} \left\{ \begin{array}{l} R^T(c_M, c_M + c_T) - R^T(c_M, 2 \cdot c_M) \\ - R^T(c_M + t, c_M + c_T) + R^T(c_M + t, 2 \cdot c_M) \end{array} \right\} \\ + \left\{ \begin{array}{l} R^T(c_M, 2 \cdot c_M + t) - R^T(c_M, 2 \cdot c_M) \\ - R^T(c_T, 2 \cdot c_M + t) + R^T(c_T, 2 \cdot c_M) \end{array} \right\} \end{array} \right] \geq 0.$$

Tedious algebra (expansion using the specific functional form of $R^T(\cdot, \cdot)$) shows that both expressions in $\{\cdot\}$ are strictly positive. Therefore, LHS = 0 at $\theta = 0, 1$ and LHS > 0 otherwise. Because $ER_E(G; G; G_2) - ER_E(G; G; G_H)$ is strictly concave in θ with an interior maximum on $[0, 1]$, it therefore follows that $ER_E(G; X; G_2) - ER_E(G; X; G_H)$ must take the same shape.

Given the two preceding results plus (17) and (18), Figure 3.3 takes the form depicted iff $ER_E(G; G; G_H) > ER_E(G; X; G_2) - ER_E(G; X; G_H)$. This is 'more restrictive' (sufficient but unnecessary for) than (17) (i.e. $ER_E(G; G; G_H) > ER_E(G; G; G_2) -$

$ER_E(G; G; G_H)$) because $ER_E(G; X; G_2) - ER_E(G; X; G_H) > ER_E(G; G; G_2) - ER_E(G; G; G_H)$ (established above). It is 'more restrictive' than (18) (i.e. $ER_E(G; X; G_H) > ER_E(G; X; G_2) - ER_E(G; X; G_H)$) because $ER_E(G; X; G_H) > ER_E(G; G; G_H)$ (established above).

3.7.6. E 's best responses if M chooses X (Figure 3.4).

First, we consider the upper part of Figure 3.4. Note that $ER_E(X; X; G_H) > \max\{ER_E(X; G; G_H), ER_E(X; G; G_F)\}$ for all θ . $ER_E(X; X; G_H) > ER_E(X; G; G_H)$ at $\theta = 0$ because E faces less 'competition' (as measured by the sum of rivals' marginal costs) in H under $\{X; X; G_H\}$; and $dER_E(X; X; G_H)/d\theta > dER_E(X; G; G_H)/d\theta$ (sufficient for this is $R^T(c_M, c_M + c_T + t) - R^T(c_M, c_M + c_T) > R^T(c_T, c_M + c_T + t) - R^T(c_T, c_M + c_T)$, which expansion using the specific functional form of $R^T(\cdot, \cdot)$ shows to hold) because under $\{X; X; G_H\}$ only E benefits from a rise in θ whereas both E and T benefit from rises in θ under $\{X; G; G_H\}$. $ER_E(X; X; G_H) > ER_E(X; G; G_F)$ at $\theta = 0, 1$ because (a) at $\theta = 0$ E faces less 'competition' abroad under $\{X; X; G_H\}$; and (b) at $\theta = 1$ E faces less 'competition' both locally and abroad under $\{X; X; G_H\}$. Whereas $ER_E(X; X; G_H)$ is linear in θ , $ER_E(X; G; G_F)$ is strictly convex in θ , which establishes $ER_E(X; X; G_H) > ER_E(X; G; G_F)$ on $\theta \in [0, 1]$.

