EUROPEAN UNIVERSITY INSTITUTE
Department of Economics

Limit Pricing and Multi-Market Entry: the strategic behaviour of multinationals under asymmetric information

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Preface

This thesis analyses strategic firm behaviour in international markets. It extends models of entry deterrence with informational asymmetries to scenarios with multinational firms. We see that trade policy has not only a direct effect on competition but also an indirect effect through influencing the actions of domestic producers.

In writing this thesis, I would like to thank my Supervisor, Stephen Martin, who has supported me throughout this long and exhausting process. There are also many others who have helped directly and indirectly in producing of this thesis and I will mention them in alphabetical order: Jacqueline Bourgogne, Marcel Boyer, Marco Haan, Isabelle Maret, Piety van de Nagel, Louis Phlips, Oliver Stehmann, Jessica Spataro, Xavier Wauthy, Marc van Wegberg, Arjen van Witteloostuijn.

Chapter 1

Introduction

For over a decade, new approaches to Industrial Organisation and International Economics have begun to dominate the literature. In the former, the strategic behaviour of oligopolists, particularly in models of uncertainty, has become prevalent. In the latter, a shift from perfect to imperfect competition has led to a more detailed micro-based analysis that can deal with the activities of multinational enterprises. Indeed, the current focus on the activities of multinationals in both fields illustrates the problem of strict definitions of subjects. One such issue is that of trade policy and strategic firm behaviour.

International economics is generally concerned with how trade policy might be used to improve welfare in the economy by manipulating the actions of firms supplying their home market. Industrial economics, on the other hand, is concerned with both welfare enhancing government policies and the strategic investments of firms. By the latter we refer to the ability of firms to affect the actions of rival firms, in order to increase their own profits. Of course, there seems no reason to assume that firms operating in an international environment are different to those in a closed economy. A potential entrant need not be a new firm, it might just as well be a multinational, already established in a foreign market. Nevertheless, if we assume that firms in our trade models are possessed with the same strategic abilities as those firms found in the IO literature, this must have an effect on trade policy. Or to put it another way, will trade policies have an effect on the strategic abilities of firms and if so, what effect does this have on welfare?

In order to analyse this issue, we need to decide on (i) what types of trade policies we should choose, (ii) what types of strategic ability our firms should be endowed with and (iii) what kinds of environments should our firms operate in. With regards (i) traditional trade policy is essentially made up of tariffs and quotas although export subsidies are also discussed extensively in the literature.[1] In what follows we will focus on tariffs and quotas, first because they are the most common form of trade policy and secondly, they have effect even when the domestic producer does not export. However, in (ii) when we consider the strategic actions of firms, we must decide on what the outcome of such actions will be. Is the domestic producer's objective to deter entry or to limit it? Does the foreign firm export or invest directly (FDI) in a market, and is it also able to restrict the actions of the domestic producer? The issue of exporting and FDI is common in the literature and therefore should be included in the research. What we need to know is under what conditions will a foreign firm switchs from exporting to FDI. Furthermore, with what abilities should we endow our firms in order to influence rivals' actions.

In the trade literature it is common to assume certain differences between the domestic producer and the foreign entrant, namely firm-specific assets and informational differences (Hirsch 1976). The firm-specific asset is some tangible or intangible asset that only the foreign firm possesses but which can be bought at a cost, by the local firm. On the other hand, the domestic producer has an informational advantage over the foreign firm as it knows the home market, the local network, its language, culture, political situation and legal system. To obtain this knowledge, the foreign firm must pay some sunk cost. We shall focus on the latter as informational advantages are something all local producers possess.

Information is an area of industrial economic research that has received a lot attention over recent years. Informational asymmetries in these models usually refer to information over costs or market demand (Milgrom and Roberts 1982, Roberts 1986).

[1] See Brander and Spencer (1985), Dixit and Kyle (1985), Eaton and Grossman (1986) and Grossman (1986).

For a foreign firm which is either exporting to or producing in another country, uncertainty over costs or market size might seem reasonable. Information regarding demand conditions and production costs in another country is not necessarily available. The standard approach is to assume that the foreign firm buys this information (Smith 1987, Motta 1991). However, there is no reason to assume that a foreign firm will have to pay for this information if it is in the interests of the domestic firm to provide it. In the limit pricing literature (starting with Milgrom and Roberts 1982) this is exactly what happens. If the foreign firm's action (i.e. its output) is dependent on market conditions, and that these conditions are unknown, then it might be in the interests of the domestic firm to provide this information. The rationale is that if the foreign firm makes a bad investment (i.e. invests too much in building a large plant when a small plant is optimal), all firms might be hurt. If this is the case, then a domestic firm has interests in revealing this information. This is why we need to consider limit pricing: it allows information about market conditions to be signalled to potential entrants.

The final point (iii) refers to the environment. Should we consider a single market or several, should we allow domestic producers to enter the foreign firm's home market, should we endow entrant's with the same strategic abilities as incumbents and should we allow for trade agreements between countries. All of these issues are important and we will deal with them in the course of this thesis. We have already discussed generally the need to look at the effects of trade policy on the strategic behaviour of firms. We now need to look at first the types of trade policies we will consider and secondly, at the types of strategic models that will best help us resolve these issues.

1.1 International Trade with Imperfect Competition

Although international economics is virtually devoted to how trade agreements can enhance welfare, recent research has focused on imperfectly competitive markets (see

Krugman 1989 for a survey of the literature). Two issues arise: one is the effect of trade policy on the actions of the firm involved (both domestic and foreign producers) and the other is the resulting effect on welfare.

Studying the welfare effects of tariffs and quotas in oligopolistic markets has gained considerable importance in international economics. Despite the abundance of quotas, most research has been devote to the welfare effects of tariffs (e.g. Katrak 1977, Svedberg 1979, Meza 1979, Brander and Spencer 1983,1985 to mention a few). Nevertheless, Fung (1989) shows that under imperfect competition, quotas and tariffs might be equivalent. He defines their equivalence as follows:

> [a] tariff is equivalent to a quota if, permitting the same import volume, the domestic output and prices are identical under the alternative trade policies.[2]

We can see this in figure 1.1. This shows reaction functions of two firms 1 and 2 that might arise from a linear demand function. The Cournot equilibrium is at x where r_1 and r_2 cross. Suppose 2 operates from another country and that country 1 imposes a quota K which is less than 2's equilibrium output. We can see in the diagram that the new equilibrium might be at y. However, the same result can be achieved by a tariff. A tariff would raise the marginal cost of firm 2 and shift its reaction function inwards. If the tariff is chosen carefully, we also reach point y. This is how Fung (1989) defines equivalence between a tariff and a quota: the impact on outputs and prices will be the same, although the welfare effects may not be equivalent.[3] Nevertheless, it is not clear whether equivalent tariffs and quotas will have an equivalent effect on the strategic behaviour of firms.

Fung's (1989) assumption of Cournot competition, is itself a restriction. However, the Cournot-Nash equilibrium is not only convenient in terms of modeling, but many firms may be seen to compete in terms of outputs. For example, in the automobile industry, firms must plan production in advance, while facing high costs of holding

[2] Originally adopted by Shibata (1986).

[3] Tariffs earn revenue which contribute to welfare, quotas do not. However, McCorriston and Sheldon (1994) show that auctioned quota licenses may result in equivalent welfare.

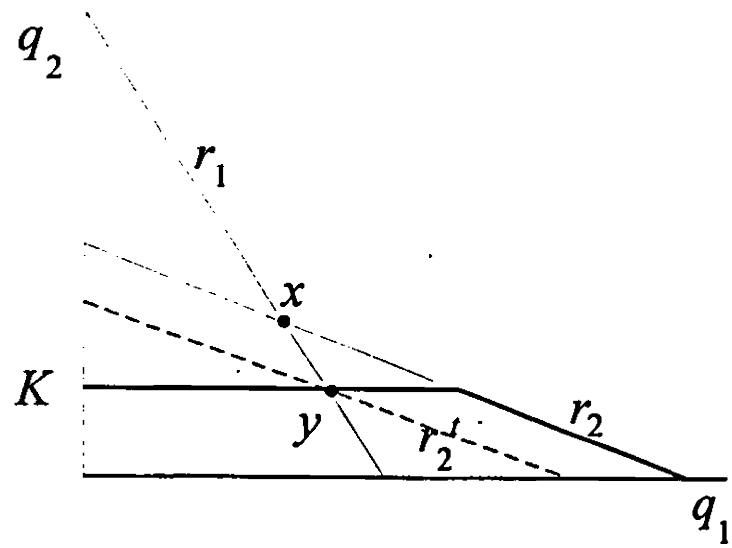

Figure 1.1: The equivalence of tariffs and quotas.

cars in stock. Prices only adjust so that sales match production (Friedman 1983 p.47-48). Moreover, Bertrand pricing is in itself unreasonable: few firms could supply the whole market if they set lower prices than their rivals. Of course, capacity constraints suggest that this will not be the case. However, allowing firms to operate up to their capacity constraints suggests a two-stage capacity-output game, and as Kreps and Scheinkman (1983) have shown, optimal capacities are the Cournot–Nash equilibrium outputs. For this reason, it seems reasonable to retain the assumption of Cournot competition throughout the rest of this thesis. Product differentiation could be included but this would have no surprising effects on our results.

Two important papers have highlighted the relationship between welfare and imports. First, Brander and Krugman (1983) consider a model of reciprocal dumping, where two firms in separate countries decide to engage in international trade, supplying the same product to the market of their rival. One of the most interesting finds of this paper is the U-shaped relationship between welfare and the transportation cost incurred by the exporter (which of course affects the price of imports). The transportation cost determines the equilibrium output of the exporter: the higher the cost, the lower will be the equilibrium output. However, welfare effects are ambiguous as

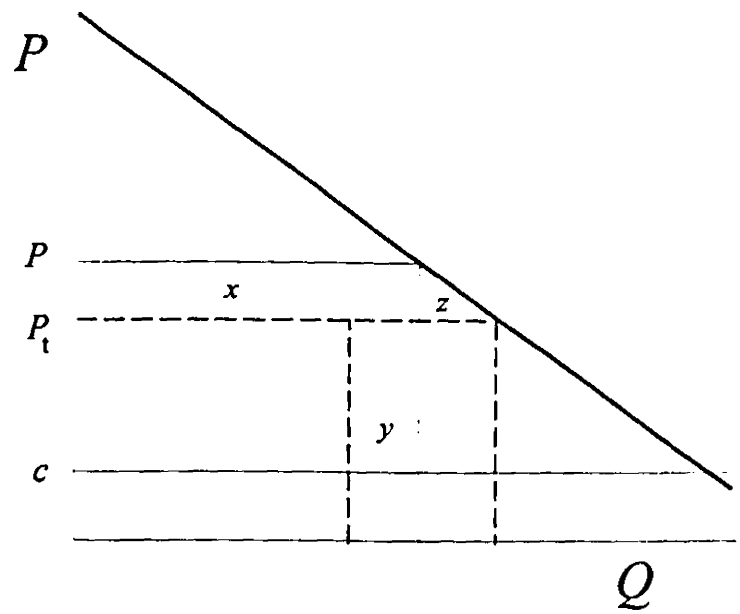

Figure 1.2: Welfare effects resulting from a reduction of a prohibitively high transportation cost.

we shall now demonstrate. Consider welfare as the sum of domestic producer and consumer surplus. First, we set the transportation cost so high there are zero imports. The price in the market is P, the monopoly price (see figure 1.2). If transportation costs are reduced, some imports will enter the domestic market and total output rises, leading to a fall in the market price to P_t. As we can see, domestic profits fall by $x+y$ while the gain in consumer surplus is $x+z$. Clearly, if $y > z$ the loss in domestic firm profits is greater than the gain in consumer surplus. This will be generally true if imports are very small. Consequently, we see that a reduction in transportation costs from a prohibitive level will lower welfare.

On the other hand, now consider the situation where transportation costs are very low such that the domestic producer no longer produces in the market. The monopoly price of the foreign firm is P (see figure 1.3). If transportation costs are increased, the price in the domestic market increases and the domestic producer may enter the market. Its profits are $w+y$ and the loss in consumer surplus is $w+x+z$. If $y < x+z$ then an increase in transportation cost reduces welfare. For small domestic

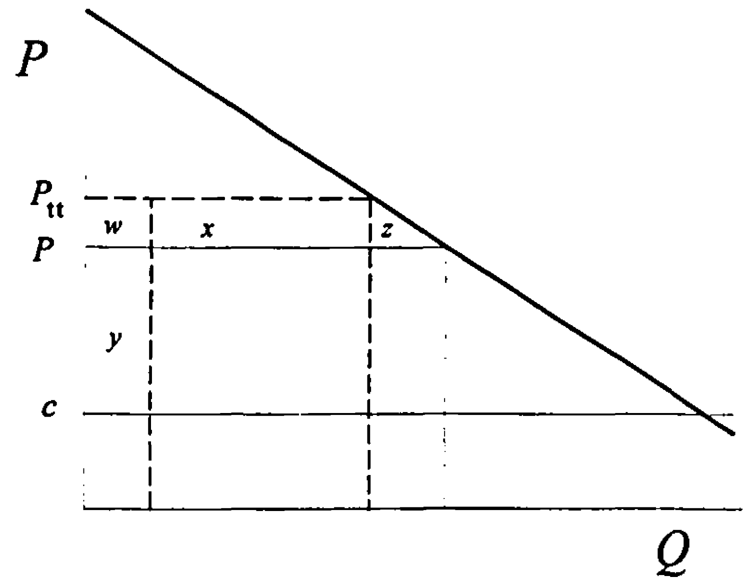

Figure 1.3: Welfare effects resulting from an increase in transportation costs when foreign firm has entry-blockading marginal costs.

production this will be the case.

As we can see transportation costs both increase and decrease welfare, depending on their size relative to the marginal cost of the incumbent firm.

Levy and Nolan (1992) noted the same result was dependent on the relative cost differences between the domestic and foreign firm. They consider a single domestic producer faced by a foreign entrant who exports to the domestic market, where both firms may have different marginal costs of production. They show that when there are no tariffs imposed on imports, welfare displays a convex relationship with respect to the entrant's marginal cost, denoted c_3 (see figure 1.4). The rationale behind this is that there is a trade off between the *terms of trade effect* and the *domestic firm output effect*. The former refers to the change in domestic prices from a change in the entrant's marginal cost (as c_3 increases, prices in the domestic market rise, reducing consumer surplus) while the latter refers to the change in the domestic firm's output i.e. an increase in c_3 raises the domestic firm's output. If c_3 is small then we have a strong terms of trade effect and a weak domestic firm output effect. The net effect

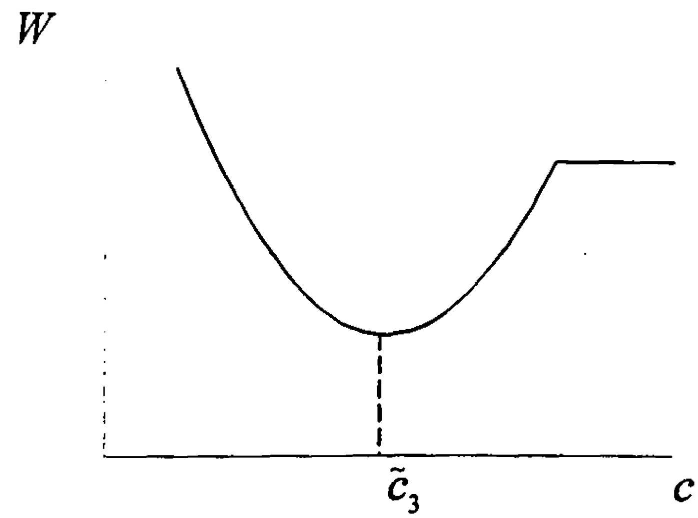

Figure 1.4: Relationship between welfare and entrant's marginal cost (Levy and Nolan 1992).

of increasing c_3 is to lower welfare. On the other hand, if c_3 is large, we have a weak terms of trade effect and a strong domestic firm output effect. Increasing c_3 has the net effect of increasing welfare.

It is clear that an increase in c_3 reduces the equilibrium output of the entrant. Levy and Nolan (1992) then extend the analysis to tariffs. Tariffs raise marginal cost and so if we interpret the entrant's marginal cost as a tariff, we see that only a high or low tariff will maximise welfare: indeed, we know that a welfare minimising tariff exists! Of course, tariffs earn revenue and this must also be included in the welfare function. Levy and Nolan (1992) show that this leads to a concave welfare function where an optimal tariff can be obtained.

Needless to say, tariffs are just one form of trade policy. Quotas are also a common form of trade policy, but they have received less attention in the imperfect competition literature.[4] Fung (1989) has pointed out the equivalence between tariffs and quotas in oligopolistic markets. His results raise three questions. First, can we find

[4] Common forms of quota are voluntary export restraints (VER's). These are voluntary restrictions on exports, whilst a quota is imposed. Nevertheless, the effects are the same and if quota rents are retained by the foreign firm, the welfare effects are equivalent.

equivalence for tariffs and quotas in a customs union. Secondly, do tariffs and quotas have equivalent effects on the strategic behaviour of firms and thirdly, do these trade policies have equivalent effects on welfare?

1.1.1 FDI versus Exporting

Analysing the effects of tariffs and quotas on welfare is just half of the story. An issue which has benefited greatly from the use of game theory is the entry mode decision. One of the first papers refering to the switch from exporting to foreign direct investment is perhaps Vernon (1966). Vernon (1966) attempts to explain the increase in post-war US FDI by the product life-cycle hypothesis. He sees the switch from exporting to FDI as part of a general pattern in the life cycle of a product. The importance of Vernon's work is the break with the traditional trade view of perfect competition. FDI can only be explained if there are market imperfections, imperfect competition being one of them. Along these lines Hymer (1976) defines the multinational as a firm in possession of some intangible proprietary asset, which can be considered as knowledge in the broadest sense of the word. Essentially the decision to invest abroad depends on possible diseconomies of scale of centralised production compared to the cost economies from producing locally. In fact, this has its origins in Coase (1937). Hymer (1976) points out that the benefits of FDI may well be industry dependent. Indeed Horst (1972) finds that large firms are more inclined to FDI than small firms. Dunning (1977) combines Hymer's intangible asset with the transaction cost approach of Williamson (1967) to develop the intangible asset hypothesis. Here, he argues that high levels of R&D, advertising and product diversity intensity favour FDI as they reduce costs by internalising risk and exploiting firm specific advantages.

Dunning (1980) extends his analysis by including location, labelling his theory the eclectic paradigm. This emphasizes the importance of ownership, location, and internalisation as factors influencing foreign direct investment. Ownership specific assets are dependent on the nationality of the multinational. Location specific assets can be both tangible or intangible. For example, they might include cultural, political or legal advantages the firm has, as well as technological advantages, marketing skills or general managerial experience. Given the possible existence of market imperfections due to entry barriers or uncertainty, a firm might find it advantageous to internalise its advantages through FDI.

However, Dunning's approach has been criticised on the grounds that it is vague about the determinants of FDI (Itaki 1991). Buckley and Casson (1981) formalise a model illustrating a multinational's choice between exporting and FDI, where they attribute different cost functions to the different modes of entry. They show that the switch from exporting to FDI may depend on market size (Horst 1971, Hymer 1976). First, they assume that the fixed cost investment for exporting is smaller than that of FDI. They argue that setting up in a foreign country must always be more expensive than a similar investment at home (e.g. cost of learning foreign language, knowing laws, customs and regulations — Hirsch 1976). On the other hand, exporting faces transportation costs which may make the production costs higher than under FDI. What is interesting is that when demand is small, equilibrium output is low and so exporting is the most profitable mode of entry (because it incurs the lowest fixed cost). However, by allowing demand to grow, equilibrium output rises and eventually FDI becomes the most profitable strategy.

Nevertheless, the model is simple but clear. Imposing a tariff increases the cost of exporting and thus induces FDI. Smith (1987) and Motta (1991) were able to show with a game-theoretic model that this relationship was not so simple. Indeed, they are able to show that reducing a tariff may induce FDI, completely the opposite result obtained by Buckley and Casson (1981). By assuming that neither the domestic producer nor the foreign firm are producing in the domestic market, they consider the effects of a tariff on their investment strategies. Suppose the domestic firm has such a high marginal cost that it will only earn profits in the domestic market if a tariff is imposed on the foreign firm. The tariff raises market prices allowing the domestic firm to earn positive profits. However, market demand is small enough to ensure that the foreign firm prefers to export. Removing the tariff makes the market unprofitable for the domestic firm, causing it to leave the market (or not enter). Furthermore, the foreign firm is now the only producer in the market, which means it faces a larger demand and thus will make larger profits under FDI. Therefore, a tariff reduction rather than a tariff increase may induce FDI. Motta (1991) extends Smith's arguments to include changes in market size and transportation costs. His results emphasize the non-monotonic nature between FDI and tariffs.

However, as we mentioned above, much of the international trade literature does not allow domestic producers to influence the entry strategy of the multinational directly. Given the existence of asymmetric information involved in foreign investment, limit pricing models seem a useful tool. Needless to say, if we are to use limit pricing as an analytical tool, we should discuss its applicability to international trade.

1.2 Limit Pricing

Bain (1949, 1956) is commonly accepted as having defined the concept of limit pricing when he forwarded the idea that an incumbent may be able to select prices lower than the profit maximising price in order to deter competitive entry.[5] In this way, incumbents would trade off present profits for future gains. Central to this is the idea of economies of scale. The entrant, a new firm in the market, faces set-up costs already covered by the incumbent. This cost asymmetry ensures that the incumbent will always earn greater profits than the entrant, thus allowing it to realise economic profits without inducing entry. The importance of Bain's proposition was that it endowed incumbents with foresight and strategic behaviour, in contrast to earlier theories which had considered the incumbent as passive to entry (Chamberlain 1933).

Bain defined three possible situations. First 'blocked entry' was used to describe a situation where the incumbent is able to prevent entry by producing at its monopoly output. In other words, the limit output is below or equal to the monopoly output, hence there is no incentive for the incumbent to deviate. Secondly, he defined a scenario where the incumbent is forced to choose an output greater than its monopoly output in order to deter entry in the second period. If the incumbent did not increase its production in the first period, then the residual demand of the entrant would be

[5] The idea of giving up present profit in order to deter future entry can also be found in Marshall (1923), Kaldor (1935), Clark (1940) and Harrod (1952).

sufficiently high for it to make positive profits. Bain calls this situation 'effectively impeded entry' although it is commonly referred to as deterred entry in the literature. It implies that the incumbent is forced to carry out some pre-entry strategy which is different to its static profit maximising strategy in order to deter entry. The final case is where the limit price is so low that the incumbent would be better off allowing entry. This is known as 'ineffectively impeded entry' or accommodated entry.