Second, we consider the lower part of Figure 3.4. At $\theta = 0$ we have $ER_E(X; X; G_2) - ER_E(X; X; G_H) = ER_E(X; G; G_2) - ER_E(X; G; G_H) > ER_E(X; G; G_2) - ER_E(X; G; G_F)$. The equality is proved using straightforward substitution from E 's expected profit functions, and the inequality is proved in Section 3.7.3 above. If c_T is 'sufficiently

larger' than c_M , then we have $ER_E(X; G; G_2) - ER_E(X; G; G_H) > ER_E(X; G; G_2) - ER_E(X; G; G_F) > ER_E(X; X; G_2) - ER_E(X; X; G_H)$ at $\theta = 1$. The former inequality is proved in Section A3 above and the latter, which relies on c_T 'sufficiently larger' than c_M , is proved as follows. At $\theta = 1$ the only element of

$$ER_E(X; G; G_2) - ER_E(X; G; G_F) > ER_E(X; X; G_2) - ER_E(X; X; G_H)$$

that depends on c_T is $ER_E(X; X; G_H)$ on the RHS, and $dER_E(X; X; G_H)/dc_T|_{\{\theta=1\}} > 0$. Therefore, for the inequality above to hold for all c_M, c_T, t in (B) it is necessary and sufficient that it is satisfied at $c_T = c_M$. However, with $c_T = c_M$ the above inequality is easily shown (via expansion using the specific functional form of $R^T(\cdot, \cdot)$) to fail. Nevertheless, the inequality holds for the parameter values in (S1), (S2), (S3); therefore, there exists some critical c_T , (strictly) inside (B), where LHS = RHS.

We have therefore tied down the relative positions of $ER_E(X; X; G_2) - ER_E(X; X; G_H)$, $ER_E(X; G; G_2) - ER_E(X; G; G_H)$, and $ER_E(X; G; G_2) - ER_E(X; G; G_F)$ at $\theta = 0, 1$. It remains to consider the relative positions of these inter-regional boundaries on $\theta \in (0, 1)$. The following results are immediate given the two rankings proved above. First, $ER_E(X; G; G_2) - ER_E(X; G; G_H)$, which is linear in θ , intersects $ER_E(X; X; G_2) - ER_E(X; X; G_H)$, which is quadratic (and strictly concave) in θ , *once* on $\theta > 0$. This follows, given their shapes, because the two are equal at $\theta = 0$ but $ER_E(X; G; G_2) - ER_E(X; G; G_H) > ER_E(X; X; G_2) - ER_E(X; X; G_H)$ at $\theta = 1$. Furthermore, $d[ER_E(X; X; G_2) - ER_E(X; X; G_H)]/d\theta > d[ER_E(X; G; G_2) - ER_E(X; G; G_H)]/d\theta$ at $\theta = 0$, so $ER_E(X; G; G_2) - ER_E(X; G; G_H) = ER_E(X; X; G_2) - ER_E(X; X; G_H)$ must have two real roots. Second, because both the LHS and the RHS are quadratic (and strictly concave) in θ , the equation $ER_E(X; G; G_2) - ER_E(X; G; G_F) = ER_E(X; X; G_2) - ER_E(X; X; G_H)$ must

have zero, one or two real solutions. We know from above that the relative positions of these two inter-regional boundaries are reversed between $\theta = 0$ and $\theta = 1$; therefore, there must be an odd number of intersections. This implies that $ER_E(X; G; G_2) - ER_E(X; G; G_F)$ and $ER_E(X; X; G_2) - ER_E(X; X; G_H)$ intersect once on $\theta \in (0, 1)$.

Our final task is to integrate (combine) our conditions on the upper and lower parts of Figure 3.4. The two conditions presented in the main text, (19) and (22), ensure that the lowest inter-regional boundaries in the upper part of Figure 3.4 lie above the highest inter-regional boundaries in the lower part of Figure 3.4 (i.e. that the ‘upper’ and ‘lower’ parts of Figure 3.4, as we have defined them, do not overlap).