Formalising models of limit pricing lead to rather simplifying assumptions about the incumbent's post-entry behaviour. Early theorists, most notably Sylos-Labini (1962) and Modigliani (1958), attempted to formalise the notion of limit pricing. Let us give a game theoretic interpretation of their work in order to clarify the basic arguments that underlie the earlier models. Assume that there is an incumbent (or coordinated cartel) and a single entrant. The game takes place over two periods with entry possible in the second period. The products of the firms are both perfect substitutes and strategic substitutes. Demand is stable over the two periods and economies of scale are present. The most important assumption, however, refers to the output of the incumbent. Sylos-Labini (1962) and Modigliani (1958) assume that the incumbent chooses a single output for the two periods. In other words, the incumbent's output does not change even after entry has taken place. This implies that the incumbent may act as a Stackelberg leader and that the entrant will assume the follower's position. It is quite easy to see that if economies of scale are present, the residual demand of the entrant may be too small for it to make positive profits. The output chosen by the incumbent to deter entry implies a market price, which is referred to as the 'limit price'.

The problem with this model is that the incumbent's first period strategy lacks credibility. The incumbent threatens to produce more than the Cournot equilibrium output in the second period and this deters the entrant. However, if the entrant enters the market regardless, then the best response of the incumbent would be to produce at the Cournot equilibrium level. We could model two types of incumbent: a tough one which will always produce at the limit output and a weak one which will accommodate entry, should it take place. Placed in a simple game theoretic model, Gilbert (1987) obtains two Nash equilibria: [tough, no entry] and [soft, entry]. It is quite easy to see that only one sub-game perfect equilibrium exists, namely [soft, entry] because [tough, no entry] does not withstand the 'testing' threat of the entrant (see Selten 1975). We can see that the concept of credibility depends on the expectations of the entrant and as we see later, this has led to the most current theoretical interpretation of limit pricing.

The credibility problem of the incumbent's high first period output was solved partially by Spence (1977) and Dixit (1979, 1980) by re-interpreting the Stackelberg (1934) model as one of sequential capacity choices. The incumbents have two strategic variables, namely output and capacity. By investing in capacity in the pre-entry game, the incumbent incurs a sunk cost which forms an exit barrier. In the event of entry, the entrant believes that the incumbent will use its excess capacity in production. The entrant, on the other hand, is new to the market, it cannot invest in capacity. For a certain range of fixed entry costs, it may be possible for the incumbent to select an output that will result in negative profits for the entrant in the post-entry Cournot equilibrium. Thus, investment in capacity by the incumbent informs the entrant of the incumbent's commitment to high production, and if this is the limit output, then entry is deterred. In the Dixit model, the commitment to capacity results from the ability of the incumbent to shift to a new reaction function and thus achieve an alternative Nash Equilibrium. Hence, credibility has been given to the proposition that the incumbent will raise its output in the post-entry game.

Nevertheless, the Dixit model relies on the incumbent using scale economies to deter entry. However, this does not solve Modigliani's belief that the threat of entry will have an effect on pre-entry prices. A major extension in keeping with the limit pricing model of Sylos-Labini–Modigliani was made by Gaskins (1971). He models an industry which is faced by a continuous threat of entry over time in a growing market. Essentially, the incumbents have to find an optimal price that will limit the amount of entry. In other words, the higher the price, the greater will be the entry into the market. The incumbent therefore, must consider the advantages of reducing price (and hence earning lower profits) in an attempt to reduce the extent of entry (which consequently raises its future profits). Nevertheless, the Gaskins' model has some limitations. He assumes that the entrants or the competitive fringe are an exogenous variable. There is no maximisation process for these firms, they are merely a rival output which is dependent on market prices. Furthermore, Gaskins finds cases where the long-run equilibrium price is higher than the limit price. Indeed, dominant firms with trivial cost advantages are able to maintain their market share, even with expanding aggregate demand.[6] Furthermore, entry is dependent on current prices which indicate current profit, not the profit that the entrant might expect to earn having entered the market.

Extensions to the Gaskins model have come most notably from Kamien and Schwartz (1971) and Flaherty (1980). Kamien and Schwartz consider a stochastic entry version of the Gaskins model where the incumbents' objective (they operate as a coordinated cartel) is to maximise present value of expected returns over the indefinite future. The conditional entry probability is a non-decreasing function of current market price and an increasing function of market growth. They show that the incumbents may reduce price below the monopoly level but that their resulting profits will never be below the post-entry profit level. However, like Gaskins, the entry process is still exogenous.

Nevertheless, Flaherty (1980) developed a model of rational entry. The entrant, like the incumbent, must find an optimal strategy for its actions given the response of the incumbent to the possible threat of entry. However, an open-loop game is assumed which means that the firms are committed for all time to their chosen output paths. The incumbent enjoys increasing returns to scale which allows it to earn greater instantaneous profits while deterring entry with a low price. Furthermore, the minimum output rate that deters entry also decreases as the output rate adjustment cost increases. Fortunately, a solution to the commitment problem was found by turning to models of incomplete information.

Some empirical support can be given to the notion of limit pricing, most of these

[6] Ireland (1972) respecifies the reaction function of the fringe firms and shows that (i) the dominant firm will set prices equal to the limit price (ii) market share is constant, and (iii) market share is equal to zero if the firm has no cost advantages.

papers being based on dynamic extensions of the Modigliani–Sylos-Labini model (see Gaskins 1971, Kamien and Schwartz 1971 and Flaherty 1980). Examples of these are Blackstone (1972) for the photocopier market, Hannon (1979) for banking and Strassmann (1990) for the airline city-pair market.

1.2.1 Incomplete Information

The idea that current prices affect the future profits of a potential entrant suggests some kind exchange in information. An incumbent is prepared to sacrifice its current profits to deter entry from its market which suggests that pre-entry prices act as a signal to the entrant. Milgrom and Roberts (1982) provided the basic signalling model which has now become central to the theory of limit pricing. They consider an incumbent monopolist and a single potential entrant in a two-period game. The incumbent has private information about its marginal cost although the entrant's marginal cost is common knowledge. Furthermore, the entrant must cover some fixed entry cost. By choosing specific marginal costs for the incumbent, Milgrom and Roberts show cases where entry will be profitable or unprofitable. For example, if we assume that the incumbent's constant marginal cost is either c_{iH} or c_{iL} where $c_{iH} > c_{iL}$ then the entrant's post entry profits can be written

$$\pi_e(c_{iH}) > F > \pi_e(c_{iL}) \tag{1.1}$$

where $F > 0$ represents the fixed cost of entry. The entrant is assumed to enter only if it expects to make positive profits. Therefore, with complete information, entry would only take place if the incumbent has a high marginal cost.[7]

All that remains is to link the unknown incumbent cost type to its pre-entry price so that the entrant can calculate its expected post-entry profits. This is achieved using the concept of sequential equilibria (Kreps and Wilson 1982). We need to attach probabilities to the incumbent's marginal cost which are updated by Bayes' rule after the entrant has observed the first period strategy of the incumbent. Therefore, if there is a high prior probability that the incumbent has a high marginal cost, the entrant

[7] If $F > \pi_e(c_{iH})$ then entry would be blocked and if $\pi_e(c_{iL}) > F$ the entry would always occur, for all incumbent cost types.

will expect positive post-entry profits. If, in fact, the incumbent has a low cost, then successfully signalling this information to the entrant will result in no entry taking place in the second period. Signalling is through lowering the pre-entry price to such an extent that a high cost incumbent would find it unprofitable to imitate such a strategy. If such a price can be found, then we have what is known as a "separating equilibrium". On the other hand, if the entrant believes that the pre-entry price is not correlated with the incumbent's marginal cost, price has no informational value and the result is a "pooling equilibrium".

Limit pricing occurs when the incumbent (whether a high or low cost firm) sets pre-entry prices below its complete information monopoly price. Consider first the separating equilibrium where the pre-entry price carries information about the incumbent's cost type. For the existence of a separating equilibrium, it must be the case that the low cost and high cost incumbents will choose different first period strategies. In other words, the equilibrium must be *incentive compatible* with a high cost firm not finding it profitable to imitate the strategy of the low cost incumbent. The incentive constraint for the high cost firm is thus,

$$\pi_{iH}^{M} + \delta\pi_{iH}^{D} > \pi_{iH}\left(\hat{p}_{iL}\right) + \delta\pi_{iH}^{M} \tag{1.2}$$

where $\delta \in (0,1)$ represents the discount factor for second period profits. On the RHS of inequality 1.2 we have the profits that the high cost firm will earn if it imitates the first period strategy of the low cost incumbent $\hat{p}_{iL}$ and as a consequence, earns monopoly profits in the second period. On the LHS of inequality 1.2 we see the profits that the high cost firm earns if it does not imitate the low cost incumbent's price. If the firm is known to be high cost (which it will be if it does not imitate the low cost firm's strategy), then it might as well choose its monopoly price p_{H}^{M} in the first period. As a consequence, it will earn duopoly profits in the second period.

The incentive constraint for the low cost incumbent is similar except that price $\hat{p}_{iL}$ will yield higher profits by deterring entry rather than allowing entry in the second period. In other words, we have:

$$\pi_{iL}\left(\hat{p}_{iL}\right) + \delta\pi_{iL}^{M} > \pi_{iL}^{M} + \delta\pi_{iL}^{D} \tag{1.3}$$

Rearranging equations 1.2 and 1.3 we get:

$$\frac{\pi_{iH}^{M}-\pi_{iH}\left(\hat{p}_{iL}\right)}{\pi_{iH}^{M}-\pi_{iH}^{D}}>\delta>\frac{\pi_{iL}^{M}-\pi_{iL}\left(\hat{p}_{iL}\right)}{\pi_{iL}^{M}-\pi_{iL}^{D}} \tag{1.4}$$

By showing that

$$\pi_{iL}^{M}-\pi_{iL}^{D}>\pi_{iH}^{M}-\pi_{iH}^{D} \tag{1.5}$$

and

$$\pi_{iH}^{M}-\pi_{iH}\left(p_{iL}\right)>\pi_{iL}^{M}-\pi_{iL}\left(p_{iL}\right) \tag{1.6}$$

we prove that there is a range of discount rates for which the incentive constraints 1.2 and 1.3 are satisfied. Inequality 1.5 is a sufficient but not necessary condition. In fact, we can allow the inequality to be reversed depending on the loss incurred in signalling expressed in equation 1.6. (For a price setting game, see Tirole (1988) for a simple proof of inequality 1.5). Nevertheless, inequality 1.6 is in fact the single crossing condition of Spence (1977).[8] Given that we are interested in cases where a low cost incumbent will deviate from its monopoly price in the first period, we require $\hat{p}_{iL}<p_L^M$. When $\hat{p}_{iL}=p_L^M$ the RHS of 1.6 is zero. However, the LHS of 1.6 is positive because $p_L^M<p_H^M$ and so the condition holds. If we take $\hat{p}_{iL}<p_L^M$ then the RHS of 1.6 will become positive although the LHS will also become more positive. What the single crossing condition states is that the high cost incumbent's profits will fall more quickly than those of the low cost firm for prices below p_L^M i.e. $\partial\pi_{iH}/\partial p_i>\partial\pi_{iL}/\partial p_i$ or $\partial^2\pi/\partial p_i\partial c_i>0$.[9]

The limit price is indeed $\hat{p}_{iL}$ because this cannot profitably be imitated by the high cost incumbent. In fact, there is a range of prices that the low cost incumbent can choose from, the upper limit of which is defined by finding some $\bar{p}$ that makes condition 1.2 hold with equality. Similarly, find some $\underline{p}$ that makes condition 1.3 hold with equality. Hence, $\hat{p}_{iL}\in\left(\underline{p},\bar{p}\right)$ indicates the range of the limit price.[10] For $\hat{p}_{iL}<p_L^M$ first period distortions will occur in the separating equilibrium. $\bar{p}$ is also known as the least cost separating price because it is the highest price possible that supports the separating equilibrium.

[8] Sometimes known as the Spence-Mirlees condition or the sorting condition.
[9] See Tirole (1988) p.369 for proof of this condition.
[10] The set of limit prices does not include the upper or lower bound values. This ensures that conditions 1.2 and 1.3 remain inequalities.

The pooling equilibrium arises when price carries no informational value about the incumbent's possible cost type. In other words, at the end of the second period, the entrant has gained no further information regarding the incumbent's marginal cost. This occurs when imitation by the high cost incumbent, of the first period strategy of the low cost incumbent will not lead to entry. Entry is something that the low cost firm (and entrant) wants to avoid. However, if the prior probability that the incumbent has a low cost is very high, then expected profits (based on prior beliefs) will not cover the fixed entry cost. When nothing is learned by the entrant about the incumbent's cost, Bayes' rule updates using the prior beliefs and consequently, imitation of the low cost incumbent's strategy will not lead to entry in the second period. The low cost incumbent can use any price it wishes in the first period, although it is usual to assume that it chooses its Pareto efficient price, p_L^M. Imitation will occur when

$$\pi_{iH}\left(p_L^M\right) + \delta\pi_{iH}^M > \pi_{iH}^M + \delta\pi_{iH}^D \tag{1.7}$$

which is the reverse of equation 1.2. Thus, in the pooling equilibrium, it is the high cost firm which deviates from its monopoly price in the first period.

The Milgrom and Roberts model shows that uncertainty is the key to deterring entry. However, the limit price itself may not actually "limit" entry because in the case of a low cost incumbent, the firm's true cost is revealed and entry does not take place, as would occur if there were complete information. Nevertheless, in the pooling equilibrium, entry is deterred by the high cost incumbent imitating the strategy of the low cost incumbent.

The signalling model of Milgrom and Roberts (1982) was generalised in a series of papers by Mailath (1987,88,89). He showed the general conditions needed for signalling behaviour to arise. Nevertheless, an important assumption was made which had significant effects on the results. Milgrom and Roberts (1982) assumed, for simplicity, that upon entry, all information would be revealed. In other words, if the entrant believed the incumbent had a high marginal cost and entered the market only to find that the incumbent had a low marginal cost, complete information Cournot outputs would prevail. Saloner (1987) assumed that the entrant's beliefs do not change and therefore its output is along an expected reaction function, rather than an actual reaction function. Mailath (1989) uses this to show that if two firms operate in a market but are uncertain of each others' costs, they will always find it profitable to signal to each other. In other words, signalling is driven not so much by a desire to deter entry but a desire to protect own market share. This is an important point, particularly if we are to look at the effects of trade policy (which generally restrict a foreign firm's output) on incumbent's pre-entry strategies.

More recently, limit pricing models have been extended to an international scenario. Incumbents, particularly dominant firms in a market (which are essentially the kind of firms we are dealing with) often operate in more than one market (either multinationals operating in geographically separated markets or multi-product firms operating in different product markets). Similarly, entrants may have the same characteristics as an incumbent, desiring to either produce in another country or to start production of a new product.

Srinivasan (1991) develops a model of a multi-market incumbent faced by a single multi-market entrant. The incumbent typically has either a high or low marginal cost which is the same for both markets, thus assuming that the products have a similar underlying technology i.e. photocopiers and facsimile machines; computer monitors and colour televisions. Geographically separated markets could also be considered.

Srinivasan finds that if the markets are symmetric in demand and cost-type differences, then separation by a low cost multi-market incumbent will be the same whether or not the signalling effort is combined across markets. However, if differences do exist, then combining signalling across markets will lead to smaller losses for the separating low cost incumbent. These differences in markets mean that it may be more profitable to set a lower limit price in one market than in the other. Indeed, this is exactly what Srinivasan finds. If there exist greater differences in the cost-types in, say market A, compared to market B, then the marginal ability to separate in A is greater than that in B. Similarly, if the (linear) demand in A is steeper than the (linear) demand in B, then combining the signalling effort will again lead to smaller losses for the low cost incumbent in the separating equilibrium. As an example, Srinivasan shows that a low cost incumbent may even produce in an unprofitable market if sufficient cost or demand differences exist. This is because the cost of signalling in this unprofitable market may be less than signalling in the profitable market (due to the cost or demand differences). However, after signalling has taken place, the incumbent will leave the market in the second period.

One limitation of Srinivasan's model is that the entrant enters both markets simultaneously (given that the incumbent is operating in both markets). It may well be the case that an entrant will enter only one of those markets. Hence, the decision over which market to enter becomes an important issue. This question was considered by Bagwell (1993). Bagwell constructs a complete information model of numerous monopolistic incumbents from different markets or regions that use their market price to deflect entry to one of the other markets. The entrant is imperfectly informed about the incumbents' investments into cost reduction and seeks to enter markets where the incumbents have high costs. By comparing the prices in each market, the entrant enters where price is highest. In fact, his model has little to do with that of Milgrom and Roberts (1982) except for the informational linkage he defines between pre-entry price and the probability of entry, similar to that used by Kamien and Schwartz (1971).

Following the usual two period format, Bagwell considers n identical markets, each inhabited by an incumbent monopolist. There is one large entrant which can enter only one market, although entry into each market is potentially profitable. In order to deflect entry into another market the incumbents are able to invest in cost reduction as well as pricing strategies in the pre-entry period. The fact that pre-entry investment into cost reduction increases second period profits (whether this be in monopoly or duopoly) for the incumbent means that lower pre-entry prices can be sustained in the first period. Therefore, low pre-entry prices imply a lower incumbent marginal cost which will lead to lower expected profits for the entrant. However, Bagwell imposes a strong restriction to the model by assuming that the incumbent would prefer not to invest in reducing marginal cost. In other words, first period profits would be higher if no investment was made.

Nevertheless, the threat of entry induces the incumbents to lower prices which in turn leads to higher output. Higher output means that the incumbent will benefit more from cost reductions, which induces investment in the first period. If all incumbents have the same pre-entry price, then the entry strategy is random because selection is based purely on the observed price. Bagwell obtains the desired result that pre-entry price can be lower than the monopoly price and that cost-reducing investment is high when there is the threat of entry. Unfortunately, no pure strategy equilibrium exists, with the result relying essentially on the entrant's randomising mixed strategy behaviour.

The models of Milgrom and Roberts (1982), Mailath (1989), Srivinasan (1991) and Bagwell (1993) provide a useful guide as to how we can use limit pricing in a model of international trade. From Milgrom and Roberts (1982) we have the classic entry deterrence model that can also be used to deter multinational entry. Mailath (1989) however provides us with a more subtle contribution. He shows how firms use signals to enhance their market share. Trade policy on the other hand, limits market share, clearly suggesting that one will have an effect on the other, and vice-versa. If we are to truly understand the effects of trade policy on the strategic behaviour of incumbents, we must be careful in whether we choose entry deterrence or market share enhancing as our incumbent's goal. Finally, Srivinasan (1991) and Bagwell (1993) show us issues that arise when multimarket entry takes place. Both raise the question of what effect do other markets have on limit pricing behaviour. In Srivinasan (1991) we see the effect on strategy when the incumbent operates in two markets. From Bagwell (1993) we see the effect on the limit price when an entrant has several markets to choose from. These papers provide the theoretical base for the chapters that follow.

1.3 Where to Next

The aim of this thesis is to bring together international trade in imperfectly competitive markets with strategic industrial organisation theory. With these tools we should be able to analyse the impact of trade policy on the strategic behaviour of firms. The thesis consists of 3 theoretical chapters that deal with the issues raised above. Chapter 2 is concerned with trade policy in a customs union. It deals with the issue of equivalence of tariffs and quotas in a customs union, as well as equivalence in their effects on limit pricing behaviour. The multimarket scenario is similar to that of Bagwell (1993) although the methodology lies very much with that of Mailath (1989). The results both complement and contrast those of Fung (1989). It goes on to explore the welfare effects of differing trade policies, relying heavily on the results obtained by Levy and Nolan (1992).

Chapter 3 considers the domestic producer's ability to influence the entry mode of the foreign multinational, via limit pricing. This extends the basic methodology of Buckley and Casson (1981), Smith (1987) and Motta (1991) to a scenario of incomplete information, thereby giving the domestic producer the possibility to "defend" its home market. We also look at the effects of trade policy on the incumbent's pre-entry strategy and the resulting welfare effects, again relying considerably on the results of Levy and Nolan (1992).

Chapter 4 extends the Brander and Krugman (1983) reciprocal dumping model to a two period game of incomplete information. Incumbents are equally entrants and neither has complete information regarding the other's marginal cost. Although the two market set-up is similar to that of Srinivasan (1991), the model in fact compares results of Milgrom and Roberts (1982) and Mailath (1989). Firms attempt to protect their home markets while at the same time, they try to penetrate foreign markets. Although under a separating equilibrium, the results of both papers complement each other, pooling equilibria yield opposite effects on limit pricing behaviour. Finally, Chapter 5 concludes the thesis with brief summary of the overall findings of the thesis and some general indications for future research.

Chapter 2

Multi-Market Entry

2.1 Introduction

European economic integration has for sometime been a hot issue in international economics. Free trade areas and customs unions are at the core of the European Community's beliefs for improving European welfare. They support the idea of the removal of trade barriers between member states, thus increasing the competitive nature of markets and hence moving the EC more closely to perfect competition (Treaty of Rome, articles 3, 9–37). Nevertheless, the Treaty of Rome also provides policies to confront possible market distortions, such as collusion, abuse of dominant position and monopolistic mergers (articles 85, 86 and the Merger Regulation, respectively). Clearly, there are two important aspects to competition policy: not only must it deal with the welfare effects of trade policies but it must also deal with the strategic behaviour of firms operating in these markets. Both points have received a tremendous amount of attention in the academic literature. International economics is virtually devoted to the welfare effects of trade policy whilst the formalisation of strategic firm behaviour has come to dominate industrial economics over these last few years. Links between these two areas of research began with Krugman (1979), Dixit and Norman (1980) and Lancanster (1980) when models of imperfect competition were formalised in an international trade setting.

Nevertheless, the gap between international economics and industrial economics has not been completely filled. Recent developments in industrial economics have revealed the importance of information in determining firm strategies (Milgrom and Roberts 1982, Roberts 1986, 1987 and Saloner 1987). For example, Roberts (1986) and Saloner (1987) provide models that help us understand the notion of predatory pricing, an abuse of dominant position for which the EC has intervened on several occasions (e.g. ECS/AKZO — 1985 OJ L 374/1, 19-22). However, there is scarce research on the effects of trade policy on firm strategy when asymmetric information might exist regarding market parameters (with the exception of Collie and Hviid 1994). Given the importance of information and the effect it has on a firm's strategy (and hence competition), it would seem instructive to see how firm strategies are influenced by different trade policies. In this chapter we will focus on the effects of two types of trade policy: national and joint quotas. In this, we attempt to analyse the effects of a common external trade policy compared to a national based policy within a customs union.

To deal with these issues, we must first focus on the types of trade policies we wish to consider and secondly, what kind of strategic behaviour we wish our firms to have. By considering limit pricing as the strategic tool of the domestic producers we discuss the following three issues. First, do equivalent tariffs and quotas exist for a customs union where a uniform external trade policy is established? Secondly, do equivalent tariffs and quotas have equivalent effects on the strategic behaviour of the domestic producers? Finally, what are the welfare effects resulting from the different trade policies? Clearly, we need to draw on two sources of literature: international economics and industrial organisation.

2.1.1 International Trade

International economics is dominated by the issue of optimal trade policies (see Krugman 1989 for a survey of the literature). The analysis of both tariffs and quotas is abundant in the literature. Despite most research being devoted to the welfare effects of tariffs (e.g. Katrak 1977, Svedberg 1979, Meza 1979, Brander and Spencer 1983,1985 to mention a few), the analysis of quotas in imperfect competition has received some attention. A simple, yet important paper by Fung (1989) shows that under imperfect competition, equivalence in quotas and tariffs might exist. Assuming Cournot competition, a quota can be seen as a constraint on the foreign firm's output. However, we know that in the Cournot model, an increase in a firm's marginal cost shifts its reaction function to the left, resulting in a new equilibrium where the affected firm produces less than before. As an additive tariff implies an increase in the foreign firm's marginal cost, it too will shift the reaction function so that the foreign firm's equilibrium output is lower. By choosing a tariff carefully, the same output reduction can be achieved under a tariff as under a quota regime. Nevertheless, can we find a tariff-quota equivalence for a customs union and will such trade policies have equivalent effects on the strategic behaviour of the domestic producers?

Another issue that is important from the point of view of trade policy is the relationship between welfare and imports. First, Brander and Krugman (1983) consider a model of reciprocal dumping, where two firms in separate countries decide to engage in international trade, supplying the same product to the market of their rival. Among other things, they find that welfare and the transportation cost exhibit a U-shaped relationship. Basically, the height of the transportation cost determines the Cournot equilibrium amount of imports. By raising transportation costs imports fall. The rise in imports affects both domestic firm profits and consumer surplus. Starting at low transportation costs and increasing, higher prices lead to a fall in consumer surplus but a rise in domestic producer profits. However, the fall in consumer surplus outweighs the gains to the home country firm. On the other hand, by starting with an almost prohibitively high transportation cost and reducing, Brander and Krugman (1983) demonstrate that this also lowers welfare: the lower prices yield gains in consumer surplus which are outweighed by the losses in profit incurred by the domestic producer.

A similar result was noted by Levy and Nolan (1992) where they demonstrate the U-shaped relationship between welfare and the foreign firm's marginal cost. They show that when there are no tariffs imposed on imports, welfare displays a convex relationship with respect to the entrant's marginal cost. Essentially there is a trade off between the *terms of trade effect* and the *domestic firm output effect*. The former refers to the change in domestic prices from a change in the entrant's marginal cost (as the marginal cost increases, prices in the domestic market rise, reducing consumer surplus) while the latter refers to the change in the domestic firm's output i.e. an increase in marginal cost raises the domestic firm's output. If the marginal cost is small then we have a strong terms of trade effect and a weak domestic firm output effect. The net effect of increasing marginal cost is to lower welfare. On the other hand, if the marginal cost is large, we have a weak terms of trade effect and a strong domestic firm output effect. Increasing marginal cost has the net effect of increasing welfare.

However, if we use quotas instead of tariffs, can we obtain similar results? A quota, like a tariff, affects production. Under the tariff, the foreign firm's cost of supplying the market is raised, leading to a fall in its equilibrium output while a quota is a flat limitation on sales. It would seem likely that a relationship similar to that of welfare and tariffs exists between welfare and quotas. Nevertheless, there is a difference: quotas do not earn revenue.[1] Indeed, most quotas seem to be imposed for political rather than economic reasons. For example, one of the most notable examples of a national quota is the famous Multi-Fibre Agreement (MFA), negotiated under the auspices of GATT in 1973. The MFA is essentially a collection of voluntary export restrictions (VER's) which sets limits on all developing countries exports to the industrialised economies. Moreover, VER's imply that quota rents are captured by the foreign firm. Hence, as quota rents are not retained by the importing nations, welfare must exhibit a similar relationship to that indicated in figure 1.4.

Given the non-economic nature of quotas it might be interesting to look at the different economic welfare effects of both a national and joint quota scheme. We refer to a national quota as a quota on the production of a firm producing in a non-member country who is exporting to the free-trade zone. A joint quota is a quota which restricts imports to the zone but not to each individual country i.e. the exporter can sell its produce in whatever market it wishes. We shall attempt to see whether

[1] McCorriston and Sheldon (1994) have attempted to calculate the possible welfare gains from capturing quota rents in the US cheese market. They show that auctioning off quota licenses may theoretically raise welfare although in practice this may not always be the case.

welfare is enhanced more by the national or the joint quotas.

2.1.2 Industrial Organisation

This is perhaps only half the story. By considering imperfect competition, we should also consider the strategic nature of domestic producers. The literature in industrial economics regarding the limitation of new competition is considerable (see Gilbert 1987). In international economics, Motta (1992) and Smith (1987) have made some progress in formalising a game-theoretic model of foreign direct investment although the incumbent and entrant still remain passive players, neither of them able to manipulate the strategy of the other firm. An area of industrial economics which has allowed for considerable strategic activity involves the control of information. In the first chapter, we explained how Milgrom and Roberts (1982) showed how entry could be deterred if incomplete information regarding the parameters of the model could be exploited by an incumbent. However, it was Mailath (1987,1988,1989) who in a series of papers generalised the Milgrom and Roberts (1982) signalling model to show that pre-entry strategies could (and would) be used to limit the strategies of rival firms. Mailath (1989) shows how an entrant's equilibrium output might depend on the information it receives about the market, and thus controlling this information may reduce the entrant's level of production. Therefore, expected output might be small implying low future profits, resulting in either entry deterrence (Milgrom and Roberts 1982), exit (Roberts 1986) or merger (Saloner 1987). Given that tariffs and quotas reduce the equilibrium output of the foreign firm, Mailath's methodology would seem more suitable for the analysis.

Nevertheless, Srinivasan (1991) and Bagwell (1993) did integrate the limit pricing model into an international context. Srinivasan (1991) models the behaviour of incumbent monopolists when they operate in several markets. However, this chapter is most closely related to Bagwell (1993) who considers the investment strategy of an entrant when faced with many geographically separate markets. Essentially the entrant is looking for the most highly profitable market in which to locate by observing the pre-entry prices of the incumbent firms. The novel idea in this paper is in the methodology: pre-entry investment into cost reduction leads to lower prices and hence signals low expected profits for the entrant. Although dispensing with the standard incomplete-information Bayesian framework, it does require the use of mixed strategies. Furthermore, the entrant is allowed only to set-up in a single market, and that trade does not exist between the incumbents.

In this chapter we consider a similar model to that of Bagwell (1993), remaining, however, with the traditional Milgrom and Roberts (1982) methodology. We start with the premise that it may be possible for the firm to use pre-entry prices to restrict the extent of future entry (expected imports). Clearly, any kind of trade policy that restricts imports will have an effect on the strategic behaviour of the domestic producer. Consequently, trade policy not only has a direct effect on welfare but also an indirect effect by affecting the strategy of the domestic firm. We consider the effects of both national and joint trade policies on welfare and firm strategy. As we study the effects of quotas on a customs union, it would seem reasonable to also consider the possibility that domestic producers supply each others' markets, without facing a quota. However, this has significant effects on our results. We study the following four scenarios:

- no trade between incumbents
  - national quota
  - joint quota
- trade between incumbents
  - national quota
  - joint quota

The strategic behaviour of the two incumbents in the pre-entry game, follows closely the methodology of Milgrom and Roberts (1982) and Mailath (1989). Limit pricing may emerge as an equilibrium strategy for certain ranges of national quotas. We then show that the limit pricing may also occur for joint quotas. Indeed, when there is no trade between the incumbents, joint quotas, as long as they bind the entrant's output constraint, will always lead to limit pricing. Nevertheless, the introduction of intra-communitarian trade will result in a different outcome. As long as the joint quota always makes the constraint binding, no limit pricing will occur, quite the opposite to the no trade model. We also show under which conditions equivalent tariffs and quotas have equivalent effects on the strategic behaviour of the incumbent. Finally, we see that although quotas tend to lower welfare, there are conditions where a welfare maximising quota exists.

The chapter is organised as follows. In Section 2.2 we set up a model of asymmetric information similar to that of Mailath (1989). Section 2.3 considers the separating equilibria that emerge under the different quota regimes when there is no incumbent trade in the second period. Within this section we also consider the equivalence of tariffs and quotas on equilibrium strategies (subsection 2.3.3) and the effect on the limit price (subsection 2.3.4). In Section 2.4 we allow for trade between the incumbents to see if this has any adverse effects on the results. Section 2.5 deals with the extensive welfare aspects of the model. Section 2.6 looks at an alternative interpretation of the model and Section 2.7 concludes.[2]

2.2 The Model

Consider two countries 1 and 2 which provide a market for a homogenous product, produced by incumbent monopolists 1 and 2 in countries 1 and 2, respectively. Firm 3 is an exporter that may enter markets 1 and 2 in some stated period. Each firm faces an inverse linear demand function denoted $p^i = 1 - Q^i$ where $i \in \{1,2\}$, $Q^i = q_1^i + q_2^i + q_3^i$ for $q_1^i, q_2^i, q_3^i \geq 0$. We assume constant marginal costs for all firms, denoted $c_1, c_2 \in \{c_L, c_H\}$ where $c_H > c_L$ and $c_3 > 0$. For simplicity, if incumbent 1 has a low marginal cost, we shall refer to it as $1L$. Furthermore, denote $\theta \in \{L, H\}$ so that firm i of cost c_θ can be written $i\theta$ for $i \in \{1,2\}$ and $\theta \in \{L, H\}$. The entrant's marginal cost c_3 may be larger or smaller than that of the incumbents but its value is always common knowledge to all firms.

[2] The assumption of free entry excludes pooling equilibria from the analysis.

The game takes place over two periods. In the first period firm 1 is an incumbent monopolist hence $Q^1 = q_1^1 > 0$, $q_2^1, q_3^1 = 0$. In the second period entry might take place, by both firms 2 and 3. However, the entrant is uncertain of the incumbent's cost types although we assume that the incumbents know each other's cost type.[3]

At the beginning of the first period, the entrant has prior beliefs $\rho_{i=1,2} \in [0,1]$ that incumbent i has a high marginal cost and $(1-\rho_{i=1,2}) \in [0,1]$ that i has a low marginal cost ($i \in \{1,2\}$). At the end of the first period, the entrant has observed the first period output of each incumbent and can therefore, update its priors. Posterior beliefs are thus $\mu_{i=1,2} \in [0,1]$ and $(1-\mu_{i=1,2}) \in [0,1]$ for high and low cost types respectively.

2.2.1 Second Period Profits

Let us consider the post-entry game. As we are interested in the effects of trade policy, we need to impose both tariffs and quotas on the entrant's production. Tariffs can be easily dealt with. A simple additive tariff will raise the entrant's constant marginal cost by the same amount. To study the effects of a tariff, it is sufficient to study the effects on strategies (of all firms) by varying the marginal cost of the entrant. On the other hand, a quota restricts the entrant's output. Therefore, the entrant maximises the following:

$$\begin{aligned}\Pi_3^*(q_1^i, q_2^i, q_3^i) = \\ \max_{q_3} \sum\nolimits_{m=1,2} \left[a - c_3 - \left(\mu_i q_{iH}^i + (1-\mu_i)\, q_{iL}^i\right) - q_3^i\right] q_3^i - F\end{aligned} \tag{2.1}$$

subject to (i)

$$K^i \geq q_3^i \tag{2.2}$$

or (ii)

$$K \geq q_3^1 + q_3^2 \tag{2.3}$$

where $F \geq 0$ is the fixed entry cost and $i \in \{1,2\}$. Note that F is paid only once and does not depend on the number of markets entered. As we see, the entrant does not know the incumbents' marginal costs, it relies on the expected (observed outputs

[3] This may seem restrictive but it simplifies an already complex model.

(prices) in the first period). The output of a high cost incumbent 1 is denoted q_{1H} and similarly for 2. (In the case of a tariff, the constraints are not binding — all equilibrium values are reported in the appendix.)

The problem facing incumbent 1, of cost type θ, in the second period, in market 1, is given by,

$$\pi_{1\theta}^{1*}\left(q_1^1, q_2^1, q_3^1\right) = \max_{q_1^1}\left(a - c_\theta - q_1^1 - q_2^1 - q_3^1\right) q_1^1 \tag{2.4}$$

If there is trade between the incumbents, then in the second period market 1 is a triopoly. However, if no trade takes place between firms 1 and 2, then $q_2^1 = 0$ and we have a duopoly situation between firms 1 and 3. In the foreign market, if we have a tripoly we maximise,

$$\pi_{1\theta}^{2*}\left(q_1^2, q_2^2, q_3^2\right) = \max_{q_1^1}\left(a - c_\theta - q_1^2 - q_2^2 - q_3^2\right) q_1^2 \tag{2.5}$$

In the Appendix we calculate the equilibrium outputs and profits for all three firms. The equilibrium outputs when no quota exists and when there is no trade are given by,

$$q_{1L}^{br} = \left(\frac{2a + c_3 - \mu_1 c_H - (4 - \mu_1) c_L}{6}\right) \tag{2.6}$$

of firm $1H$,

$$q_{1H}^{br} = \left(\frac{2a + c_3 - (1 + \mu_1) c_H - (3 - \mu_1) c_L}{6}\right) \tag{2.7}$$

and of firm 3:

$$q_3(\mu_1) = \frac{a - 2c_3 + \mu_1 c_H + (1 - \mu_1) c_L}{3} \tag{2.8}$$

We can see that as the entrant calculates its expected profits using beliefs μ_1. Thus, μ_1 enters into the incumbent's equilibrium output. From now on, we shall define the incumbent's output by $q_{i\theta}^{br}$ to indicate that it is a best-response to the output of the entrant. However, the entrant's output changes depending on the type of quota which indeed leads to changes in the incumbent's output. Nevertheless, it will suffice to show the changes in the entrant's output in order to indicate the different resulting profits. If the entrant faces a national quota, it produces at that quota K^i. If it faces

		$\pi^j_{i\theta}$, for $i,j=1,2$
no trade	no quota	$\pi^1_{1\theta}\left(q^{br}_{1\theta}, q_3(\mu_1)\right)$
	quota	$\pi^1_{1\theta}\left(q^{br}_{1\theta}, K^1\right)$
	joint quota	$\pi^1_{1\theta}\left(q^{br}_{1\theta}, q_3(\mu_1,\rho_2)\right)$
trade	no quota	$\pi^1_{1\theta}\left(q^{br}_{1\theta}, q_{2\theta}, q_3(\mu_1,\rho_2)\right)$
	quota	$\pi^1_{1\theta}\left(q^{br}_{1\theta}, q_{2\theta}, K^1\right)$
	joint quota	$\pi^1_{1\theta}\left(q^{br}_{1\theta}, q_{2\theta}, q_3(\mu_1,\rho_2)\right)$

Table 2.1: Summary of Equilibrium Profits

a joint quota, it produces,

$$q_3^1(\mu_1,\mu_2) = \frac{(\mu_1-\mu_2)(c_H-c_L)+3K}{6} \tag{2.9}$$

The entrant's output depends on μ_1, μ_2 and K. In Table 2.1 the equilibrium profits are denoted for the different equilibria discussed.

Having described the second period entry game, let us now turn to the first period, to see what strategies are available to the incumbents. Milgrom and Roberts (1982) show how pre-entry prices can influence the expected profits of the entrant. A low price implies a low marginal cost (given demand is known) and due to the single crossing condition of Spence (1974), it is always possible for a low cost incumbent to find a price low enough that cannot be profitably imitated by a high cost incumbent. As we use outputs in this model, a low price is the result of a high output. Therefore, we shall be looking for outputs that are able to provide information to the entrant about the incumbents' marginal costs.

To simplify the model further, we assume small fixed entry costs so that entry is always profitable in the second period, whatever the cost types of the incumbents. This allows us to focus on the entrant's output allocation given the quota imposed.

2.3 Equilibrium with No Incumbent Trade

In a separating equilibrium both incumbents reveal their true cost type. The entrant updates its beliefs using Bayes' rule. For consistency of beliefs Bayes' rule states:

$$\begin{aligned}\hat{q}^i_{iL} &\neq \hat{q}^i_{iH}, \mu_i\left(\hat{q}^i_{iL}\right) = 0 \text{ and } \mu_i\left(\hat{q}^i_{iH}\right) = 1 \\ \hat{q}^i_{iL} &= \hat{q}^i_{iH}, \mu_i\left(\hat{q}^i_{iL}\right) = \mu_i\left(\hat{q}^i_{iH}\right) = \rho_i\end{aligned}$$

The first statement (first line) of Bayes' rule is required for a separating equilibrium, while the second statement (the second line) is a requirement for a pooling equilibrium. As entry is always profitable in this model, pooling equilibria will not result. As in Mailath (1989), low cost incumbents always have an incentive to signal their cost type.

2.3.1 National Quota

Let us consider the case of firm 1 in market 1. We require conditions that show that it is profitable for a low cost incumbent $1L$ to produce a first period output that cannot be imitated by a high cost incumbent $1H$ and thus enjoy a smaller entrant output in the second period. This is similar to Mailath (1989). For example, in the first period, firm 1 chooses some output $\hat{q}_{1L}$ yielding profits $\pi^1_{1L}(\hat{q}_{1L})$. In the second period, firm 1 acts as a Cournot player (in the sense that it does not deviate from the single period equilibrium) and earns profits $\pi^1_{1L}\left(q^{br}_{1L}, q_3(\mu_1)\right)$ where μ_1 refers to the beliefs that firm 3, the entrant, has about firm 1's cost type. Note that $\partial q_3/\partial \mu_1 > 0$ which means that the entrant will produce more if it believes the incumbent to have a high marginal cost. Firm 1 simply reacts according to its reaction function. If firm 1 is able to convey the message in the first period that it has a low marginal cost, it will earn $\pi^1_{1L}(q_{1L}, q_3(0))$. However, if firm 3 is convinced that firm 1 has a high marginal cost, then firm 1 earns $\pi^1_{1L}\left(q^{br}_{1L}, q_3(1)\right) < \pi^1_{1L}(q_{1L}, q_3(0))$. The reason why $1L$ earns lower profits if the entrant believes it have a high marginal cost is because this belief causes the entrant to produce more in the market than it otherwise would, i.e. $\partial q_3/\partial c_1 > 0$. Therefore, firm $1L$ has an incentive to inform firm 3 of its cost type. However, $1H$ has an incentive to imitate $1L$ because it can earn $\pi^1_{1H}\left(q^{br}_{1H}, q_3(0)\right) > \pi^1_{1H}(q_{1H}, q_3(1))$

(this time the entrant produces a lower output than it would have done in the case of complete information). Clearly, we need to find an output level in the first period that ensures higher profits for $1L$ by signalling and which cannot be imitated profitably by firm $1H$.

The incentive constraint of $1L$ is given by,

$$\pi_{1L}^{1}(\hat{q}_{1L}) + \delta\pi_{1L}^{1}(q_{1L}, q_3(0)) > \pi_{1L}^{1} + \delta\pi_{1L}^{1}\left(q_{1L}^{br}, K^1\right) \tag{2.10}$$

On the LHS we see the first period profits of $1L$ for some output $\hat{q}_{1L}^{1}$ followed by the Cournot equilibrium duopoly profits. On the RHS, we see the monopoly profits of firm $1L$ when it produces at its monopoly output in the first period, and as it has not signalled its cost type, Bayes' rule no longer applies and out-of-equilibrium beliefs allow us to assign whatever values we wish. We assume that firm 3 considers the incumbent to have a high marginal cost. The reasoning for this is that if it were profitable for $1L$ to signal, it would have done so. Therefore, by not doing so, the incumbent in market 1 cannot have a low marginal cost.

For $1H$, a similar incentive constraint exists,

$$\pi_{1H}^{1}(\hat{q}_{1L}) + \delta\pi_{1H}^{1}\left(q_{1H}^{br}, q_3(0)\right) \leq \pi_{1H}^{1} + \delta\pi_{1H}^{1}\left(q_{1H}^{br}, K^1\right) \tag{2.11}$$

This time, we require that the high cost type incumbent prefers not to imitate the strategy of the low cost type incumbent. In other words, its profits are higher if it plays its monopoly output in the first period (earning monopoly profits) and then accepting a smaller market share in the second period. Although higher profits can be earned imitating the low cost incumbent's output, the accompanying losses overwhelm the gains. This is virtually the same scenario as Mailath (1989) although his first period is a duopoly. Nevertheless, it is a signalling model to gain market share, not to deter entry.

Conditions for a separating equilibrium arise from rearranging inequalities 2.10 and 2.11 in terms of δ, hence,

$$\frac{\pi_{1H}^{1} - \pi_{1H}^{1}(\hat{q}_{1L})}{\pi_{1H}^{1}\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^{1}\left(q_{1H}^{br}, K^1\right)} \geq \delta > \frac{\pi_{1L}^{1} - \pi_{1L}^{1}(\hat{q}_{1L})}{\pi_{1L}^{1}(q_{1L}, q_3(0)) - \pi_{1L}^{1}\left(q_{1L}^{br}, K^1\right)} \tag{2.12}$$

If we can find $\delta > 0$ such that 2.12 holds, then a separating equilibrium exists. Two conditions sufficient for separation emerge from 2.12. First,

$$\pi_{1H}^{1} - \pi_{1H}^{1}(\hat{q}_{1L}) > \pi_{1L}^{1} - \pi_{1L}^{1}(\hat{q}_{1L}) \tag{2.13}$$

and,

$$\pi_{1L}^{1}(q_{1L}, q_3(0)) - \pi_{1L}^{1}\left(q_{1L}^{br}, K^1\right) > \pi_{1H}^{1}\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^{1}\left(q_{1H}^{br}, K^1\right) \tag{2.14}$$

Inequality 2.13 reappears several times in the text and so we state the following:

Lemma 2.1 *The inequality*

$$\pi_{1H}^{1} - \pi_{1H}^{1}(\hat{q}_{1L}) > \pi_{1L}^{1} - \pi_{1L}^{1}(\hat{q}_{1L})$$

always holds.

Proof. See Appendix.

The lemma is in fact the single crossing condition due to Spence (1974). It implies that a low cost firm will find it less costly to deviate from its monopoly output in the first period than a high cost incumbent.

Note that if the constraint is too small, there may be no advantage to the low cost firm in signalling its low cost type. If the quota is so small that the entrant always produces up to the constraint for both types of incumbent, first period signalling will not affect second period profits. The entrant's output will be the same whether it competes against either a high or low cost incumbent, hence, there is no incentive for the low cost firm to reveal its cost type. Therefore, limit pricing will only occur if $K^i > q_3^i(0)$, where $q_3^i(0)$ is the unrestricted complete information Cournot equilibrium output of the entrant.

Proposition 2.1 *For $K^i > q_3^i(0), i \in \{1,2\}$, at least one separating equilibrium exists for the national quota where limit pricing takes place.*

Proof. See Appendix.

Of course, this says nothing about the actual value of the quota, only that limit pricing may occur when $K^i > q_3^i(0)$ and that if $K^i \leq q_3^i(0)$, limit pricing will not emerge as an equilibrium strategy. Before discussing the effect of the quota on the limit price, let us first turn to the imposition of a joint quota.