3.7.7. T 's expected profit functions.

The expected profit functions given below for T can be verified by following the derivations of E 's expected profit functions given above.

$$E\pi_T(G; G; \emptyset) = 2 \cdot \left[1 - (1 - \theta)^2 \right] \cdot R^D(c_M, c_M) + 2 \cdot (1 - \theta)^2 \cdot R^D(c_T, c_M) - G$$

$$E\pi_T(G; G; G_H) = E\pi_T(G; G; G_F) = ER_E(G; X; G_2) - G$$

$$E\pi_T(G; G; G_2) = ER_E(G; G; G_2) - G$$

$$E\pi_T(G; X; \emptyset) = \theta \cdot \left[\begin{array}{l} R^D(c_M, c_M) \\ + R^D(c_M + t, c_M) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^D(c_T, c_M) \\ + R^D(c_T + t, c_M) \end{array} \right]$$

$$E\pi_T(G; X; G_H) = ER_E(G; X; G_H)$$

$$E\pi_T(G; X; G_F) = ER_E(G; X; G_F)$$

$$E\pi_T(G; X; G_2) = ER_E(G; G; G_H)$$

$$E\pi_T(X; G; \emptyset) = \theta \cdot \left[\begin{array}{l} R^D(c_M, c_M + t) \\ + R^D(c_M, c_M) \end{array} \right] + (1-\theta) \cdot \left[\begin{array}{l} R^D(c_T, c_M + t) \\ + R^D(c_T, c_M) \end{array} \right] - G$$

$$E\pi_T(X; G; G_H) = \theta \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_M + 2 \cdot t) \\ + R^T(c_M, 2 \cdot c_M) \end{array} \right] + (1-\theta) \cdot \left[\begin{array}{l} R^T(c_T, c_M + c_T + 2 \cdot t) \\ + R^T(c_T, c_M + c_T) \end{array} \right] - G$$

$$E\pi_T(X; G; G_F) = ER_E(X; X; G_2) - G$$

$$E\pi_T(X; G; G_2) = ER_E(X; G; G_2) - G$$

$$E\pi_T(X; X; \emptyset) = R^D(c_T, c_M + t) + R^D(c_T + t, c_M)$$

$$E\pi_T(X; X; G_H) = \theta \cdot \left[\begin{array}{l} R^T(c_T, 2 \cdot c_M + 2 \cdot t) \\ + R^T(c_T + t, 2 \cdot c_M) \end{array} \right] + (1-\theta) \cdot \left[\begin{array}{l} R^T(c_T, c_M + c_T + 2 \cdot t) \\ + R^T(c_T + t, c_M + c_T) \end{array} \right]$$

$$E\pi_T(X; X; G_F) = ER_E(X; X; G_F)$$

$$E\pi_T(X; X; G_2) = ER_E(X; G; G_F)$$

3.7.8. *M*'s expected profit functions.

The expected profit functions given below for *M* can be verified by following the derivations of *E*'s expected profit functions given above.

$$E\pi_M(G; G; \emptyset) = 2 \cdot [1 - (1-\theta)^2] \cdot R^D(c_M, c_M) + 2 \cdot (1-\theta)^2 \cdot R^D(c_M, c_T) - G$$

$$E\pi_M(G; G; G_H) = E\pi_M(G; G; G_F) = \theta \cdot [R^T(c_M, 2 \cdot c_M) + R^T(c_M, 2 \cdot c_M + t)] \\ + \theta \cdot (1-\theta) \cdot \left[\begin{array}{l} R^T(c_M, c_M + c_T) \\ + R^T(c_M, c_M + c_T + t) \end{array} \right] + (1-\theta)^2 \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_T) \\ + R^T(c_M, 2 \cdot c_T + t) \end{array} \right] - G$$

$$E\pi_M(G; G; G_2) = 2 \cdot [1 - (1 - \theta)^2] \cdot R^T(c_M, 2 \cdot c_M) + 2 \cdot (1 - \theta)^2 \cdot R^T(c_M, 2 \cdot c_T) - G$$

$$E\pi_M(G; X; \emptyset) = \theta \cdot \left[\begin{array}{l} R^D(c_M, c_M + t) \\ + R^D(c_M, c_M) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^D(c_M, c_T + t) \\ + R^D(c_M, c_T) \end{array} \right] - G$$