2.3.2 Joint Quota

The incentive constraints for the incumbents when the entrant is subjected to a joint quota follow a pattern similar to that for national quotas. For the case of the joint quota, it may or may not bind when the incumbent has a low marginal cost. For the national quota, a binding constraint when competing with a low cost incumbent meant that the low cost firm had no incentive to signal its cost type. However, this is not the case for the joint quota, as we shall see. We obtain two incentive constraints, depending on whether or not the constraint binds for the low cost firm when it signals its cost type in the first period. We have,

$$\pi_{1L}^{1}\left(\hat{q}_{1L}\right)+\delta\pi_{1L}^{1}\left(q_{1L},q_{3}\left(0\right)\right)>\pi_{1L}^{1}+\delta\pi_{1L}^{1}\left(q_{1L}^{br},q_{3}\left(0,\rho_{2}\right)\right) \tag{2.15}$$

and

$$\pi_{1L}^{1}\left(\hat{q}_{1L}\right)+\delta\pi_{1L}^{1}\left(q_{1L}^{br},q_{3}\left(0,\rho_{2}\right)\right)>\pi_{1L}^{1}+\delta\pi_{1L}^{1}\left(q_{1L}^{br},q_{3}\left(1,\rho_{2}\right)\right) \tag{2.16}$$

A point of interest for the joint quota is that limit pricing still occurs even when the constraint is close to zero (i.e. the entrant's total output is very small but positive). This is because the entrant is free to allocate its output to either of the two markets in whatever proportions it desires, depending on the relative residual demand it is likely to face. We see this in the entrant's allocation rule indicated in inequality 2.9.

Similarly, the incentive constraint for the high cost incumbent is,

$$\pi_{1H}^{1}\left(\hat{q}_{1L}\right)+\delta\pi_{1H}^{1}\left(q_{1L},q_{3}\left(0\right)\right)\leq\pi_{1H}^{1}+\delta\pi_{1H}^{1}\left(q_{1H}^{br},q_{3}\left(1,\rho_{2}\right)\right) \tag{2.17}$$

and

$$\pi_{1H}^{1}\left(\hat{q}_{1L}\right)+\delta\pi_{1H}^{1}\left(q_{1H}^{br},q_{3}\left(0,\rho_{2}\right)\right)\leq\pi_{1H}^{1}+\delta\pi_{1H}^{1}\left(q_{1H}^{br},q_{3}\left(1,\rho_{2}\right)\right) \tag{2.18}$$

The only difference in Case (ii) is that the incumbent must consider 2's cost type in its optimisation problem because this affects the entrant's output allocation.

Proposition 2.2 *For $K>0$, at least one separating equilibrium exists for the joint quota.*

Proof. See Appendix.

The fact that a separating equilibrium exists is not surprising given the similarity with Mailath's oligopoly signalling model. The low cost type incumbents are able to ensure their market share by signalling. However, when a joint quota is imposed, the incumbent cannot guarantee its second period profits. All that is certain is that the entrant will know each incumbent's cost type by the end of the first period.

Typically, a range of outputs (and hence prices) exists which supports the separating equilibrium. However, it seems reasonable to assume that an incumbent will choose an output that yields it the highest first period profits without upsetting the separating equilibrium. This is known as the least cost separating output and is derived by finding a pre-entry incumbent output that makes inequalities 2.11, 2.17 and 2.18 hold with equality. We obtain,

$$\underline{q}_1^N = \frac{a-c_H}{2} + \sqrt{\delta\left[\pi_{1H}^1\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^1\left(q_{1H}^{br}, K^1\right)\right]} \tag{2.19}$$

for the national quota and

$$\underline{q}_1^J = \frac{a-c_H}{2} + \sqrt{\delta\left[\pi_{1H}\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^1(1,\rho_2)\right]} \tag{2.20}$$

and

$$\underline{q}_1^{JJ} = \frac{a-c_H}{2} + \sqrt{\delta\left[\pi_{1H}^1\left(q_{1H}^{br}, q_3(0,\rho_2)\right) - \pi_{1H}^1\left(q_{1H}^{br}, q_3(1,\rho_2)\right)\right]} \tag{2.21}$$

for the joint quota where $\underline{q}_1^N$ is the least cost separating output under a national quota, $\underline{q}_1^J$ is the least cost separating output when the constraint only binds when the entrant believes it competes with low cost incumbent and $\underline{q}_1^{JJ}$ when the constraint always binds, regardless of the incumbent's cost type. Whereas the least cost separating output is always dependent on the size of the quota imposed, the least cost separating output under the joint quota of firm i is also dependent on ρ_j, the prior beliefs that the entrant holds regarding the other incumbent's cost type.

2.3.3 Equivalence in Strategic Behaviour

At this point, we can ask ourselves if an equivalent tariff would have the same effect on signalling as a quota. We know that an additive tariff t increases the entrant's marginal cost and therefore reduces its equilibrium output i.e. $\partial q_3^1/\partial c_3 < 0$. First, consider the national quota case. Assume an additive tariff yields an entrant equilibrium output $q_3^1(\mu_1, t)$ in market 1, where q_3^1 is dependent on the expected cost type of the incumbent plus the tariff. Clearly, we require that $q_3^1(1, t^*) = K^1$ and so $q_3^1(0, t^*) < K^1$. However, $q_3^1(0, t^*) < q_3^1(0)$ because $\partial q_3^1/\partial t < 0$ which implies

$$\pi_{1H}^1\left(q_{1H}^{br}, q_3^1(0)\right) < \pi_{1H}^1\left(q_{1H}^{br}, q_3^1(0, t^*)\right) \tag{2.22}$$

Hence, $\underline{q}^N(t) > \underline{q}^N$ which means that the limit price is lower for all quota equivalent tariffs. Furthermore, if the national quota is reduced such that $K^1 \leq q_3^1(0)$ then $\underline{q}_1^N = q_{1H}^1$ which implies that a non-distortionary separating equilibrium exists. However, this is not true for an equivalent tariff as differentiating the profit function of $1H$ yields

$$\frac{\partial^2 \pi_{1H}^1\left(q_{1H}^{br}, q_3^1(\mu_1, t)\right)}{\partial c_3 \partial \mu_1} = -\frac{1}{18}(c_H - c_L) < 0 \tag{2.23}$$

which implies that increasing t in order to reduce the equilibrium output of the entrant in line with a reduction in the quota, increases the distance between $\pi_{1H}^1\left(q_{1H}^{br}, q_3(0, t)\right)$ and $\pi_{1H}^1\left(q_{1H}^{br}, q_3^1(1, t)\right)$. Therefore, $\partial \underline{q}_1^N/\partial t > 0$ and $\partial \underline{q}_1^N/\partial K^1 > 0$.

Let us now look the joint quota. The entrant's allocation to each market must also be achieved by a tariff imposed on both markets. We therefore have

$$q_3^i(\mu_i, \mu_j) = \frac{(\mu_i - \mu_j)(c_H - c_L) + 3K}{6} = \frac{a - 2(c_3 + t) + \mu_i c_H + (1 - \mu_i) c_L}{3} \tag{2.24}$$

which rearranges to

$$t^{**} = \frac{2}{4}a + \frac{1}{4}\left[(\mu_i + \mu_j) c_H + (2 - \mu_i - \mu_j) c_L\right] - \frac{3}{4}K - c_3$$

This implies that t^{**} is the same for both market $i, j = 1, 2$. Therefore, a joint tariff exists which yields the equivalent output in both markets as under the joint quota. As above we see that $q_3^1(1, \rho_2) = q_3^1(1, t^{**})$ but that $q_3^1(0) < q_3^1(0, t^{**})$ which implies that the limit price will always be higher under a quota-equivalent tariff.

However, if we reduce the joint quota so that it is always binding, we see that $q_3^1(0, \rho_2) = q_3^1(0, t^{**})$. In other words, the equivalent tariff will yield a similar strategic response in the incumbent, but only when the constraint is always binding.

We can summarise with the following proposition.

Proposition 2.3 *Equivalent tariffs and quotas for both national and joint trade policies have opposite effects on the limit price. Whereas an increasing tariff lowers the limit price, an equivalent, increasingly restrictive quota raises the limit price. However, when we consider small joint quotas where the entrant's output is always binding, an equivalent tariff will yield an equivalent response in the incumbent's actions.*

2.3.4 The Extent of Limit Pricing

Above, we noted that in order to obtain limit pricing behaviour, we need to restrict the range of the national quotas. We stated that a national quota must bind the entrant's output if the incumbent has a high marginal cost, but that the constraint no longer binds when the incumbent has a low marginal cost. For the joint quota, the separating equilibrium exists whether or not the quota binds when the incumbent has a low marginal cost. However, we need to define the range of the joint quota which causes the constraint to bind. Consider the position from market 1 when the constraint no longer binds. If 1 signals a low cost type then $q_3^1(0) = (a - 2c_3 + c_L)/3$. However, $1L$ does not know what the entrant's output in market 2 will be although it knows its expected output $q_3^2(\rho_2) = (a - 2c_3 + \rho_2 c_H + (1-\rho_2) c_L)/3$. If $K > \bar{K} \equiv q_3^1(0) + q_3^2(\rho_2)$ then $1L$ expects that the constraint is not binding and that the entrant will produce its Cournot equilibrium output in both markets. We also need to define a minimum for the constraint. This is simply $\underline{K} \equiv q_3^1(0) + q_3^2(0)$. Hence, for $\underline{K} < K < \bar{K}$ the constraint created by the joint quota is binding.

$$K^1 > \frac{3K + (1-\rho_2)(c_H - c_L)}{6} \tag{2.25}$$

We can now turn to the analysis of the limit prices that result from a joint or national quota.

Proposition 2.4 *For* $K^1, K^2 \in \left(\underline{K}, \bar{K}\right)$ *and* $K^1 + K^2 = K$ *then*

$$\underline{q}_i^N - \underline{q}_i^J = \begin{cases} \geq 0 \text{ if } K^i \geq q_3^i(1, \rho_2) \\ < 0 \text{ otherwise.} \end{cases}$$

Proof. Consider $\underline{q}_i^N \gtreqless \underline{q}_i^J$. Then

$$\underline{q}_i^N \gtreqless \underline{q}_i^J$$

$$\begin{aligned}
\pi^i_{iH}\left(q^{br}_{iH}, q_3\left(1,\rho_j\right)\right) &\gtreqless \pi^i_{iH}\left(q^{br}_{iH}, q_3\left(1,K^i\right)\right) \\
-\left(1-\rho_j\right)\left(c_H - c_L\right) &\gtreqless 3\left(K^j - K^i\right) \\
K^i &\gtreqless \frac{\left(1-\rho_j\right)\left(c_H - c_L\right) + 3K}{6} \\
K^i &\gtreqless q^i_3\left(1,\rho_2\right)
\end{aligned}$$

Therefore, $K^i > q^i_3(1,\rho_2)$ implies $\underline{q}^N_i > \underline{q}^J_i$. ■

This makes sense: if the incumbent expects a lower entrant output under the joint quota compared to the national quota (implied by $K^i > q^i_3(1,\rho_2)$) then there are less incentives to signal cost type. Note that if $K^1 = K^2$ then $K^i < q^i_3(1,\rho_j)$ so that $\underline{q}^J_i > \underline{q}^N_i$.

A further remark to make refers to $\underline{q}^{JJ}_1$, the least cost separating output when the constraint is always binding for the joint quota.

Corollary 2.5 *The limit price falls as the joint quota decreases in size i.e.* $\partial \underline{q}^{JJ}_1 / \partial K < 0$.

Proof. We consider a joint quota that is always binding. Find some $\underline{q}^{JJ}_1$ that makes inequality 2.18 hold with equality. Rearrange to get,

$$\begin{aligned}
\Psi &\equiv \delta\left[\pi^1_{1H}\left(q^{br}_{1H}, q^1_3\left(0,\rho_2\right)\right) - \pi^1_{1H}\left(q^{br}_{1H}, q^1_3\left(1,\rho_2\right)\right)\right] \\
&= \pi^1_{1H} - \pi^1_{1H}\left(\underline{q}^{JJ}_1\right) \qquad (2.26)
\end{aligned}$$

We can use Ψ as a proxy for the limit price. Substitute in the parameter values and differentiate Ψ with respect to K to get,

$$\frac{\partial \Psi}{\partial K} = -\frac{1}{24}\left(c_H - c_L\right) < 0 \qquad (2.27)$$

Therefore, as K falls, Ψ rises. In order for equality to remain, a rise in Ψ must be linked with a rise in $\underline{q}^{JJ}_1$. Hence, $\uparrow K, \downarrow \Psi, \downarrow \underline{q}^{JJ}_1$, i.e. $\partial \underline{q}^{JJ}_1 / \partial K < 0$ which means that as the joint quota falls in size, the limit price also falls. ■

When the quota is always constraining the entrant's output, no matter what the incumbent's cost type, a national quota of a similar size will result in no limit pricing behaviour. Moreover, the joint quota may stimulate pre-entry signalling from the low cost incumbent when under a national quota, this would not occur.

2.4 Equilibrium with Incumbent Trade

In this section we allow the incumbents to enter each others' markets, without restrictions, in the second period. As above, we study the effects of a national and joint quota on the strategic behaviour of the incumbents. The results are similar to those obtained in the previous section, with the exception of the small joint quota.

2.4.1 National Quota

Let us move on to the separating equilibrium for both national and joint quotas when the incumbents also engage in international trade. The incumbents enter each other's markets in the second period, unconstrained by the national quota. Firm 3, on the other hand, is constrained by the quota. However, this means that the entrant could face two high cost incumbents, two low cost incumbents or both cost types. To ensure that the low cost incumbents have an incentive to signal in the first period, we assume that the quota is larger than the complete information equilibrium output the entrant would produce when facing two low cost incumbents. However, if the quota is to constrain the entrant's output it must be smaller than the complete information equilibrium output when facing at least one high cost incumbent for sure. It is assumed that the incumbents know each others' costs.

The incentive constraint for the low cost incumbent $1L$ is,

$$\pi_{1L}^{1}(\hat{q}_1) + \delta\pi_{1L}^{1}(q_{1L}, q_{2\theta}, q_3(0)) > \pi_{1L}^{1} + \delta\pi_{1L}^{1}\left(q_{1L}^{br}, q_{2L}^{br}, K^1\right) \tag{2.28}$$

Similarly, the incentive constraint for the high cost incumbent $1H$ is

$$\pi_{1H}^{1}(\hat{q}_1) + \delta\pi_{1H}^{1}\left(q_{1H}^{br}, q_{2H}^{br}, q_3(0)\right) \leq \pi_{1H}^{1} + \delta\pi_{1H}^{1}\left(q_{1H}^{br}, q_{2H}^{br}, K^1\right) \tag{2.29}$$

As we can see, the constraints for the separating equilibrium are very similar to those in the no trade model. However, we obtain second period tripoly profits instead of duopoly profits. Solving equation 2.28 for equality, we get:

$$\bar{q}_1^N = \frac{a - c_L}{2} + \sqrt{\delta\left[\pi_{1L}^{1}(q_{1L}, q_{2\theta}, q_3(0)) - \pi_{1L}^{1}\left(q_{1L}^{br}, q_{2L}^{br}, K^1\right)\right]} \tag{2.30}$$

and then solving equation 2.29 similarly yields,

$$\underline{q}_1^N = \frac{a - c_H}{2} + \sqrt{\delta \left[\pi_{iH\theta'} \left(q_{1H}^{br}, q_{2H}^{br}, q_3(0) \right) - \pi_{iH\theta'}^{N} \left(q_{1H}^{br}, q_{2H}^{br}, K^1 \right) \right]} \tag{2.31}$$

As in the previous section, for some first period output $\hat{q}_i \in \left(\underline{q}_i^N, \bar{q}_i^N \right)$ a separating equilibrium exists. Therefore, it is sufficient to show that

$$\pi_{1L}^1 \left(q_{1L}, q_{2\theta}, q_3(0) \right) - \pi_{1L}^1 \left(q_{1L}^{br}, q_{2L}^{br}, K^1 \right) > \pi_{iH\theta'} \left(q_{1H}^{br}, q_{2H}^{br}, q_3(0) \right) - \pi_{iH\theta'}^{N} \left(q_{1H}^{br}, q_{2H}^{br}, K^1 \right) \tag{2.32}$$

for the separating equilibrium to hold. Substituting in the parameter values we find that equation 2.32 simplifies to $c_H > c_L$, hence a separating equilibrium exists.

The fact that the incumbents enter each other's markets changes little in the signalling game. Indeed, this situation is similar to Mailath's (1989) n firm example of signalling, with the exception that one of the firms does not signal and its capacity is constrained. However, the result we obtain is more interesting when we compare it with the case of the joint quota, explained below.

2.4.2 Joint Quota

For the joint constraint we need to consider the case where the quota only binds if the incumbent has a high cost and when the constraint always binds, regardless of the incumbent's type. In the former, the low cost incumbent has the following incentive constraint:

$$\pi_{1L}^1 \left(\hat{q}_{1L} \right) + \delta \pi_{1L}^1 \left(q_{1L}, q_{2\theta}, q_3(0) \right) > \pi_{1L}^1 + \delta \pi_{1L}^1 \left(q_{1L}^{br}, q_{2\theta}^{br}, K/2 \right) \tag{2.33}$$

and the high cost incumbent,

$$\pi_{1H}^1 \left(\hat{q}_{1L} \right) + \delta \pi_{1H}^1 \left(q_{1H}^{br}, q_{2\theta}^{br}, q_3(0) \right) \leq \pi_{1H}^1 + \delta \pi_{1H}^1 \left(q_{1H}^{br}, q_{2\theta}^{br}, K/2 \right) \tag{2.34}$$

Signalling still takes place because market share gains can still be made by separating. As above, sufficient conditions for a separating equilibrium are,

$$\begin{aligned} & \frac{\pi_{1H}^1 - \pi_{1H}^1 \left(\hat{q}_{1L} \right)}{\pi_{1H} \left(q_{1H}^{br}, q_{2\theta}^{br}, q_3(0) \right) - \pi_{1H}^1 \left(q_{1H}^{br}, q_{2\theta}^{br}, K/2 \right)} \geq \delta \\ & > \frac{\pi_{1L}^1 - \pi_{1L}^1 \left(\hat{q}_{1L} \right)}{\pi_{1L}^1 \left(q_{1L}, q_{2\theta}, q_3(0) \right) - \pi_{1L}^1 \left(q_{1L}^{br}, q_{2\theta}^{br}, K/2 \right)} \end{aligned} \tag{2.35}$$

By Lemma 2.1 the numerator of the LHS is greater than that of the RHS. However, we need to check the denominator to see if,

$$\pi^1_{1L}\left(q_{1L}, q_{2\theta}, q_3(0)\right) - \pi^1_{1L}\left(q^{br}_{1L}, q^{br}_{2\theta}, K/2\right)$$
$$> \pi_{1H}\left(q^{br}_{1H}, q^{br}_{2\theta}, q_3(0)\right) - \pi^1_{1H}\left(q^{br}_{1H}, q^{br}_{2\theta}, K/2\right) \quad (2.36)$$

Again, substituting in the parameter values and simplifying reduces equation 2.36 to $c_H > c_L$, hence a separating equilibrium exists. Again this result is similar to the previous section. We see that the presence of another firm in the market does not upset the separating equilibrium, although it may lead to non-distortionary pre-entry strategies.

The least cost separating output is given by

$$\underline{q}^J_i = \frac{a - c_H}{2} + \sqrt{\delta\left[\pi_{iH\theta'}\left(q^{br}_{1H}, q^{br}_{2H}, q_3(0)\right) - \pi^i_{iH\theta'}\left(q^{br}_{1H}, q^{br}_{2H}, K/2\right)\right]} \quad (2.37)$$

which is similar that of the free trade case, with the exception that if the incumbent signals a high marginal cost, the constraint is binding and the entrant allocates the same quantity to each market. The difference in the least cost separating outputs is given by

$$\begin{aligned} \underline{q}^J_i &\gtreqless \underline{q}^N_i \\ \pi^i_{iH\theta'}\left(q^{br}_{1H}, q^{br}_{2H}, K^i\right) &\gtreqless \pi^i_{iH\theta'}\left(q^{br}_{1H}, q^{br}_{2H}, K/2\right) \\ K/2 &\gtreqless K^i \end{aligned}$$

Clearly, if $K^1 > K/2$ then $\underline{q}^N_1 > \underline{q}^J_1$ but because $K = K^1 + K^2$ it must also be that $K/2 > K^2$ which implies $\underline{q}^J_2 > \underline{q}^N_2$.

However, when the constraint is very small, so that it always binds, the results are quite different. When there was no intra-communitarian trade, a small national quota $K^i < \underline{K}$ led to an absence of limit pricing behaviour. The entrant's output would not change on entry into the market due to the constraint imposed on its output, thus removing the need to signal cost type. Nevertheless, when an equivalent joint quota was imposed, limit pricing could still emerge as an equilibrium strategy. If we consider trade between the incumbents, a very small national quota has the same effect as in the no-trade case. However, a joint quota will have a similar effect.

Proposition 2.6 *For intra-communitarian trade, when the joint quota is very small, such that the constraint, K, always binds, there will be no limit pricing.*

Proof. The incentive constraints for the low and high cost types are:

$$\pi_{1L}^{1}\left(\hat{q}_{1L}\right)+\delta\pi_{1L}^{1}\left(q_{1L}^{br},q_{2\theta}^{br},K/2\right)>\pi_{1L}^{1}+\delta\pi_{1L}^{1}\left(q_{1L}^{br},q_{2\theta}^{br},K/2\right) \tag{2.38}$$

and

$$\pi_{1H}^{1}\left(\hat{q}_{1L}\right)+\delta\pi_{1H}^{1}\left(q_{1H}^{br},q_{2\theta}^{br},K/2\right)<\pi_{1H}^{1}+\delta\pi_{1H}^{1}\left(q_{1H}^{br},q_{2\theta}^{br},K/2\right) \tag{2.39}$$

respectively. As we see, the low cost firm gains nothing by signalling its cost type. This applies for the high cost firm. Therefore, there will be no limit pricing. ■

What we see is that when the joint quota is very small, limit pricing never takes place. This is the opposite result to the same quota when there was no trade between the incumbents. The reason for this is that when the incumbents trade, the residual demand for the entrant is the same in both markets. Indeed, regardless of the incumbents' actual cost types, the demand that the entrant faces is the same and so it allocates its restricted output equally between the two. In other words, both high and low cost type incumbents choose their monopoly outputs in the second period because the entrant's output is so small that it will produce up to the quota, whatever their cost type might be.

The effects of trade policy on the incumbent's actions are similar to those of the previous section. However, when the quota is small so that the entrant always produces up to its constraint, regardless of the incumbents cost types, no limit pricing occurs. With a similar tariff, we would still obtain limit pricing behaviour because firms would still have an incentive to protect their market shares.

Joint quotas force incumbents to act more strategically than under the national quota system because it forces them to consider the strategies of firms in other markets. As we have seen, symmetric quotas will lead to a lower limit price (higher least cost separating output) under a joint quota than under a national quota. However, if national quotas differ significantly between countries, this relationship could be reversed.