$$E\pi_M(G; X; G_H) = 2 \cdot \theta^2 \cdot R^T(c_M, 2 \cdot c_M + t) + 4 \cdot \theta \cdot (1 - \theta) \cdot R^T(c_M, c_M + c_T + t) + 2 \cdot (1 - \theta)^2 \cdot R^T(c_M, 2 \cdot c_T + t) - G$$

$$E\pi_M(G; X; G_F) = \theta \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_M + 2 \cdot t) \\ + R^T(c_M, 2 \cdot c_M) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_T + 2 \cdot t) \\ + R^T(c_M, 2 \cdot c_T) \end{array} \right] - G$$

$$E\pi_M(G; X; G_2) = E\pi_M(G; G; G_H)$$

$$E\pi_M(X; G; \emptyset) = \theta \cdot \left[\begin{array}{l} R^D(c_M, c_M) \\ + R^D(c_M + t, c_M) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^D(c_M, c_T) \\ + R^D(c_M + t, c_T) \end{array} \right]$$

$$E\pi_M(X; G; G_H) = \theta \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_M) \\ + R^T(c_M + t, 2 \cdot c_M + t) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_T) \\ + R^T(c_M + t, 2 \cdot c_T + t) \end{array} \right]$$

$$E\pi_M(X; G; G_F) = (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_T + t) \\ + R^T(c_M + t, 2 \cdot c_T) \end{array} \right] + \theta \cdot (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_M, c_M + c_T + t) \\ + R^T(c_M + t, c_M + c_T) \end{array} \right] + \theta^2 \cdot [R^T(c_M, 2 \cdot c_M + t) + R^T(c_M + t, 2 \cdot c_M)]$$

$$E\pi_M(X; G; G_2) = \theta \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_M) \\ + R^T(c_M + t, 2 \cdot c_M) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_T) \\ + R^T(c_M + t, 2 \cdot c_T) \end{array} \right]$$

$$E\pi_M(X; X; \emptyset) = R^D(c_M, c_T + t) + R^D(c_M + t, c_T)$$

$$E\pi_M(X; X; G_H) = \theta \cdot \left[\begin{array}{l} R^T(c_M, c_M + c_T + t) \\ + R^T(c_M + t, c_M + c_T + t) \end{array} \right] + (1 - \theta) \cdot \left[\begin{array}{l} R^T(c_M, 2 \cdot c_T + t) \\ + R^T(c_M + t, 2 \cdot c_T + t) \end{array} \right]$$

$$E\pi_M(X; X; G_F) = R^T(c_M, 2 \cdot c_T + 2 \cdot t) + R^T(c_M + t, 2 \cdot c_T)$$

$$E\pi_M(X; X; G_2) = E\pi_M(X; G; G_F)$$

Sunk cost of greenfield-FDI, $G (\times 100)$

	0	0.25	0.5	0.75	1
12	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}
10	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}
8	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{G; ∅}</u> {X; ∅}
7	<u>{X; ∅}</u> {X; ∅}	<u>{X; ∅}</u> {X; ∅}	<u>{G; ∅}</u> {X; ∅}	<u>{G; ∅}</u> {X; ∅}	<u>{X; G_H}</u> {G; ∅}
6	<u>{X; ∅}</u> {X; ∅}	<u>{G; ∅}</u> {X; ∅}	<u>{X; G_H}</u> {G; ∅}	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }
5	<u>{X; G_H}</u> <u>{G; ∅}</u>	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }
4	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }
3	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }	<u>{G; G_H}</u> {X; G _H }	<u>{G; G_F}</u> {X; G _H }
2	<u>{X; G_H}</u> {X; G _H }	<u>{X; G_H}</u> {X; G _H }	<u>{G; G_H}</u> {X; G _H }	<u>{G; G_H}</u> <u>{X; G_H}</u>	<u>{G; G_F}</u> {X; G _H }
1	<u>{G; G₂}</u> <u>{G; G₂}</u>	<u>{G; G₂}</u> <u>{G; G₂}</u>	<u>{G; G₂}</u> {G; G ₂ }	<u>{G; G₂}</u> <u>{G; G₂}</u>	<u>{G; G₂}</u> <u>{G; G₂}</u>
0	<u>{G; G₂}</u> <u>{G; G₂}</u>	<u>{G; G₂}</u> <u>{G; G₂}</u>	<u>{G; G₂}</u> <u>{G; G₂}</u>	<u>{G; G₂}</u> <u>{G; G₂}</u>	<u>{G; G₂}</u> <u>{G; G₂}</u>