2.5 Welfare Effects

We should now look at the welfare effects of imposing the different types of quota. We ignore the analysis of the effect of tariffs on welfare as this has already been dealt with extensively by Levy and Nolan (1992). In some sense, the results here complement their findings for tariffs, by illustrating the welfare differences that emerge when equivalent quotas are applied. Furthermore, we can look at the welfare effects of strategic changes in the firms' behaviour. In order to do this we need to consider both first and second period welfare.

Welfare is assumed to be the sum of consumer and producer surplus. We can ignore the profits earned by the entrant as it does not produce in the market. Furthermore, we assume that quota rents are captured by the entrant. Inclusion of quota rents implies that each government sets a price for the quota. However, choosing prices and quotas that maximise welfare is beyond the scope of the present analysis (see McCorriston and Sheldon 1994 for a detailed analysis).

2.5.1 First Period Welfare

In the first period, the incumbents are the sole producers in the market. We can show that any kind of first period price distortions will raise first period welfare. Denote first period welfare by the function $W_1^1(q)$ which is the sum of producer and consumer surplus i.e.

$$W_1^1(q) = \pi_1^1(q) + \int_{q=0}^{q} P(q)\,dq - P(q)\,q \tag{2.40}$$

As $\pi_1^1(q) = [P(q) - c]\,q$ we can differentiate with respect to q to obtain

$$\frac{\partial W_1^1}{\partial q} = P(q) - c > 0 \tag{2.41}$$

The incumbent's price is strictly greater than its marginal cost. Otherwise, it would obtain zero first period profits which cannot be compensated by discounted future profits. Looking at the different quota cases we can easily compare first period welfare. Furthermore, we see that the second order condition $\partial^2 W_1^1/\partial q^2 = P'(q) < 0$ implies that the welfare function is concave: as output rises, welfare increases before eventually decreasing. However, as we restrict ourselves to $P(q) > c$ then welfare is always increasing in q. Using the results from the previous section we can state the following proposition.

Proposition 2.7 *First period welfare in each market increases under a joint quota only when $q_3^i(1,\rho_j) > K^i$.*

Proof. If $q_3^i(1,\rho_j) > K^i$ then $\underline{q}_1^J > \underline{q}_1^N$. By concavity of the welfare function with respect to output

$$\Delta W_1^i = W_1^i\left(\underline{q}_i^N\right) - W_1^i\left(\underline{q}_i^J\right) < 0 \tag{2.42}$$

Therefore, we can state

$$\Delta W_1^i = \begin{cases} < 0 \text{ if } q_3^i(1,\rho_j) > K^i \\ \geq 0 \text{ otherwise.} \end{cases} \tag{2.43}$$

for $i = 1,2$ $i \neq j$. ■

Problems arise when $q_3^1(1,\rho_j) > K^1$ but $q_3^2(1,\rho_j) < K^2$. A joint quota will increase welfare in market 1 but will lower it in market 2. However, welfare gains may outweigh losses, depending on the relative least cost separating outputs.

What about the effect of the quota on first period welfare, via the limit price? Differentiating the welfare function with respect to K^1 we get

$$\frac{\partial W_1^1}{\partial K^1} = (P(q) - c)\frac{\partial \underline{q}_1^N}{\partial K^1} > 0 \tag{2.44}$$

In other words, as we increase the quota the least cost separating output increases and welfare increases. Note that because no quota yields the highest least cost separating output, there is no quota such that $\partial W_1^1/\partial K^1 = 0$. The second order condition gives

$$\frac{\partial^2 W_1^1}{\partial (K^1)^2} = \frac{\partial P}{\partial \underline{q}_1^N}\frac{\partial q^N}{\partial K^1} + (P(q) - c)\frac{\partial^2 \underline{q}_1^N}{\partial (K^1)^2} < 0 \tag{2.45}$$

as $\partial P/\partial \underline{q}_1^N < 0$, $\partial \underline{q}_1^N/\partial K^1 > 0$ and $\partial^2 \underline{q}_1^N/\partial (K^1)^2 < 0$.[4] Therefore, as the quota rises, welfare increases but at a decreasing rate.

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[4] Using the equilibrium values

$$\frac{\partial q^N}{\partial K^1} = \frac{q_{1H}^{br}\sqrt{\delta}}{2\sqrt{\left[\pi_{1H}^1\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^1\left(q_{1H}^{br}, K^1\right)\right]}} > 0$$

In the case of intra-communitarian trade, $q_3^i(1,\rho_j) = K/2$ so that welfare in both countries is identical under the joint quota. However, welfare is different under the national quotas only if $K^1 \neq K^2$. If $K^1 > K^2$ then the welfare in country 1 will be higher than that of country 2 because $\underline{q}_1^N > \underline{q}_2^N$. Of course, we showed above that when the incumbents engage in trade, $K^1 > K/2 > K^2$ which implies $\underline{q}_1^N > \underline{q}_1^J = \underline{q}_2^J > \underline{q}_2^N$. In order to see the full effect on welfare, let us look at figure 2.1. Consider $\underline{q}_i^J = y$ and $\underline{q}_1^N = z$ and $\underline{q}_2^N = z'$. We can see that welfare is always higher under the joint quota, as the gains in one market offset the losses in the other i.e. By concavity of the welfare function, we can see that

$$\begin{aligned} W_1^1\left(\underline{q}_1^J\right) + W_1^2\left(\underline{q}_2^J\right) &> W_1^1\left(\underline{q}_1^N\right) + W_1^2\left(\underline{q}_2^N\right) \\ 2W_i^i\left(\underline{q}_i^J\right) &> W_1^1\left(\underline{q}_1^N\right) + W_1^1\left(\underline{q}_2^N\right) \\ W_i^i\left(\underline{q}_i^J\right) &> \frac{1}{2}\sum W_i^i\left(\underline{q}_i^N\right) \end{aligned}$$

Given these results, what kind of simple policy can we suggest? The government knows that signalling is at its most pronouced when the quotas are large. If both countries set $K^i = \bar{K}$ then welfare will be the same under a national quota system as under a joint quota system, as long as $\rho_1 = \rho_2$. Hence, $\underline{q}_1^N = \underline{q}_2^N = \underline{q}_2^J = \underline{q}_2^J$. Needless to say, if $\rho_1 \neq \rho_2$, then $\underline{q}_i^N \neq \underline{q}_i^J$ and welfare will be higher under national quotas.

2.5.2 Second Period Welfare

Second period welfare is a little more complex as we need to consider the effect of the entrant's output on welfare. A quota is set by a government before the first period of the game. At this stage only prior beliefs can be used to estimate the incumbent's cost type. First, let us look at the effect of a national quota on welfare. Summing

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and

$$\frac{\partial^2 \underline{q}_1^N}{\partial (K^1)^2} = -\frac{\pi_{1H}^1\left(q_{1H}^{br}, K^1\right)\sqrt{\delta}}{4\left(\sqrt{\left[\pi_{1H}^1\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^1\left(q_{1H}^{br}, K^1\right)\right]}\right)^2} - \frac{\sqrt{\delta}}{4\sqrt{\left[\pi_{1H}^1\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^1\left(q_{1H}^{br}, K^1\right)\right]}} < 0$$

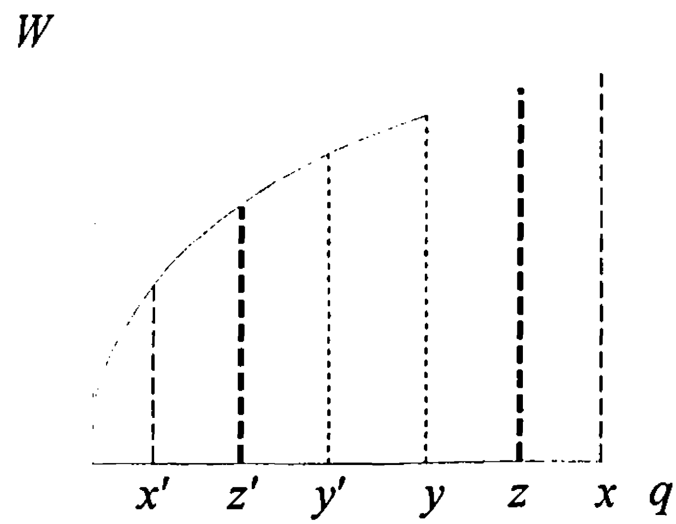

Figure 2.1: First period welfare as a function of the least cost separating output.

consumer and producer surplus in the second period yields

$$W_2^i\left(\rho_i, K^i\right) = \left(\frac{a-(\rho_i c_H+(1-\rho_i)\,c_L)-K^i}{2}\right)^2 + \frac{1}{2}\left(\frac{a-(\rho_i c_H+(1-\rho_i)\,c_L)+K^i}{2}\right)^2 \tag{2.46}$$

The higher the output of the entrant (implied by a higher K^i), the lower will be the domestic producer's profits, but the larger will be consumer surplus. Therefore, restricting the entrant's output will have the same effect on welfare as marginal cost does, as described by Levy and Nolan (1992). As we discuss the case where the quota is always binding, let us consider c_3 so small that the domestic producer just remains in the market i.e. $c_3 = 2c_i - a + \epsilon$ (where ϵ is small). Imposing a quota raises prices and allows the domestic producer to enter the market. The relationship between the welfare and the quota can be seen in figure 2.2. In fact, we can think of this function depicting the maximum quota possible for all levels of entrant marginal cost i.e. think of the maximum quota $\bar{K}$. Note that as the marginal cost of the entrant rises, we must restrict the range of quotas, thus limiting our analysis to the LHS of figure 2.2. The horizontal part on the RHS of figure 2.2 represents the point where the quota is no longer binding for a very low cost entrant. If the entrant had a higher marginal

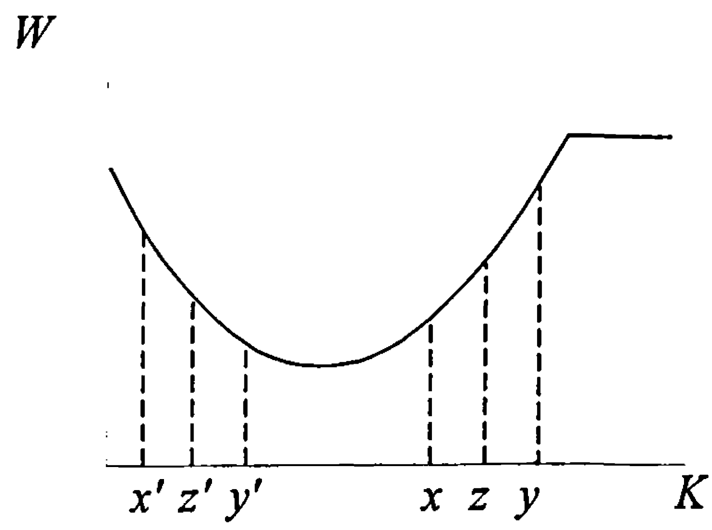

Figure 2.2: Relationship between second period welfare and entrant's output.

cost, this horizontal part of the welfare function would start some where to the left of the present line.

To illustrate the effects of a quota on welfare, assume that the entrant has a very low marginal cost, so that we can impose a large quota which might put us at z in the diagram. Increasing the quota to y will yield higher welfare while restricting it to x will reduce welfare. On the other hand, if the entrant has a rather high marginal cost, the quota will be smaller, perhaps z'. Here we obtain the opposite result. By increasing the quota to y' welfare falls while restricting the quota further to x' raises welfare.

However, we must also note that the marginal costs of the incumbent firms may also differ. Of course, this will have an effect on the welfare function, as we can see in figure 2.3. Denote the welfare function of a country which has a high (low) cost incumbent by W_H (W_L) we see that W_L lies above W_H and that $W'_H > W'_L$. The fact that lower marginal costs imply higher welfare is obvious: low costs lead to both lower prices and higher profits. The difference in the slopes of the two functions can be seen by differentiating the welfare function with respect to K^m. For example, for country 1 we have

$$\begin{aligned}\frac{\partial W_2^1(\mu_1, K^1)}{\partial K^1} &= \frac{1}{2}\left(K^1 - q_{1\theta}^{br}\right) \\ &= -\frac{1}{4}\left(a - (\rho_1 c_H + (1-\rho_1) c_L) - 3K^1\right) \qquad (2.47)\end{aligned}$$

We see that welfare is falling (rising) for $q_{1\theta}^{br} > K^1 (< K^1)$ and that the slope of the welfare function is increasing in the incumbent's cost i.e. denote $c_1 = (\rho_i c_H + (1-\rho_i) c_L)$ then $\partial^2 W_2/\partial K^1 \partial c_1 = 1/4 > 0$. Let us summarise the result in the following proposition.

Proposition 2.8 *Welfare is maximised by (i) free trade when $c_3 < c_1$ and (ii) by a complete embargo when $c_3 > c_1$.*

In other words, if the entrant's marginal cost is less than that of the incumbent, then $q_{1\theta}^{br} < K^1$. However, due to the convexity of the welfare function, welfare rises as K^1 increases. Clearly, free trade yields the highest welfare. On the other hand, if $c_3 > c_1$ then $q_{1\theta}^{br} > K^1$ and welfare is falling in K^1, hence a complete embargo would yield the highest level of welfare. With these results, economic reasons to impose quotas seem difficult to find unless import licenses can be imposed (McCorriston and Sheldon 1994).

It is now possible to study the second period welfare effects of a national and joint quota. Under the joint quota, the entrant's total output is constrained and its allocation between the two markets depends on the relative differences in the marginal costs of the incumbents. Therefore, we denote welfare under a joint quota by

$$\begin{aligned}W_2^i(\rho_1, \rho_2, K) &= \left(\frac{6a - ((7\rho_1 - \rho_2) c_H + (6 - 7\rho_1 + \rho_2) c_L) - 3K}{12}\right)^2 \\ &\quad -\frac{1}{2}\left(\frac{6a - ((5\rho_1 + \rho_2) c_H + (6 - 5\rho_1 - \rho_2) c_L) + 3K}{12}\right)^2 \qquad (2.48)\end{aligned}$$

The difference in welfare between a national and joint quota is thus

$$\begin{aligned}\Delta W_2 &= W_2^1\left(c_1, K^1\right) + W_2^2\left(c_2, K^2\right) - W_2^1(c_1, c_2, K) - W_2^2(c_1, c_2, K) \\ &= -\frac{1}{16}\left[(\rho_1 - \rho_2)(c_H - c_L) - 3\left(K^1 - K^2\right)\right] \\ &\quad \times \left[(\rho_1 - \rho_2)(c_H - c_L) + \left(K^1 - K^2\right)\right] \qquad (2.49)\end{aligned}$$

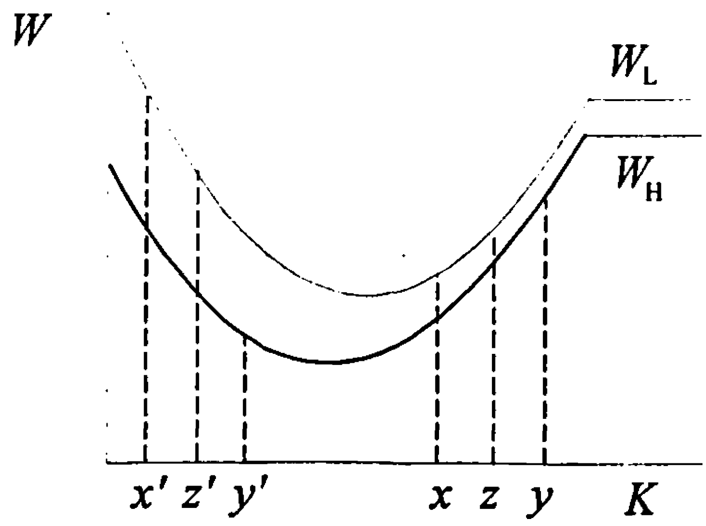

Figure 2.3: Relationship between welfare and entrant's output for a high and low cost incumbent.

Therefore, if $\Delta W_2 > 0$ ($\Delta W_2 < 0$) then joint quotas reduce (increase) welfare.

We can see that there are two effects at work, the differences in the national quotas and the differences in marginal costs between the two countries. For example, when $\rho_1 = \rho_2$ equation 2.49 reduces to $3(K^1 - K^2)^2/16$ which is always positive, hence $\Delta W_2 > 0$. On the other hand, when $K^1 = K^2$ equation 2.49 reduces to $-(\rho_1 - \rho_2)(c_H - c_L)^2/16$ which is always negative for $\rho_1 \neq \rho_2$, hence $\Delta W_2 < 0$.

A more general explanation for these two results can be seen using figures 2.2 and 2.3. First, $K^1 \neq K^2$ and $c_1 = c_2 = c$ is implied by figure 2.2 taking $K^1 = x$ and $K^2 = y$ (or $K^1 = x'$ and $K^2 = y'$). As the marginal costs are the same, the entrant will allocate the same output to each market under the joint quota, where $(K^1 + K^2)/2 = z$ (or z'). As the costs are the same, we know that

$$W_2^i\left(\rho_1, \rho_2, \left(K^1 + K^2\right)/2\right) = W_2^i\left(\rho, \left(K^1 + K^2\right)/2\right) \tag{2.50}$$

Hence

$$\begin{aligned}\Delta W_2 &= \sum_i W_2^i\left(\rho_i, K^i\right) - \sum_i W_2^i\left(\rho_i, \left(\sum_i K^i\right)/2\right) \\ &= W_2^1\left(\rho_i, K^1\right) + W_2^2\left(\rho_i, K^2\right) - W_2^1\left(\rho_i, \left(K^1 + K^2\right)/2\right)\end{aligned}$$

$$-W_2^2\left(\rho_i,\left(K^1+K^2\right)/2\right) \tag{2.51}$$

Using the fact that the welfare function is convex to the origin, we know that

$$W_2^i\left(\rho_i,\left(K^1+K^2\right)/2\right) < \frac{1}{2}W_2^1\left(\rho_i,K^1\right)+\frac{1}{2}W_2^2\left(\rho_i,K^2\right) \tag{2.52}$$

which implies $\Delta W_2 > 0$.

Secondly, when $K^1 = K^2$ and $\rho_1 \neq \rho_2$ we must turn to figure 2.3. We begin at $K^1 = K^2 = z$ (or z'). When the joint quota is imposed, the entrant allocates resources according to the relative marginal cost differences between the incumbents. The country with the highest marginal cost will face the largest entrant output. If $\rho_1 > \rho_2$ then country 1 welfare is represented by W_H. The joint quota will lead to a reallocation of resources such that the entrant will produce y (or y') in 1 and x (x') in 2 (note that $y - z = z - x$). Whether we take z or z' as our starting point, welfare always rises because the slope of W_L is always less than that of W_H. In other words, the move from z to y for 1 produces higher welfare gains than the losses incurred in 2 resulting from a move from z to x.

Suppose $K^1 \neq K^2$ and $\rho_1 \neq \rho_2$. Clearly, the two effects discussed above will work against each other. Looking at equation 2.49 we see that if $K^1 > K^2$ and $c_1 > c_2$ then $\Delta W_2 \geq 0$ if $3\left(K^1 - K^2\right) \geq (\rho_1 - \rho_2)(c_H - c_L) > 0$. To understand, let us do the following manipulation. From 2.49 we have

$$\begin{aligned}
&\Rightarrow\ 3\left(K^1 - K^2\right) \geq (\rho_1-\rho_2)(c_H-c_L)\\
&\Rightarrow\ K^1 \geq \frac{(\rho_1-\rho_2)(c_H-c_L)}{3} + K^2\\
&\Rightarrow\ 2K^1 \geq \frac{(\rho_1-\rho_2)(c_H-c_L)}{3} + K^2 + K^1\\
&\Rightarrow\ K^1 \geq \frac{(\rho_1-\rho_2)(c_H-c_L) + 3\left(K^2+K^1\right)}{6}\\
&\Rightarrow\ K^1 \geq q_3^1(\rho_1,\rho_2)
\end{aligned}$$

In other words, if we consider the change in entrant output following a move from a national to a joint quota, welfare will fall if the entrant allocates less output to the high cost market. On the other hand, if more output is allocated, then welfare improves under the joint quota scheme. Similarly, if $K^1 > K^2$ and $\rho_1 < \rho_2$ then

$\Delta W_2 \geq 0$ if $(K^1 - K^2) \geq (\rho_2 - \rho_1)(c_H - c_L) > 0$. Manipulating will again yield that $\Delta W_2 \geq 0$ if $K^1 \geq q_3^2(\rho_1, \rho_2)$ i.e. welfare falls with the joint quota if the reallocation is less than the largest national quota. This again is due to the convexity of the welfare functions. Any output allocation between K^1 and K^2 will lower welfare. However, allocations outside this range will raise welfare under the joint quota.

Joint quotas can offer welfare gains only if the output allocation lies outside the range of the national quotas. Indeed, this result also holds if we introduce incumbent trade in the second period. Using the equilibrium values we see that

$$\Delta W_2 = \frac{5}{36}\left(K^1 - K^2\right)^2 > 0 \tag{2.53}$$

for $K^1 \neq K^2$. In other words, the joint quota always reduces welfare when incumbent trade takes place. When there is trade between the incumbents, the entrant always allocates the same output to each market i.e. $q_3^i(\rho_1, \rho_2) = (K^1 + K^2)/2$. Clearly, $(K^1 + K^2)/2 \in (K^1, K^2)$ which means that welfare must fall under the joint quota.

Let us summarise the results of this section with the following proposition.

Proposition 2.9

$$\Delta W_2 = \begin{cases} \geq 0 \ \textit{if} \ q_3^i(\rho_1, \rho_2) \in [K^1, K^2] \\ < 0 \ \textit{otherwise} \end{cases}$$

The result is driven by the convexity of the welfare function. Policy conclusions suggest that a joint quota is preferable when there are cost differences between the two domestic producers. This leads to a more competitive allocation of goods between the markets. However, a complete embargo or no quota at all would yield even greater welfare.

Nevertheless, we noted earlier that first period welfare is concave with respect to the quota while the second period welfare is convex. If we added together the first and second period welfare functions and differential with respect to K^1 we obtain an optimum if

$$\frac{\partial\left(W_1^1 + W_2^1\right)}{\partial K^1} = \left(P\left(\underline{q}_1^N\right) - c_L\right)\frac{\partial \underline{q}_1^N}{\partial K^1} - \frac{\delta}{2}\left(q_{1\theta}^{br} - K^1\right) = 0 \tag{2.54}$$

The first term is always positive and the second can be both positive and negative. As long as the first term is not too positive, we can find some K^* such that

$\partial (W_1^1 + W_2^1)/\partial K^1 = 0$. All we need to know now is whether this is a maximum or a minimum. The second order condition for a maximum is

$$\frac{\partial^2 W_1^1}{\partial (K^1)^2} = \frac{\partial P}{\partial q_1^N}\frac{\partial q^N}{\partial K^1} + (P(q) - c)\frac{\partial^2 q_1^N}{\partial (K^1)^2} + \delta\frac{3}{4} < 0 \tag{2.55}$$

which could certainly be satisfied for δ small enough. Of course, a quota which maximises welfare could only exist if $q_{1\theta}^{br} > \bar{K}$. In this situation, the entrant's marginal cost is relatively high, requiring a relatively small maximum quota. However, due to the convexity of the welfare function in the second period, a complete embargo would be more welfare enhancing. However, this would stop pre-entry limit pricing and thus lower first period welfare.

Setting national quotas equal to each other enhances first period welfare. In the second period, if cost differences exist, a joint quota will produce higher welfare. However, this only leads to the same first period welfare as the joint quota if $\rho_1 = \rho_2$. On the other hand, if $\rho_1 = \rho_2$ then unequal national quotas yield higher second period welfare. But then this yields lower first period welfare.

2.6 An Alternative Interpretation

An alternative interpretation of the national and joint quota scenario can be applied to the analysis. Consider the following situation. The entrant is a multinational enterprise which sets up plants in two geographically separate markets. We might think of the quota as a capacity constraint that a multinational entrant faces when it sets up production in a country. The capacity constraint might represent maximum plant production: when the entrant is faced by a high cost incumbent it has excess capacity; when faced by a low cost incumbent its output is constrained.[5] The two countries might form a free-trade agreement allowing the multinational to export and import between the two depending on demand. We can allow or restrict trade between the two markets by the incumbent firms, depending on the technologies we endow them with.

[5] If the entrant builds the plant, knowing only prior beliefs, then the optimal plant size will equal the expected output and hence will not lie on the reaction function.

As we see, little differs from the former analysis: we can restrict the entrant's output which affects the strategy of the incumbent. If two markets can be supplied, then the same allocation rule must also exist for the entrant. The difference in the size of national quotas can be seen in the different sizes of production units. Of course, if these are the same, opening up free trade between the two countries can only enhance joint welfare. Even if plant size is determined by prior beliefs, welfare will never decrease, and at the worse, it will remain the same.

2.7 Conclusion

This chapter has considered the effects of trade policy on the strategic behaviour of domestic producers *vis-a-vis* foreign competitors. First, we were able to show that the equivalent tariffs and quotas may not have equivalent effects on limit pricing behaviour. Indeed, when national quotas are considered, a tariff lowers the limit price while an equivalent quota raises it. Furthermore, when quotas are always binding, regardless of the incumbent's marginal cost, no limit pricing behaviour will be observed. On the other hand, the tariff always enhances signalling, until a prohibitive tariff deters entry entirely. We were able to show that a joint quota does have an equivalent tariff and that if the quota is very small, the tariff and quota will have an equivalent effect on the limit price. Thus, the results of Fung (1989) can be extended to equivalent firm strategies but only for a single restrictive case.

Secondly, we compared the effect of national and joint quotas on the limit price. We saw that quotas of similar sizes did not always have similar effects on the incumbents' first period strategies. If the incumbents did not engage in trade and if national quotas were of equal size, the limit price under a joint quota was found to be lower than under a national quota. However, if national quotas differ in size, this result may not always hold. Essentially, if the allocation of entrant output under a joint quota is greater than under a national quota, then the limit price will be lower under the former regime compared to the latter. This makes sense: the higher the entrant's output, the lower the incumbent's expected profits and hence the greater the incentive for a high cost firm to imitate the strategy of a low cost incumbent.

Consequently, the low cost firm must find a lower limit price in order to reveal its cost type. When we allowed for incumbent trade in the second period, limit pricing still existed as an equilibrium strategy with the national quota. However, under a joint quota scheme, no signalling would take place because the incumbents were unable to affect the equilibrium output of the entrant.

Thirdly, we turned to the analysis of welfare. We saw that first period welfare is concave while second period welfare is convex with respect to the quota. Quotas basically raise pre-entry prices in the separating equilibrium, lowering welfare. On the other hand, we found that second period welfare is optimised by either free trade or a complete embargo on imports. The former is the case when the entrant has a lower marginal cost than the incumbent. Its production in the market reduces the incumbent's profits but this is outweighed by gains in consumer surplus resulting from lower prices. In contrast, if the incumbent has a lower marginal cost than the entrant, then restricting the entrant's output further raises welfare: the loss in consumer surplus from higher prices is outweighed by the gains in the incumbent's profits. The comparison between national and joint quotas allows us to conclude two things: if prior beliefs differ, the joint quota raises total expected welfare; if national quotas differ, a joint quota lowers welfare. Differences in beliefs imply a difference in expected costs which means that the joint quota will lead to a better allocation of resources. Welfare may fall in one of the markets but the overall effect will be positive. On the other hand, if beliefs are the same for both markets, but national quotas differ, the reallocation of resources under the joint quota lowers welfare because the losses in one market do not compensate for the gains in the other market. This is because of the convex nature of the welfare function, reflecting the fact that removing the quota increases welfare at an increasing rate.

Trade policy attempts to enhance welfare in an economy. However, as it affects the strategies of all firms, there are also indirect effects on welfare. First period welfare is never enhanced by a quota whereas it is by a tariff. On the other hand, if a quota is to be imposed for political reasons, a joint quota will generally improve welfare. Second period welfare depends on the belief (cost) differences between the firms. Either a complete embargo or free trade yield the highest levels of welfare. However, if quotas are to be imposed, then as long as the differences in beliefs about costs are large and that the differences in national quotas are small, a joint quota may yield higher welfare levels. Furthermore, by considering the case where the entrant's marginal cost is smaller than that of the incumbent's, it might be possible to find an optimal quota which maximises two period welfare. Therefore, restricting the entrant's output leads to welfare losses in the first period (due to a higher limit price) which are balanced by the welfare gains in the second period.

Appendix

2.7.1 Second Period Incomplete Information Equilibria

No Quota, No Incumbent Trade

First, let us consider the case of no trade and no quota imposed on the entrant's output. A duopoly will result in both markets 1 and 2, so let us consider market 1, the home market of firm 1. In the second period, firm $1L$, firm $1H$ and firm 3 maximise,

$$\pi_{1L}^{1}\left(q_{1L}, q_3\left(\mu_1\right)\right) = \max_{q_{1L}^{1}}\left(a - c_L - q_{1L}^{1} - q_3^{1}\left(\mu_1\right)\right) q_{1L}^{1} \tag{2.56}$$

$$\pi_{1H}^{1}\left(q_{1H}, q_3\left(\mu_1\right)\right) = \max_{q_{1H}^{1}}\left(a - c_H - q_{1H}^{1} - q_3^{1}\left(\mu_1\right)\right) q_{1H}^{1} \tag{2.57}$$

and

$$\pi_3^{i}\left(q_{1\theta}, q_{2\theta}, q_3\left(\mu_1, \mu_2\right)\right) =$$

$$\max_{q_3^{m}}\left(a - c_3 - \left(\mu_i q_{iH}^{i} + \left(1 - \mu_i\right) q_{iL}^{i}\right) - q_3^{i}\right) q_3^{i} - F \tag{2.58}$$

for each market for $i \in \{1, 2\}$. The total profits of firm 3 will be

$$\Pi_3 = \pi_3^{1}\left(q_{1\theta}, q_{2\theta}, q_3\left(\mu_1, \mu_2\right)\right) + \pi_3^{2}\left(q_{1\theta}, q_{2\theta}, q_3\left(\mu_1, \mu_2\right)\right) \tag{2.59}$$

The first order conditions for $1L, 1H$,and 3 are thus,

$$\frac{\partial \pi_{1L}^{1}}{\partial q_{1L}^{1}} = a - c_L - 2q_{1L}^{1} - q_3^{1} = 0 \tag{2.60}$$

$$\frac{\partial \pi_{1H}^{1}}{\partial q_{1H}^{1}} a - c_H - 2q_{1H}^{1} - q_3^{1} = 0 \tag{2.61}$$

and

$$\frac{\partial \pi_3^1}{\partial q_3^1} = a - c_3 - \mu_1 q_{1H}^1 - (1-\mu_1) q_{1L}^1 - 2q_3^1 \leq 0 \tag{2.62}$$

respectively. The reaction functions of firm 1 and 3 are given by,

$$q_{1\theta}^{br} = \frac{a - c_\theta - q_3}{2} \tag{2.63}$$

and

$$q_3(\mu_1) = \frac{a - c_3 - \mu_1 q_{1H}^1 - (1-\mu_1) q_{1L}^1}{2} \tag{2.64}$$

respectively. Note that the entrant's output depends on its beliefs and firm 1. Whatever output the entrant produces the incumbent reacts along its reaction function. When all information is revealed, we will write the unrestricted complete information Cournot equilibrium output for firm 1 as simply $q_{1\theta}$. When outputs are written within a profit function which denotes the market where the profits are made, we discard the market qualification.

Solving, we get the unrestricted Cournot duopoly output in market 1 of firm $1L$,

$$q_{1L}^{br} = \left(\frac{2a + c_3 - \mu_1 c_H - (4-\mu_1) c_L}{6}\right) \tag{2.65}$$

of firm $1H$,

$$q_{1H}^{br} = \left(\frac{2a + c_3 - (1+\mu_1) c_H - (3-\mu_1) c_L}{6}\right) \tag{2.66}$$

and of firm 3:

$$q_3(\mu_1) = \frac{a - 2c_3 + \mu_1 c_H + (1-\mu_1) c_L}{3} \tag{2.67}$$

As the output of firm 3 is dependent on the beliefs that it holds about the incumbents' marginal costs, we write its output as a function of μ_1, the probability that firm 1 will have a high marginal cost. The expected profits of the entrant are,

$$\pi_3^1(q_{1\theta}, q_3(\mu_1)) = \left(\frac{a - 2c_3 + \mu_1 c_H + (1-\mu_1) c_L}{3}\right)^2 \tag{2.68}$$

for market 1. The duopoly profits of the incumbent are given by

$$\pi_{1\theta}^1\left(q_{1\theta}^{br}, q_3(\mu_1)\right) = \left(\frac{2a - 3c_\theta + 2c_3 - \mu_1 c_H - (1-\mu_1) c_L}{6}\right)^2 \tag{2.69}$$

where $\theta \in \{L, H\}$. We can see from the symmetry imposed that the duopoly profits of firms 2 and 3 in market 2 will depend on μ_2 in the same way as they do for market 1 for firms 1 and 3.

National Quota, No Incumbent Trade

When the quota is small enough so that the constraint is binding, the entrant produces the quota, $K^i$for each market, $i \in \{1,2\}$. From above, we can use the same maximisation process for firms 1 and 3. However, this time the quota is less than the entrant's Cournot output. As the entrant would like to produce as close to the Cournot output as possible, it will produce at the level of the quota, hence $q_3^i = K^i$. The entrant's post-entry profit is given by equation 2.58 by substituting q_3^1 for K^1 and q_{1H} and q_{1L} for their respective reaction functions, in equations 2.65 and 2.66. This yields,

$$\pi_3^1\left(q_{1\theta}^{br}, K^1\right) = \left(\frac{a - 2c_3 + \mu_1 c_H + (1-\mu_1)\,c_L - K^1}{2}\right) K^1 \tag{2.70}$$

for both markets 1 and 2.

The duopoly profit of the incumbent is simply $\left(q_{1\theta}^{br}\right)^2$, hence,

$$\pi_{1\theta}^1\left(q_{1\theta}^{br}, K^1\right) = \left(\frac{a - c_\theta - K^1}{2}\right)^2 \tag{2.71}$$

Similar profits can be calculated for firms 2 and 3 in market 2.

Immediately, we see that the duopoly profits of the entrant only depend on beliefs if the constraint is not binding. If the constraint is binding for all incumbent cost types, the entrant will just produce up to the constraint in the post-entry game. As we shall see later in the analysis of the separating equilibrium, sufficient conditions for limit pricing rely on the size of the quota imposed.

Joint Quota, No Incumbent Trade

When a joint constraint is imposed by both countries the entrant's output is dependent on the relative differences in the incumbents' marginal costs. The joint quota means that firm 3's total output in both markets 1 and 2 is restricted. In other words, $q_3^1 + q_3^2 = K$. Given this relationship, we can write $q_3^2 = K - q_3^1$ and substitute it out of the maximisation process. We can rewrite the entrant's maximisation over the two markets, presented in equation 2.59 as,

$$\Pi_3 = \max_{q_3^1} \pi_3^1\left(q_{1\theta}, q_{2\theta}, q_3^1\left(\mu_1, \mu_2\right)\right) + \pi_3^2\left(q_{1\theta}, q_{2\theta}, K - q_3^1\left(\mu_1, \mu_2\right)\right) \tag{2.72}$$

The first order conditions for the entrant under the joint quota are hence,

$$\begin{aligned}\frac{\partial \Pi_3}{\partial q_3^1} &= \left(a - c_3 - \mu_1 q_{1H}^1 - (1-\mu_1)\, q_{1L}^1 - 2q_3^1\right) \\ &\quad - \left(a - c_3 - \mu_2 q_{2H}^2 - (1-\mu_2)\, q_{2L}^2 - 2\left(K - q_3^1\right)\right) = 0 \quad (2.73)\end{aligned}$$

substituting in the first order conditions of the incumbents (from equation 2.60 and 2.61 and similarly for firm 2), we obtain the equilibrium allocation for firm 3 in market 1,

$$q_3^1(\mu_1,\mu_2) = \frac{(\mu_1-\mu_2)(c_H-c_L)+3K}{6} \quad (2.74)$$

and similarly for market 2,

$$q_3^2(\mu_1,\mu_2) = \frac{(\mu_2-\mu_1)(c_H-c_L)+3K}{6} \quad (2.75)$$

Equation 2.74 is the same as 2.9 defined in the text. If beliefs are the same for each market (i.e. $\mu_1 = \mu_2$), then the entrant divides its output equally between the two. However, if $\mu_1 > \mu_2$ then the entrant will allocate more output to 1.

When the entrant's output binds to the constraint, firm 1's output is,

$$q_{1\theta}^1(\mu_1,\mu_2) = \left(\frac{6a - 6c_\theta - (\mu_1-\mu_2)(c_H-c_L) - 3K}{12}\right) \quad (2.76)$$

and similarly for firm 2 in market 2. Again, when the constraint does not hold, we have the unrestricted Cournot output exactly as in the previous case i.e. for firm 1 in market 1, equilibrium output would be $q_{1\theta}(\mu_1)$.

The profit of firm 3 is therefore found by substituting all the equilibrium values into,

$$\begin{aligned}\pi_3^1\left(q_{1\theta}^{br}, q_3^1(\mu_1,\mu_2)\right) &= \left[\frac{(\mu_1-\mu_2)(c_H-c_L)+3K}{6}\right] \\ &\times \left[\frac{6(a-2c_3+c_L)+(c_H-c_L)(5\mu_1+\mu_2)-3K}{12}\right]\end{aligned} \quad (2.77)$$

when $q_3^1 + q_3^B = K$. Similarly, firm 1 earns,

$$\pi_{1\theta}^1\left(q_{1\theta}^{br}, q_3(\mu_1,\rho_2)\right) = \left(\frac{6a - 6c_\theta - (\mu_1-\rho_2)(c_H-c_L) - 3K}{12}\right)^2 \quad (2.78)$$

Note that firm 1 uses ρ_2 instead of μ_2 in estimating the entrant's output allocation in the second period. This is because firm 1 knows what it will signal (that is its decision) but it does not know what firm 2 in market 2 will signal, regardless of whether 1 knows 2's true cost type. Of course, as we have no pooling equilibria and both incumbents know exactly what the other is likely to do, then we could in fact use μ_2 because, for example, a low cost firm will separate in the first period. Nevertheless, in other to keep things a little more general in the sense that the incumbents may not know exactly the strategy of the other, we shall use ρ_2 as 1's signal to the entrant. This changes little in the analysis.

No Quota, Incumbent Trade

When the incumbents trade, the second period complete information equilibrium will be characterised by a tripoly in both markets. Again firm $1L$, firm $1H$ and firm 3 maximise,

$$\pi_{1L}^1(q_{1L}, q_{2L}, q_3(\mu_1)) = \max_{q_{1L}^1}\left(a - c_L - q_{1L}^1 - q_{2L}^1 - q_3^1\right) q_{1L}^1 \quad (2.79a)$$

$$\pi_{1H}^1(q_{1H}, q_{2L}, q_3(\mu_1)) = \max_{q_{1H}^1}\left(a - c_H - q_{1H}^1 - q_{2L}^1 - q_3^1\right) q_{1H}^1 \quad (2.79b)$$

$$\pi_{1L}^1(q_{1H}, q_{2L}, q_3(\mu_2)) = \max_{q_{2L}^1}\left(a - c_\theta - q_{1H}^1 - 2q_{2L}^1 - q_3^1\right) q_{2L}^1 \quad (2.79c)$$

$$\pi_{1H}^1(q_{1H}, q_{2H}, q_3(\mu_1)) = \max_{q_{2H}^1}\left(a - c_\theta - q_{1H}^1 - 2q_{2H}^1 - q_3^1\right) q_{2H}^1 \quad (2.79d)$$

and

$$\Pi_3^*(q_1^m, q_2^m, q_3^m) = \max_{q_3^{i=1,2}} (a - c_e - (\mu_1 q_{1H}^1 + (1-\mu_1) q_{1L}^1) q_3^1 - (\mu_2 q_{2H}^2 + (1-\mu_2) q_{2L}^2) - q_3^2) q_3^2 - F \quad (2.80)$$

First, we consider the case where there is no constraint. The first order conditions for 1, 2 and 3 are thus,

$$\frac{\partial \pi_{1L}^1(q_{1L}, q_{2L}, q_3(\mu_1))}{\partial q_{1L}^1} = a - c_L - q_{1L}^1 - 2q_{2L}^1 - q_3^1 = 0 \quad (2.81a)$$

$$\frac{\partial \pi_{1H}^1(q_{1H}, q_{2L}, q_3(\mu_1))}{\partial q_{1HL}^1} = a - c_H - q_{1H}^1 - 2q_{2L}^1 - q_3^1 = 0 \quad (2.81b)$$

$$\frac{\partial \pi_{1L}^1(q_{1H}, q_{2L}, q_3(\mu_2))}{\partial q_{1LH}^1} = a - c_H - q_{1H}^1 - 2q_{2L}^1 - q_3^1 = 0 \quad (2.81c)$$

$$\frac{\partial \pi_{1H}^1(q_{1H}, q_{2H}, q_3(\mu_1))}{\partial q_{1HH}^1} = a - c_H - q_{1H}^1 - 2q_{2H}^1 - q_3^1 = 0 \quad (2.81d)$$

for all types of firm 1and,

$$\begin{aligned}\frac{\partial \pi_3^1}{\partial q_3^1} &= a - c_3 - \mu_1\mu_2\left(q_{1HH}^1 + q_{2HH}^1\right) - \mu_1(1-\mu_2)\left(q_{1HL}^1 + q_{2LH}^1\right) \\ &\quad -(1-\mu_1)\mu_2\left(q_{1LH}^1 + q_{2HL}^1\right) - \\ &\quad (1-\mu_1)(1-\mu_2)\left(q_{1LL}^1 + q_{2LL}^1\right) - 2q_3^1 = 0 \end{aligned} \tag{2.82}$$

for firm 3. These can be solved simultaneously to yield the following equilibrium outputs,

$$\begin{pmatrix} q_{1LL}^1 \\ q_{1HL}^1 \\ q_{1LH}^1 \\ q_{1HH}^1 \\ q_{2LL}^1 \\ q_{2LH}^1 \\ q_{2HL}^1 \\ q_{2HH}^1 \\ q_3^1 \end{pmatrix} = \begin{pmatrix} \frac{1}{12}(3(a+c_3) - \mu_2(c_H - c_L) - \mu_1 c_H) - \frac{1}{2}c_L \\ \frac{1}{12}(3(a+c_3) - \mu_2(c_H - c_L) - \mu_1 c_H) + \frac{1}{6}c_L - \frac{2}{3}c_H \\ \frac{1}{12}(3(a+c_3) - \mu_2(c_H - c_L) - \mu_1 c_H) - \frac{5}{6}c_L + \frac{1}{3}c_H \\ \frac{1}{12}(3(a+c_3) - \mu_2(c_H - c_L) - \mu_1 c_H) - \frac{1}{6}c_L - \frac{1}{3}c_H \\ \frac{1}{12}(3(a+c_3) - \mu_2(c_H - c_L) - \mu_1 c_H) - \frac{1}{2}c_L \\ \frac{1}{12}(3(a+c_3) - \mu_2(c_H - c_L) - \mu_1 c_H) - \frac{5}{6}c_L + \frac{1}{3}c_H \\ \frac{1}{12}(3(a+c_3) - \mu_2(c_H - c_L) - \mu_1 c_H) + \frac{1}{6}c_L - \frac{2}{3}c_H \\ \frac{1}{12}(3(a+c_3) - \mu_2(c_H - c_L) - \mu_1 c_H) - \frac{1}{6}c_L - \frac{1}{3}c_H \\ \frac{1}{4}(a - 3c_3 + (\mu_1 + \mu_2)(c_H - c_L + 2c_L)) \end{pmatrix} \tag{2.83}$$

Note that in order to save space, we add a second subscript to the output of the incumbents. For example, (i) q_{1LL}^1 is the Cournot output of firm 1 in market 1 when firm 2 has a low marginal cost; (ii) q_{2HL}^1 is the output of a high cost firm 2 in market 1 when firm 1 has a low marginal cost.

The equilibrium profits for the entrant and the incumbents are found by substituting the equilibrium outputs into the objective functions for each type. Therefore, the equilibrium profits of the different types of firm 1 are

$$\pi_{1LL}^1 = \frac{1}{144}(3c_3 + 3a + \mu_2 c_L + \mu_1 c_L - \mu_1 c_H - \mu_2 c_H - 6c_L)^2 \tag{2.84}$$

$$\pi_{1HL}^1 = \frac{1}{144}(3c_3 + 3a + \mu_2 c_L + \mu_1 c_L - \mu_1 c_H - \mu_2 c_H + 2c_L - 8c_H)^2 \tag{2.85}$$

$$\pi_{1LH}^1 = \frac{1}{144}(3c_3 + 3a + \mu_2 c_L + \mu_1 c_L - \mu_1 c_H - \mu_2 c_H + 4c_H - 10c_L)^2 \tag{2.86}$$

$$\pi_{1HH}^1 = \frac{1}{144}(3c_3 + 3a + \mu_2 c_L + \mu_1 c_L - \mu_1 c_H - \mu_2 c_H - 2c_L - 4c_H)^2 \tag{2.87}$$

Due to the symmetry of the model, firm 2 will enjoy the same profits in its home market. Furthermore, as there is no cost of entry for the incumbents, their profits in the foreign market will be the same as their home profits, hence $\pi^1_{1\theta\theta'} = \pi^2_{1\theta\theta'}$ where $\theta, \theta' \in \{H, L\}$. Notice that these profits are in fact, best response profits to firm 3's output.