Probability of spillovers, θ

Table A3.1: Determination of acquisition price in (S1) $t = 0.05$; $c_M = 0.2$; $c_T = 0.25$
 Entry on LHS of cell (on RHS of cell in bold type) is BR to X (G). M 's preferred choice is underlined.

Sunk cost of greenfield-FDI, $G (\times 100)$

	0	0.25	0.5	0.75	1
12	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{X; ∅}</u> {X; ∅}
10	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{G; ∅}</u> {X; ∅}
8	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{G; ∅}</u> {X; ∅}
7	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	{G; G _F } <u>{G; ∅}</u>
6	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{G; ∅}</u> {X; ∅}	{G; ∅} {G; ∅}	<u>{G; G_F}</u> {X; G _H }
5	<u>{X; ∅}</u> {X; ∅}	{X; ∅} {X; ∅}	<u>{G; ∅}</u> {X; ∅}	{G; G _H } {X; G _H }	<u>{G; G_F}</u> {X; G _H }
4	<u>{X; ∅}</u> {X; ∅}	{G; ∅} {X; ∅}	{G; G _H } <u>{G; ∅}</u>	<u>{G; G_{H}}}</u> {X; G _H }	<u>{G; G_{F}}}</u> {X; G _H }
3	<u>{X; ∅}</u> {X; ∅}	{G; ∅} {G; ∅}	<u>{G; G_{H}}}</u> {X; G _H }	<u>{G; G_{H}}}</u> {X; G _H }	<u>{G; G_{F}}}</u> {X; G _H }
2	<u>{X; ∅}</u> {X; ∅}	<u>{G; G_{H}}}</u> {G; G ₂ }	<u>{G; G_{H}}}</u> {G; G ₂ }	<u>{G; G_{H}}}</u> {G; G ₂ }	<u>{G; G_{F}}}</u> {X; G _H }
1	<u>{X; G_{H}}}</u> {X; G _{H}}}	<u>{G; G_{H}}}</u> {G; G ₂ }	<u>{G; G_{2}}}</u> {G; G ₂ }	<u>{G; G_{2}}}</u> {G; G ₂ }	<u>{G; G_{2}}}</u> <u>{G; G_{2}}}</u>
0	<u>{G; G_{2}}}</u> <u>{G; G_{2}}}</u>	<u>{G; G_{2}}}</u> <u>{G; G_{2}}}</u>	<u>{G; G_{2}}}</u> {G; G ₂ }	<u>{G; G_{2}}}</u> {G; G ₂ }	<u>{G; G_{2}}}</u> <u>{G; G_{2}}}</u>

Probability of spillovers, θ

Table A3.2: Determination of acquisition price in (S2) $t = 0.05$; $c_M = 0.2$; $c_T = 0.4$
 Entry on LHS of cell (on RHS of cell in bold type) is BR to X (G). M 's preferred choice is underlined.