National Quota, Incumbent Trade

If a national quota is imposed by country 1, then firms 2 and 3 will be obliged to restrict their output. If the quota is set at K^1 then the output of both 2 and 3 in this market will be K^1. This simplifies somewhat the calculations for equilibrium. Using the profit functions displayed in equations 2.79, firm 1 of type θ can expected to earn:

$$\pi^i_{1\theta\theta'}\left(q_{1\theta\theta'}, q^i_{2\theta\theta'}, K^i\right) = \max_{q_1^m}\left(a - c_\theta - q^i_{1\theta\theta'} - q^i_{2\theta\theta'} - K^i\right) q^i_{1\theta\theta'} \tag{2.88}$$

for $i \in \{1,2\}$. Similarly for firm 2 in market 1. Using the first order conditions for the incumbents from the previous section, we get the reaction functions,

$$q^{br}_{i\theta\theta'}\left(q^i_{j\theta'\theta}, K^i\right) = \frac{a - c_\theta - q^i_{j\theta'\theta} - K^i}{2} \tag{2.89}$$

for $i, j \in \{1,2\}$, $i \neq j$, and $\theta, \theta' \in \{H, L\}$. Solve this for firms 1 and 2 to obtain,

$$q^{br}_{i\theta\theta'}\left(K^i\right) = \frac{a - 2c_\theta + c_{\theta'} - K^i}{3} \tag{2.90}$$

which yields profits,

$$\pi^1_{1\theta\theta'}\left(q^{br}_{1\theta\theta'}, q^{br}_{2\theta'\theta}, K^1\right) = \left(\frac{a - 2c_\theta + c_{\theta'} - K^i}{3}\right)^2 \tag{2.91}$$

Joint Quota, Incumbent Trade

When a joint quota is imposed, it is would be natural to assume that there exists free trade between the incumbents. Therefore, the incumbents can produce up to their Cournot equilibrium outputs. However, firm 3 is not part of the trade agreement and therefore must decide on where to allocate its output optimally. The optimisation of the entrant is

$$\Pi_3 = \max_{q_3^{i=1,2}} \left(a - c_3 - \left(\mu_1 q_{1H}^1 + (1-\mu_1)\, q_{1L}^1\right) - \left(\mu_2 q_{2H}^1 + (1-\mu_2)\, q_{2L}^1\right) - q_3^1\right) q_3^1 + \left(a - c_3 - \left(\mu_1 q_{1H}^B + (1-\mu_1)\, q_{1L}^2\right) - \left(\mu_2 q_{2H}^2 + (1-\mu_2)\, q_{2L}^2\right) - q_3^2\right) q_3^2 - F \tag{2.92}$$

subject to

$$K = q_3^1 + q_3^2 \tag{2.93}$$

Substitute the constraint into the objective function to remove q_3^2 (i.e. $q_3^2 = K - q_3^1$) and differentiate to get the first order conditions.

$$a - c_3 - \left(\mu_1 q_{1H}^1 + (1-\mu_1)\, q_{1L}^1\right) - \left(\mu_2 q_{2H}^1 + (1-\mu_2)\, q_{2L}^1\right) - 2q_3^1 = a - c_3 - \left(\mu_1 q_{1H}^2 + (1-\mu_1)\, q_{1L}^2\right) - \left(\mu_2 q_{2H}^2 + (1-\mu_2)\, q_{2L}^2\right) - 2\left(K - q_3^1\right) \tag{2.94}$$

Remember that the incumbents are identical in the sense that $q_{1H}^1 = q_{1H}^2 = q_{2H}^2 = q_{2H}^1$ and similarly for low cost firms 1 and 2. Therefore, cancelling on both sides reduces to,

$$q_3^1 = K/2 \tag{2.95}$$

This is because on entry, the entrant expects each market to be occupied by an incumbent 1 of cost type c_θ and an incumbent 2 of cost type c_θ, for $\theta \in \{L, H\}$. Therefore, whatever market it enters, the residual demand will be the same and so the entrant divides its constrained output equally between the two markets. This result is quite different to the no-trade model where the cost type of the incumbents affects the entrant's output allocation to each market. When the entrant produces $K/2$ in each market, the incumbent earns,

$$\pi_{i\theta\theta'}^J (K/2) = \left(\frac{a - c_\theta - K/2}{3}\right)^2 \tag{2.96}$$

2.7.2 Proofs

Proof for Lemma 2.1: Considering the case of limit pricing (i.e. strategies where $\hat{q}_1 > q_{1L}$) the single crossing condition (Spence 1974) shows that it is more costly for a high cost firm to increase its output than it is for a low cost firm. Essentially, this requires that the slope of the low cost incumbent's profit when producing above the monopoly output is greater (less negative) than that of the high cost firm.

Show that $\pi_{1L}-\pi_{1L}(\hat{q}_1)<\pi_{1H}-\pi_{1H}(\hat{q}_1)$ for $\hat{q}_1>q_{1L}$. Monopoly profits are given by $\pi_{1L}=\max(a-c_\theta-q_{1\theta})\,q_{1\theta}$ which yields equilibrium output $q_{1\theta}=(a-c_\theta)/2$ and profit $\pi_{1\theta}=(a-c_\theta)^2/4$. Therefore,

$$\pi_{1L}-\pi_{1L}(\hat{q}_1)<\pi_{1H}-\pi_{1H}(\hat{q}_1) \tag{2.97}$$

yields,

$$\left(\frac{a-c_L}{2}\right)^2-(a-c_L-\hat{q}_1)\,\hat{q}_1<\left(\frac{a-c_H}{2}\right)^2-(a-c_H-\hat{q}_1)\,\hat{q}_1 \tag{2.98}$$

and rearranging gives us,

$$\frac{1}{4}(c_H-c_L)(2a-c_H-c_L-4q_1)<0 \tag{2.99}$$

for $(2a-c_H-c_L)/4\equiv(q_{1L}+q_{1H})/2<\hat{q}_1$. Therefore, a sufficient condition is that $\hat{q}_1>q_{1L}$. ■

Proof for Proposition 2.1:

National Quotas We need to show that an incumbent $1L$, can find an output that sustains the inequalities expressed in equations 2.28 and 2.29. Denote $\bar{q}_1^N$ and $\underline{q}_1^N$ as the outputs that solve equations 2.28 and 2.29 for equality, respectively. If $\underline{q}_1^N<\bar{q}_1^N$ then we can find some $\hat{q}_1^N\in\left[\underline{q}_1^N,\bar{q}_1^N\right]$ for which the incentive constraints hold. The solutions for $\underline{q}_1^N$ and $\bar{q}_1^N$ are:

$$\bar{q}_1^N=\frac{a-c_L}{2}+\sqrt{\delta\left[\pi_{1L}^1(q_{1L},q_3(0))-\pi_{iL}^1\left(q_{1L}^{br},K^1\right)\right]} \tag{2.100}$$

and

$$\underline{q}_1^N=\frac{a-c_H}{2}+\sqrt{\delta\left[\pi_{1H}^1\left(q_{1H}^{br},q_3(0)\right)-\pi_{iH}^1\left(q_{1H}^{br},K^1\right)\right]}. \tag{2.101}$$

it is sufficient to show that

$$\pi_{1L}^1(q_{1L},q_3(0))-\pi_{iL}^1\left(q_{1L}^{br},K^1\right)\geq\pi_{iH}^1\left(q_{1H}^{br},q_3(0)\right)-\pi_{iH}^1\left(q_{1H}^{br},K^1\right) \tag{2.102}$$

to complete the proof. By substituting in the parameter values we can write:

$$\left(\frac{a-c_L-k_i(0)}{2}\right)^2-\left(\frac{a-c_L-k_i(1)}{2}\right)^2 \geq \left(\frac{a-c_H-k_i(0)}{2}\right)^2-\left(\frac{a-c_H-k_i(1)}{2}\right)^2 \tag{2.103}$$

which reduces to $c_H > c_L$. Therefore, $\underline{q}_1^N < \bar{q}_1^N$ which implies a limit price can be found.

Proof for Proposition 2.2:

Joint Quota For the joint quota, we need to find $\bar{q}_1^J$ and $\underline{q}_1^J$. First, when the constraint does not bind when the low cost firm signals, we must solve equations 2.15 and 2.17 for equality, respectively. Similarly, the solutions are:

$$\bar{q}_1^J = \frac{a-c_L}{2} + \sqrt{\delta\left[\pi_{1L}^1\left(q_{1L}, q_3(0)\right) - \pi_{1L}^1\left(q_{1L}^{br}, q_3(1,\rho)\right)\right]} \tag{2.104}$$

and

$$\underline{q}_1^J = \frac{a-c_H}{2} + \sqrt{\delta\left[\pi_{1H}^1\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^1\left(q_{1H}^{br}, q_3(1,\rho_2)\right)\right]}. \tag{2.105}$$

Again, it is sufficient to show that

$$\pi_{1L}^1\left(q_{1L}, q_3(0)\right) - \pi_{1L}^1\left(q_{1L}^{br}, q_3(1,\rho_2)\right) \geq \pi_{1H}^1\left(q_{1H}^{br}, q_3(0)\right) - \pi_{1H}^1\left(q_{1H}^{br}, q_3(1,\rho_2)\right). \tag{2.106}$$

As above, this reduces to $c_H > c_L$. Secondly, assume the constraint is always binding. We need to solve equations 2.16 and 2.18 for equality, respectively. The solutions are:

$$\bar{q}_1^{JJ} = \frac{a-c_L}{2} + \sqrt{\delta\left[\pi_{1L}^1\left(q_{1L}^{br}, q_3(0,\rho_2)\right) - \pi_{1L}^1\left(q_{1L}^{br}, q_3(1,\rho_2)\right)\right]} \tag{2.107}$$

and

$$\underline{q}_1^{JJ} = \frac{a-c_H}{2} + \sqrt{\delta\left[\pi_{1H}^1\left(q_{1H}^{br}, q_3(0,\rho_2)\right) - \pi_{1H}^1\left(q_{1H}^{br}, q_3(1,\rho_2)\right)\right]} \tag{2.108}$$

Again, it is sufficient to show that

$$\pi_{1L}^1\left(q_{1L}^{br}, q_3(0,\rho_2)\right) - \pi_{1L}^1\left(q_{1L}^{br}, q_3(1,\rho_2)\right) \geq \pi_{1H}^1\left(q_{1H}^{br}, q_3(0,\rho_2)\right) - \pi_{1H}^1\left(q_{1H}^{br}, q_3(1,\rho_2)\right). \tag{2.109}$$

which reduces to $c_H > c_L$, which concludes the proof. ■

Chapter 3

The Mode of Entry

3.1 Introduction

The switch from exporting to foreign direct investment (FDI) and its welfare effects have long been a point of interest for international economists. Recent work (Smith 1987, Motta 1992, Horstmann and Markusen 1987,1991) has emphasized the game-theoretic nature of the investment decision, illustrating the strategic importance of trade policy. However, despite the oligopolistic modeling of these papers, little has been said about the strategic role of the domestic producer. It is common in Industrial Organisation to model incumbent firms with some kind of entry deterrence capability (e.g. Spence 1977, Dixit 1980 consider capacity as an entry deterring variable). It would seem reasonable to believe that the potential entrants considered in these industrial economics papers may well be multinational enterprises which have a choice of entering the market via exporting or FDI. Thus, it is the aim of this chapter to bring together two areas of research, namely strategic investment models and multinational investment models, and to show their effects on trade policy.

From the former we consider the well-known limit pricing model of Milgrom and Roberts (1982). They show how uncertainty over certain parameters can be exploited by a fully informed firm in order to deter market entry. From the latter we consider the Smith-Motta model of a tariff-jumping multinational enterprise (Smith 1987, Motta 1991). Both show that no simple relationship exists between the cost variables and the exporting-FDI choice.

This chapter has several important findings. First, with uncertainty, a domestic producer can determine the mode of entry of a multinational entrant. Secondly, pre-entry prices may be lower with uncertainty than with complete information. Third, tariffs influence the entry mode directly and through their impact on the incumbent's behaviour.

3.1.1 Literature

Let us first consider the relevant material on exporting and FDI before turning to the strategic capabilities of the incumbent. The literature on the switch between exporting and FDI begins with Vernon (1966) who modeled FDI as part of the product life cycle. However, Hymer (1976) suggests that multinationals possess some intangible asset which is best exploited by retaining this advantage within the organisation. Dunning (1977, 1980) extends this to include two other factors: localisation and internalisation advantages, which he calls the eclectic paradigm. Dunning's intangible asset hypothesis has subsequently been modeled as a form of sunk cost, an asset already in the possession of the multinational (Helpman 1984, Markusen 1984).

Cost advantages and market size were specifically modeled by Buckley and Casson (1981). They used the idea of growing demand as a means to illustrate the switch from exporting to FDI. Exporting represents a low fixed cost but high production costs (i.e. cost of transportation, tariffs etc.). FDI, on the other hand, avoids these extra running costs by producing in the target market. However, the construction of a new plant with the added cost of setting up in a foreign country (Hirsch 1976) involves a relatively higher fixed cost. Buckley and Casson argue that when demand is small, profits are low and thus FDI may not be able to cover its investment costs. However, as demand grows, expected profits under FDI grow faster than those under exporting and hence at some point, a switch takes place.

Nevertheless, it was Smith (1987) and Motta (1992) who first modeled the entry mode decision in a game-theoretic setting. They considered two firms: a potential host country producer and a foreign multinational. Both firms have the choice of entering or not entering the home market while the multinational has the added possibility of entering via exporting or FDI. The results are quite extraordinary. Whereas a tariff may induce FDI, its removal may have the same effect! Essentially a tariff raises the profits of the host country producer so we might obtain an equilibrium where both firms enter the market (the multinational via exporting). Removing the tariff lowers the host country producer's profits, perhaps to the extent that it can no longer produce profitably in the market. It exits (or in fact, never enters) and the multinational is now a monopolist. However, due to the increase the multinational's market share, it prefers to invest directly in the host country (similar to Buckley and Casson's argument that as the market size grows, FDI becomes more profitable). Needless to say, such results have important implications for trade policy.

However, the results obtained by Smith (1987) and Motta (1992) are based on two *potential* producers, both considering entry into a market. (Motta does consider a sequential version of the game although the strategy of the host country producer is still limited: either enter or not enter.) It might seem more reasonable to consider the case of a host country incumbent facing a multinational entrant. This allows us to explore the strategic investment capabilities of the incumbent *vis-à-vis* the entry mode decision of the entrant, so far unexplored in the literature.

We must ask ourselves two questions. First, what is the best outcome for the incumbent: exporting or foreign direct investment, and secondly, how might the incumbent influence the multinational's decision? If we consider the two firms as Cournot output-setters, then it is easy to show that a firm's profit is increasing in its rival's marginal cost (see Tirole 1988). Given the higher marginal cost of exporting (transport costs, tariffs etc.), it is clear that an incumbent would prefer to face an exporter.

Of course, in order to answer the second question, we need to know under what conditions the multinational will choose exporting over FDI (and *vice-versa*). The driving force behind Motta (1992), Smith (1987) and Buckley and Casson (1981) is market share. The larger the market share, the more likely a firm will choose FDI in order to exploit economies of scale. Empirical papers, notably Pain (1993) and Cushman (1985) have found a significant link between market size and FDI. Given this evidence, and the commonly assumed notion that the domestic firm knows its home market better than the multinational (Hirsch 1976) it seems reasonable to model the export-FDI decision as a game of incomplete information (Harsanyi 1967–8).

This scenario is common in entry deterring models of limit pricing where the entrant is uncertain of its post-entry profits, namely Milgrom and Roberts (1982). Nevertheless, these models are limited because they do not consider the mode of entry of the entrant. In this paper, we combine the informational asymmetries of the limit pricing models with the multinational entry models associated with foreign direct investment (FDI) and exporting. In order to generalise the model to large and small production processes, we consider two types of entry technology, one of low fixed cost and high marginal cost (exporting) and the other of high fixed cost and low marginal cost (FDI).

Government policy through the use of tariffs may have considerable effects on the strategic behaviour of the incumbent. The research on the effect of tariffs has been extensive. Welfare gains to domestic countries resulting from tariffs have been shown to exist for domestic countries when demand is either linear (Katrak 1977 and Svedberg 1979) or non-linear (Meza 1979 and Brander and Spencer 1984). However, the introduction of incomplete information to these optimal tariff models is scarce (see Collie and Hviid 1994). A key article in this analysis is that of Levy and Nolan (1992). They show the welfare effects that result from tariffs when the incumbent and entrant have different marginal costs. Their results showed that tariffs may lead to higher or lower welfare, depending on the relative size of the entrant's marginal cost, *vis-à-vis* the incumbent's marginal cost. As we shall see, this plays an important role in the limit pricing model.

Having discussed the entrant's motivations regarding entry, we should now turn to the incumbent's strategic capabilities. We propose to show that the limit price may be used by the incumbent to signal information about its cost and hence influence the mode of entry. As we discussed in Chapter 1, limit pricing conveys the idea that current prices might signal future profitability. Moreover, Milgrom and Roberts (1982) formalised this idea showing that the pre-entry price can be used to signal the expected size of future demand. If demand (residual demand in an oligopoly) is expected to be small, then expected future profits are small and hence entry might be deterred. If residual demand is expected to be large (and hence high expected profits) then entry might take place. It is straightforward to see the possible link between limit pricing and the entry mode. A small residual demand would mean a lower equilibrium output for the entrant, and exporting would be more profitable; a large residual demand would mean a higher equilibrium output for the entrant and hence FDI would be the more profitable strategy.

However, we must be sure that the motivations for signalling are intact. Entry deterrence clearly leaves the incumbent with higher second period profits. In order for signalling to occur in the entry mode model we must be sure that incentives exist. However, we should note that under exporting the entrant's marginal cost is higher (due to transportation and possible tariffs) implying higher market prices. This will clearly benefit the domestic producer. Thus, the simple assumptions made by Buckley and Casson (1981) regarding the cost function under exporting and FDI suggest that the former yields greater incumbent profits than the latter. Under these circumstances, if there is uncertainty regarding the incumbent's marginal cost (which seems particularly reasonable for a *foreign* potential entrant), then there may well be conditions under which the incumbent finds it profitable to engage in limit pricing behaviour in order to influence the entry mode decision. As we shall see, this may indeed be the case.

In Section 3.2 we define a signalling model showing the conditions where signalling emerges as an equilibrium strategy. Section 3.3 demonstrates that limit pricing may influence the mode of entry. In Section 3.4 we show the existence of a pooling equilibrium where a high cost firm is able to deter FDI by imitating the strategy of the low cost firm. Then in Section 3.5 we look at the effects of a tariff on the limit price. Section 3.6 is concerned with the welfare aspects of the model and in Section 3.7 we indicate an alternative interpretation. Finally, Section 3.8 concludes.

3.2 The Model

Let us consider a model where there is an incumbent monopolist (the host-country's domestic producer) denoted firm 1 and a single potential entrant (the multinational), firm 2, which has a protected home market. We assume that the goods produced are perfect and strategic substitutes. Assume an inverse linear demand function $p(Q) = a - Q$ where $Q = q_1 + q_2, (q_1 > 0, q_2 \geq 0)$. The entrant has the choice of two production technologies, exporting and FDI. The plant cost X is assumed the same for both modes of production, with the difference that FDI incurs an extra sunk learning cost, Δ (Motta 1992). The total fixed cost of FDI is thus given by $Z = X + \Delta$.

The marginal cost of operating a plant is given by c_X. However, exporting incurs greater variable costs than FDI because of transportation, $s > 0$ and tariffs $t \geq 0$. Therefore, the marginal cost of exporting is given by $c_X = c_Z + s + t$. Our aim is to show that for certain equilibria, exporting is preferred to FDI and *vice-versa*. Let us show that for some range of $q_2 \in [0, \tilde{q}]$ exporting is less costly than FDI and for $q_2 > \tilde{q}$, strictly more costly.

The cost function of firm 2 under exporting and FDI is given by $C(q_2, X) = (c_Z + s + t) q_2 + X$ and $C(q_2, Z) = c_Z q_2 + X + \Delta$, respectively. When $q_2 = 0$, $C(0, X) > C(0, Z)$. As we increase q_2, the cost functions will eventually cross at $q_2 = \tilde{q} \equiv \Delta/(s+t)$. For $q_2 > \tilde{q}$ FDI is the least costly entry mode. A similar result can be obtained for general convex cost functions (see Mailath 1989). This is essentially the argument that Buckley and Casson (1981) used to indicate the switch from exporting to FDI. However, we need to develop the arguments a little further for our oligopolistic model. Nevertheless, it is clear that if the entrant's Cournot equilibrium output is high $(q_2 > \tilde{q})$, the entrant's total cost is lowest if it enters via FDI. On the other hand, if the entrant's Cournot equilibrium output is low $(q_2 < \tilde{q})$, then exporting yields the lowest total cost. To summarize, the cost function of the multinational can be given by $C(q_2, T) = c_T q_2 + T$ where $c_T \in \{c_X, c_Z\}$ and $T \in \{X, Z\}$ represent its marginal and fixed costs, respectively.

Of course, in a duopoly the size of the equilibrium output of firm 2 depends on the equilibrium output of firm 1. Although firm 2 has a choice over the type of technology it will choose when it enters the market, firm 1 does not. Indeed, firm 1's equilibrium output falls as its own marginal cost rises. Therefore, if the marginal cost of firm 1 is relatively high, then its equilibrium output will be relatively small. Therefore, the residual demand facing firm 2 will be relatively high. If the residual demand is high, firm 2 expects a high equilibrium output if it enters. Therefore, it selects technology Z because this gives it the highest profits when the equilibrium output is high.

Let us be a little more precise about the cost function of firm 1. As an incumbent firm, we assume that firm 1 has already covered its fixed set-up costs. Assume that the marginal costs c_θ of firm 1are also constant where $c_\theta \in \{c_L, c_H\}$, $c_H > c_L$. For simplicity, we shall often refer to a high cost incumbent as $1H$ (and similarly $1L$ for low cost type). Let us consider the second period equilibrium. It is a fairly standard result that the entrant's Cournot equilibrium output rises with the incumbent's marginal cost. Therefore, a high cost incumbent implies a high equilibrium output and *vice-versa* for a low cost incumbent. We need to show that this could be sufficient to influence the entrant's choice of entry technology.

However, the entrant does not know the incumbent's marginal cost. In the first period, the incumbent can select some output that is observed by the entrant. Having observed this output, the entrant then decides on how to enter the market. We assume that entry is always feasible, whatever the incumbent's cost type. Denote $\rho \in [0,1]$ as the prior probability that the incumbent has a high cost and $(1-\rho) \in [0,1]$ as the prior probability that the incumbent has a low cost. Posterior beliefs which are up-dated using Bayes' rule are denoted similarly by $\mu \in [0,1]$ and $(1-\mu) \in [0,1]$. The decision by the entrant to export can be expressed by $E : (0,Q) \rightarrow \{0,1\}$ where $E = 1$ signifies that the entrant will export into the market and $E = 0$ implies FDI. This states that the entrant's entry mode is dependent on the incumbent's pre-entry output which allows the entrant to infer the incumbent's cost type (at least in the separating equilibrium).