Sunk cost of greenfield-FDI, $G (\times 100)$

	0	0.25	0.5	0.75	1
12	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$
10	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$
8	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$
7	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{G; \emptyset\}$	$\{X; \emptyset\}$
6	$\{X; \emptyset\}$	$\{X; \emptyset\}$	$\{G; \emptyset\}$	$\{X; \emptyset\}$	$\{X; G_H\}$
5	$\{G; \emptyset\}$	$\{G; \emptyset\}$	$\{X; G_H\}$	$\{X; G_H\}$	$\{G; G_F\}$
4	$\{X; G_H\}$	$\{X; G_H\}$	$\{G; G_F\}$	$\{G; G_F\}$	$\{X; G_H\}$
3	$\{G; G_F\}$	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$
2	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$
1	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$
0	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$	$\{G; G_2\}$

Probability of spillovers, θ

Table A3.3: Determination of acquisition price in (S3) $t = 0.15$; $c_M = 0.2$; $c_T = 0.25$
 Entry on LHS of cell (on RHS of cell in bold type) is BR to X (G). M's preferred choice is underlined.

3.7.9. Endnotes to the Appendix.

¹ The proof that $E\pi_E(G; X; G_H) > E\pi_E(G; X; G_F)$ for all θ proceeds in two steps. First, we show that $E\pi_E(G; X; G_H)$ is strictly concave in θ . Expanding $E\pi_E(G; X; G_H)$, the term on θ^2 is

$$\left\{ R^T(c_M, 2 \cdot c_M + t) - R^T(c_M, c_M + c_T + t) - \left[R^T(c_T, 2 \cdot c_M + t) - R^T(c_T, c_M + c_T + t) \right] \right\} \\ + \left\{ R^T(c_M + t, 2 \cdot c_M) - R^T(c_M + t, c_M + c_T) - \left[R^T(c_T + t, 2 \cdot c_M) - R^T(c_T + t, c_M + c_T) \right] \right\}$$

Tedious algebra (expansion using the specific functional form of $R^T(\cdot, \cdot)$) shows that both expressions in $\{\cdot\}$ are strictly negative because $c_T > c_M$, thereby proving the strict concavity of $E\pi_E(G; X; G_H)$. (The general result used here and elsewhere, which can be easily shown, is $R^T(a, \alpha) - R^T(a, \beta) > R^T(b, \alpha) - R^T(b, \beta)$ iff $\alpha > \beta$ and $b > a$ or iff $\beta > \alpha$ and $a > b$.) Second, given that $E\pi_E(G; X; G_F)$ is linear in θ , the necessary-and-sufficient condition for $E\pi_E(G; X; G_H) > E\pi_E(G; X; G_F)$ on $\theta \in [0, 1]$ is $E\pi_E(G; X; G_H) > E\pi_E(G; X; G_F)$ at both end-points. This requires

$$\theta = 0: R^T(c_T + t, c_M + c_T) - R^T(c_T + t, c_M + c_T + t) > R^T(c_T, c_M + c_T) - R^T(c_T, c_M + c_T + t)$$

and

$$\theta = 1: R^T(c_M + t, 2 \cdot c_M) - R^T(c_M + t, 2 \cdot c_M + t) > R^T(c_M, 2 \cdot c_M) - R^T(c_M, 2 \cdot c_M + t)$$

both of which can be shown to hold via tedious algebra (again, by expansion using the specific functional form of $R^T(\cdot, \cdot)$) if $t > 0$.

² $E\pi_E(X; G; G_F) > E\pi_E(X; G; G_H)$ at $\theta = 0$ iff

$$R^T(c_T, c_M + c_T + t) - R^T(c_T, c_M + c_T) > R^T(c_T + t, c_M + c_T + t) - R^T(c_T + t, c_M + c_T),$$

and $E\pi_E(X; G; G_F) > E\pi_E(X; G; G_H)$ at $\theta = 1$ iff

$$R^T(c_M, 2 \cdot c_M + t) - R^T(c_M, 2 \cdot c_M) > R^T(c_M + t, 2 \cdot c_M + t) - R^T(c_M + t, 2 \cdot c_M).$$

Both conditions above can be shown to hold via tedious algebra (expansion using the specific functional form of $R^T(\cdot, \cdot)$) because $t > 0$.

If $c_M < c_T$, then the strict convexity of $E\pi_E(X; G; G_F)$ in θ is easily verifiable by expansion and inspection of the (sign of the) coefficient on θ^2 .

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