Notation	
$\theta \in \{H, L\}$	cost types of the incumbent
$T \in \{X, Z\}$	Fixed costs of the entrant
c_θ, c_T	incumbent and entrant marginal costs
ρ, μ	prior and posterior probabilities that incumbent is high cost
$q_{1\theta}$	monopoly output of incumbent 1θ
$\hat{q}_1$	first period output of incumbent
$\pi_{1\theta}$	monopoly profit of incumbent 1θ
$\pi_{1\theta}(\mu, c_2)$	second period duopoly profit of incumbent $1\theta'$
$\pi_2(\mu, c_2)$	second period expected duopoly profit of entrant
$\bar{\Delta}$	upper bound of $Z - X$
$\underline{\Delta}$	lower bound of $Z - X$

Table 3.1: Notation

3.2.1 Second Period Profits

Before we can look at the signalling game in the first period, we need to know the second period profits for all the firms. In the second period, both firms compete as Cournot output setters (remember, entry is never deterred). An incumbent of cost type $\theta \in \{H, L\}$ can be denoted 1θ. It's equilibrium profits are given by,

$$\pi_{1\theta}(\mu, c_T) = \max_{q_1}(a - c_\theta - q_1 - q_2)\, q_1 \tag{3.1}$$

Note that the incumbent's second period profits are dependent on its own marginal cost, c_θ, the entrant's beliefs about its marginal cost, μ, and the marginal cost of the entrant, c_2.

The entrant (multinational) on the other hand, maximises expected profits. In other words, the entrant does not learn the true cost type of the incumbent on entering the market: beliefs determine the profit maximising output. Therefore, the entrant's equilibrium expected profits are given by,

$$\pi_2(\mu, c_T) = \max_{q_2}(a - c_T - q_2 - \mu q_{1H} - (1 - \mu)\, q_{1L})\, q_2 - T \tag{3.2}$$

The difference is that we do not include the actual cost type of the incumbent in the entrant's expected profits. Moreover, we are not concerned with the entrant's actual profits as expected profits determine the entry mode decision. Further, note that we do not write explicitly the fixed cost T of the entrant in its profit function: this is implied by c_T. The first order conditions for firms 1θ and 2 are,

$$\frac{\partial \pi_{1\theta}(\mu, c_T)}{\partial q_1} = a - c_\theta - 2q_1 - q_2 = 0 \tag{3.3}$$

$$\frac{\partial \pi_2(\mu, c_T)}{\partial q_2} = a - c_T - 2q_2 - \mu q_{1H} - (1-\mu) q_{1L} = 0 \tag{3.4}$$

We can rewrite the first order conditions as,

$$\begin{pmatrix} a - c_L \\ a - c_H \\ a - c_T \end{pmatrix} = \begin{pmatrix} 2 & 0 & 1 \\ 0 & 2 & 1 \\ 1-\mu & \mu & 2 \end{pmatrix} \begin{pmatrix} q_{1L} \\ q_{1H} \\ q_{2T} \end{pmatrix} \tag{3.5}$$

(remember, there are two types of incumbent 1θ) which yields the following equilibrium outputs,

$$q_{1L} = \frac{2a + 2c_T - \mu c_H - c_L(4-\mu)}{6} \tag{3.6}$$

$$q_{1H} = \frac{2a + 2c_T - c_L(1-\mu) - c_H(3+\mu)}{6} \tag{3.7}$$

$$q_2 = \frac{a - 2c_T + \mu c_H + (1-\mu) c_L}{3} \tag{3.8}$$

The equilibrium profits follow,

$$\pi_{1L}(\mu, c_T) = \left(\frac{2a + 2c_2 - \mu c_H - c_L(4-\mu)}{6}\right)^2 \tag{3.9}$$

$$\pi_{1H}(\mu, c_T) = \left(\frac{2a + 2c_2 - c_L(1-\mu) - c_H(3+\mu)}{6}\right)^2 \tag{3.10}$$

$$\pi_2(\mu, c_T) = \left(\frac{a - 2c_2 + \mu c_H + (1-\mu) c_L}{3}\right)^2 - T \tag{3.11}$$

Note that the equilibrium profits are simply the square of the equilibrium outputs.[1]

We need to show under what conditions the entrant will prefer to use technology X or Z. If $\pi_2(\mu, c_X) > \pi_2(\mu, c_Z)$ then firm 1 will enter the market via technology

[1] Of course, this is only true for the entrant if we ignore the fixed entry cost T.

X. However, if the opposite is the case, then technology Z will be used. Entry will always take place, no matter which technology is selected. The profits that firm 2 makes depend on the cost type of firm 1.

3.2.2 The Entry Mode Decision

Following Motta (1992) and Smith (1987), the entry mode decision is dependent on the expected residual demand. We need to show that when the incumbent has a low marginal cost, the entrant is faced with a small residual demand and thus prefers to enter the market via exporting. On the other hand, if the incumbent has a high marginal cost, then the entrant faces a large residual demand and enters via FDI. We can show that when incumbent costs are low, technology X is preferred by the entrant. This occurs if,

$$\pi_2(0, c_X) \geq \pi_2(0, c_Z) \tag{3.12}$$

$$\text{and } \pi_2(1, c_Z) > \pi_2(1, c_X) \tag{3.13}$$

Explicitly, using the values above, we can write,

$$\left(\frac{a - 2c_X + c_L}{3}\right)^2 - X \geq \left(\frac{a - 2c_Z + c_L}{3}\right)^2 - Z \tag{3.14}$$

$$\left(\frac{a - 2c_Z + c_H}{3}\right)^2 - Z > \left(\frac{a - 2c_X + c_H}{3}\right)^2 - X \tag{3.15}$$

which can be rearranged to eliminate the fixed costs giving us $(c_H - c_L)(c_X - c_Z) > 0$. Remember, $c_X = c_Z + s + t$, hence $(c_H - c_L)(s + t) > 0$.

The above implies that

$$\pi_2(0, c_Z) - \pi_2(0, c_X) > \pi_2(1, c_Z) - \pi_2(1, c_X) \tag{3.16}$$

By considering a continuous range of marginal costs for both firms, we can show that $\partial^2 \pi_2(\mu, c_T) / \partial c_T \partial \mu < 0$.[2] As the entrant's profits fall monotonically and continuously in c_T and rise monotonically and continuously in μ, choosing any $c_T \in$

[2] Rearranging, we have,

$$\pi_{2X}(0) - \pi_{2Z}(0) > \pi_{2X}(1) - \pi_{2Z}(1)$$

which is the same as,

$$\pi_2(0, c_X) - \pi_2(0, c_Z) > \pi_2(1, c_X) - \pi_2(1, c_Z)$$

$\{c_Z, c_X\}$ where $c_X > c_Z$ and $\mu \in \{0,1\}$ is sufficient for equation 3.16 to hold. Indeed, we can show this to be true by substituting in the equilibrium values,

$$\frac{\partial^2 \pi_2}{\partial c_T \partial \mu} = -\frac{4}{9}(c_H - c_L) < 0 \tag{3.17}$$

The difference in fixed costs for the two types of technology is Δ, the sunk information cost incurred when setting up in the host country. From $\pi_2(0, c_X) - \pi_2(0, c_Z)$ we can calculate the upper bound,

$$\overline{\Delta} \equiv 4/9\,(a - c_X - c_Z + c_H)(c_X - c_Z) \tag{3.18}$$

and from $\pi_2(1, c_Z) - \pi_2(1, c_X)$ the lower bound for

$$\underline{\Delta} \equiv 4/9\,(a - c_X - c_Z + c_L)(c_H - c_L) \tag{3.19}$$

Therefore, as long as $c_H > c_L$ and $c_X > c_Z$ we can find some $\Delta \in \left(\underline{\Delta}, \bar{\Delta}\right)$ which satisfies the inequalities required governing the entrant's mode of entry.

Given that it is in the interests of an incumbent to signal that it has a low marginal cost, $1L$ must find a first period output that cannot be profitably imitated by $1H$. If this is possible, then the entrant is able to gain complete information about the incumbent's cost type and thus select the appropriate mode of entry.

3.2.3 Optimal Strategies

In the first period the incumbent is a monopolist. It is aware of the entry mode decision of the entrant and attempts to influence this according to its capabilities. The limitations on the incumbent's first period strategy are its actual marginal cost,

This can be written as,

$$\int_{c_2=c_Z}^{c_X} \frac{\partial \pi_2(0, c_T)}{\partial c_T} dc_T > \int_{c_2=c_Z}^{c_X} \frac{\partial \pi_2(1, c_T)}{\partial c_T} dc_T$$

and again rearranging gives us,

$$\int_{\mu=0}^{1} \int_{c_T=c_Z}^{c_X} \frac{\partial^2 \pi_2(\mu, c_T)}{\partial \mu \partial c_T} dc_T d\mu < 0$$

the prior beliefs of the entrant and a tariff (if any). Following Milgrom and Roberts (1982) we look for a sequential equilibrium (Kreps and Wilson 1982).

The incumbent has to optimise the following:

$$\hat{q}_{1\theta} \in \underset{q_{1\theta}}{\operatorname{argmax}} \{\pi_{1\theta}(\hat{q}_{1\theta}) + \delta [E\pi_{1\theta}(\mu, c_X) + (1-E)\pi_{1\theta}(\mu, c_Z)]\} \tag{3.20}$$

for $\theta \in \{H, L\}$, $E \in \{0,1\}$, $\mu \in [0,1]$ and $T \in \{X, Z\}$. As we see, the incumbent, whatever its cost type, must choose some first period strategy that will influence the entrant's mode of entry.

The entry conditons for the entrant depend on its expected profit in the post-entry game. Let us first impose the conditions we require. Optimality for the entrant is given by,

$$E = \begin{cases} 1 \text{ if } \pi_2(\mu, c_X) \geq \pi_2(\mu, c_Z) \\ 0 \text{ otherwise} \end{cases} \tag{3.21}$$

for $\theta \in \{H, L\}$, $E \in \{0,1\}$, $\mu \in [0,1]$ and $T \in \{X, Z\}$.

Finally, for Bayes' consistency of beliefs, we have,

$$\begin{array}{llll} \text{If} & \hat{q}_{1H} \neq \hat{q}_{1L} & \text{then} & \mu\langle\hat{q}_{1H}\rangle = 1, \mu\langle\hat{q}_{1L}\rangle = 0 \\ \text{If} & \hat{q}_{1H} = \hat{q}_{1L} = q_{1L} & \text{then} & \mu\langle\hat{q}_{1H}\rangle = \mu\langle\hat{q}_{1L}\rangle = \rho \end{array}$$

Bayes' rule instructs the entrant on how to deal with the first period incumbent output it observes. If $\hat{q}_{1H} \neq \hat{q}_{1L}$ the entrant should be able to deduce the incumbent's cost type. For example, if the entrant observes $\hat{q}_{1H}$, the incumbent has high marginal cost and $\mu = 1$; otherwise if $\hat{q}_{1L}$ is observed, then the incumbent has a low marginal cost and $\mu = 0$. A high cost incumbent will typically play its monopoly output in the first period when $\hat{q}_{1H} \neq \hat{q}_{1L}$. However, if some other output $q_1 \notin (\hat{q}_{1H}, \hat{q}_{1L})$ is observed, the entrant assumes that the incumbent has a high marginal cost.. If $\hat{q}_{1H} = \hat{q}_{1L}$ then output chosen in equilibrium is uninformative and hence, the posterior belief of the entrant is the same as its prior, i.e. $\mu = \rho$. As is commonly assumed, the pooling output is taken to be the monopoly output of the low cost type incumbent, q_{1L}.[3] Again, if some output of equilibrium output is observed $q_1 \neq q_{1L}$ the incumbent is

[3] Please note that $q_{1\theta}$ is taken to be the monopoly output of firm 1θ. However, $\hat{q}_{1\theta}$ is the first period output of firm 1θ. Fir limit pricing in the separating equilibrium, we obtain $\hat{q}_{1L} > q_{1L}$ and $\hat{q}_{1H} = q_{1H}$, hence, $\hat{q}_{1L} \neq \hat{q}_{1H}$. In the pooling equilibrium, $\hat{q}_{1L} = q_{1L} = \hat{q}_{1H} > q_{1H}$.

assumed to have a high marginal cost. The collection $\{\hat{q}_{1\theta}, 2\langle\hat{q}_{1\theta}\rangle, \mu\langle\hat{q}_{1\theta}\rangle\}$ forms a sequential equilibrium.

To summarise, the entrant prefers to export if it believes the incumbent has a low marginal cost. The incumbent must find some strategy which will maximise its profits. In a separating equilibrium, this implies that $1L$ must find an output (price) that cannot be imitated by $1H$.

3.3 Separating Equilibrium

In the separating equilibrium, the entrant is fully informed about the incumbent's cost type. As the entrant chooses exporting when faced with a low cost incumbent, and that exporting is the desired mode of entry for the incumbent, a high cost incumbent has an incentive to imitate the strategy of a low cost incumbent. If this occurred, the entrant would learn nothing about the incumbent's cost and would base its entry decision on its prior beliefs. However, if priors are such that,

$$E = 1 \text{ if } \pi_2(\rho, c_Z) \geq \pi_2(\rho, c_X)$$

then the entrant will enter the market using FDI. Clearly, if a low cost incumbent can avoid this, it will find a strategy that cannot be imitated by a high cost incumbent.

The incentive constraint for the low cost incumbent is given by,

$$\pi_{1L}(\hat{q}_{1L}) + \delta\pi_{1L}(0, c_X) > \pi_{1L} + \delta\pi_{1L}(1, c_Z) \tag{3.22}$$

The LHS of equation 3.22 states that the low cost incumbent can find some output in the first period that will indicate it has a low marginal cost with certainty, i.e. $\hat{q}_{1L} \neq \hat{q}_{1H}$. Consequently, the entrant updates its posterior beliefs so that $E(\mu = 0) = 1$, and therefore enters the market through exporting. On the other hand, the RHS of equation 3.22 indicates the incumbent's profit if it does not signal its type in the first period. The entrant then believes that the incumbent has a high marginal cost i.e. $E(\mu = 1) = 0$, and enters the market via FDI. However, the incumbent in reality has a low marginal cost and so that its best response is to move along its reaction function and earn its best response profits.[4]

4

For the high cost incumbent, we need to ensure that it has no incentive to imitate the strategy of the low cost incumbent.

$$\pi_{1H}(\hat{q}_{1L}) + \delta\pi_{1H}(0, c_X) \leq \pi_{1H} + \delta\pi_1(1, c_Z) \tag{3.23}$$

On the RHS of equation 3.23 the high cost incumbent produces its monopoly output in the first period and earns complete information profits in the second period, i.e. $\hat{q}_{1H} = q_{1H}$. It finds this strategy more profitable than imitating the output of the low cost incumbent which is expressed on the LHS of equation 3.23. The entrant believes the incumbent to have a low cost and enters the market via exporting. However, as the incumbent actually has a high marginal cost, it must shift along its reaction function in the second period to maximise profit. Note that $\pi_{1H}(\mu, c_X) > \pi_{1H}(\mu, c_Z)$ which is an incentive for the high cost incumbent to imitate the strategy of the low cost incumbent. It is this possibility that leads to limit pricing as it forces the low cost incumbent to find a pre-entry output that cannot be imitated by the high cost firm.

Rearranging the incentive constraints gives us the following condition for a separating equilibrium,

$$\frac{\pi_{1H} - \pi_{1H}(\hat{q}_{1L})}{\pi_{1H}(0, c_X) - \pi_1(1, c_Z)} \geq \delta > \frac{\pi_{1L} - \pi_{1L}(\hat{q}_{1L})}{\pi_{1L}(0, c_X) - \pi_{1L}(1, c_Z)} \tag{3.24}$$

If δ can be found that satisfies 3.24, then a separating equilibrium exists. Indeed, two sufficiency conditions for 3.24 are

$$\pi_{1H} - \pi_{1H}(\hat{q}_{1L}) > \pi_{1L} - \pi_{1L}(\hat{q}_{1L}) \tag{3.25}$$

and

$$[\pi_{1L}(0, c_X) - \pi_{1L}(1, c_Z)] > [\pi_{1H}(0, c_X) - \pi_{1H}(1, c_Z)] \tag{3.26}$$

We can now state the first result.

Proposition 3.1 *$c_H > c_L$ and $c_X > c_Z$ are sufficient conditions for the existence of a range of discount factors over which a separating equilibrium exists.*

We do not make the common but simplied assumption that on entry, all information is revealed. Here we follow Saloner (1987) and Martin (1995).

Proof. Condition 3.21 is implied by the inequalities 3.25 and 3.26. If these hold, we can find some $\delta > 0$ that satisfies the separating equilibrium.

First, show that $\pi_{1L} - \pi_{1L}(\hat{q}_1) < \pi_{1H} - \pi_{1H}(\hat{q}_1)$ for $\hat{q}_1 > q_{1L}$.[5] Monopoly profits are given by $\pi_{1L} = \max(a - c_\theta - q_{1\theta}) q_{1\theta}$ which yields equilibrium output $q_{1\theta} = (a - c_\theta)/2$ and profit $\pi_{1\theta} = (a - c_\theta)^2/4$. Therefore,

$$\pi_{1L} - \pi_{1L}(\hat{q}_1) < \pi_{1H} - \pi_{1H}(\hat{q}_1) \tag{3.27}$$

yields,

$$\left(\frac{a - c_L}{2}\right)^2 - (a - c_L - \hat{q}_1)\hat{q}_1 < \left(\frac{a - c_H}{2}\right)^2 - (a - c_H - \hat{q}_1)\hat{q}_1 \tag{3.28}$$

and rearranging gives us,

$$\frac{1}{4}(c_H - c_L)(2a - c_H - c_L - 4q_1) < 0 \tag{3.29}$$

for $(2a - c_H - c_L)/4 \equiv (q_{1L} + q_{1H})/2 < \hat{q}_1$. Therefore, condition 3.25 holds.

Secondly, show that inequality 3.26 holds. Substitute in the equilibrium profits and simplify to get,

$$\begin{aligned} [\pi_{1L}(0, c_X) - \pi_{1L}(1, c_Z)] - [\pi_{1H}(0, c_X) - \pi_{1H}(1, c_Z)] &> 0 \\ \Leftrightarrow \frac{1}{6}(c_H - c_L)(c_H - c_L + 2(c_X - c_Z)) &> 0 \end{aligned} \tag{3.30}$$

It is sufficient that $c_H > c_L$ and $c_X > c_Z$ for 3.26 to hold. ■

We have our first result which is that we can find conditions where pre-entry prices affect the entry decision of the multinational. What is interesting is that the cost of becoming informed about the market is bourn by the incumbent and not the multinational, and that the information is received before the entry decision is taken. This contrasts the traditional view of informational cost (e.g. Motta 1992) which is incurred only by the multinational when it chooses FDI. However, the information presented here is different to that of former papers where the cost of information is known before hand.

In the Milgrom and Roberts (1982) paper, entry is either deterred or accommodated. Their limit price is negatively related to the entrant's cost: a fall in the

[5] Single crossing condition (Spence 1974).

entrant's cost reduces the incumbent's post-entry profits and increases the high cost incumbent's incentives to imitate the low cost incumbent's strategy. Consequently, the low cost incumbent selects an even lower limit price.

Let us now compare these results with the entry mode model. First, we need to calculate the upper and lower bounds of incumbent outputs that will satisfy the separating equilibrium. Find some q_1' that equates inequality 3.22 and q_1'' that equates inequality 3.23. Equating and rearranging, we obtain,

$$q' = \frac{a - c_L}{2} + \sqrt{\delta\left[\pi_{1L}\left(0, c_X\right) - \pi_{1L}\left(1, c_Z\right)\right]} \tag{3.31}$$

$$q'' = \frac{a - c_H}{2} + \sqrt{\delta\left[\pi_{1H}\left(0, c_X\right) - \pi_{1H}\left(1, c_Z\right)\right]} \tag{3.32}$$

Note that $q'' < q'$ and that $q'' > q_{1H}$ for $\delta > 0$. It is normally assumed that the low cost incumbent will produce at the least cost separating output, $\underline{q}$, the smallest output possible that does not overturn the separating equilibrium, where

$$\underline{q} = \begin{cases} q_{1L} \text{ if } q'' \leq q_{1L} \\ q'' \text{ otherwise} \end{cases}$$

This simply states that a separating equilibrium may exist at monopoly prices and lower, depending on the parameters chosen. Of course, if $\underline{q} = q_{1L}$, we do not observe distortionary prices: the monopoly price is a sufficient signal. However, it is more interesting to focus on equilibria where $q'' > q_{1L}$ as this represents the idea that a firm must give up some present profit in order to deter entry.

This output fixes the limit price as being the highest price that the incumbent can charge without inducing the employment of technology Z. Note that $\underline{q}$ is dependent on c_H, c_L, c_X and c_Z. Milgrom and Roberts (1982) obtain,

$$\underline{q}_{\text{M\&R}} = \frac{a - c_H}{2} + \sqrt{\delta\left[\pi_{1H} - \pi_{1H}\left(1, c_T\right)\right]} \tag{3.33}$$

where π_{1H} is the monopoly profit of a high cost incumbent, and $\pi_{1H}\left(1, c_T\right)$ represents post-entry duopoly profits for fixed cost T (assuming that $\underline{q}_{\text{M\&R}} > q_{1L}$). The important thing to note is that the entrant's marginal cost enters only into $\pi_{1H}\left(1, c_T\right)$: an increase in the entrant's marginal cost leads to an increase in the incumbent's profits, reducing the least cost separating output and raising the limit price. In other words, $dq_{M\&R}/dc_2 < 0$. However, for the entry mode model, we obtain the opposite result. Remembering that $c_X = c_Z + s + t$ we can differentiate the bracketed terms inside the root in equation 3.32 with respect to c_Z to get,

$$\frac{d\left[\pi_{1H}(0, c_X) - \pi_{1H}(1, c_Z)\right]}{dc_Z} = \frac{(c_H - c_L) + 2(s + t)}{9} > 0$$

Therefore, $dq/dc_z > 0$. In contrast to the result of Milgrom and Roberts (1982), an increase in the marginal cost of the entrant increases the post-entry profits of FDI but increases more so the post-entry profits a high cost incumbent can obtain facing an exporter.

However, the limit price of Mailath (1989) would have similar properties. In the Mailath (1989) paper, signalling occurs to preserve market share, with entry always taking place. Consequently, the rival firm's marginal cost always enters into the firm's ex-post profit function.

3.4 Pooling Equilibrium

In the pooling equilibrium, no information is revealed about the incumbent's cost and so the entrant updates using its prior beliefs. Such a situation might occur if prior beliefs are such that the entrant always enters the market via exporting. The entry decision for the entrant is thus,

$$E = \begin{cases} 1 \text{ if } \pi_2(\rho, c_X) \geq \pi_2(\rho, c_Z) \\ 0 \text{ if } \pi_2(\rho, c_X) < \pi_2(\rho, c_Z) \end{cases}$$

If,

$$\pi_2(\rho, c_X) > \pi_2(\rho, c_Z) \tag{3.34}$$

the entrant expects higher profits by exporting. Clearly, both types of incumbent prefer this scenario as the entrant will enter the market with the high marginal cost of exporting, which will raise market prices. Consequently, we might believe that there is no incentive for the low cost incumbent to reveal its cost type as this will have no effect on the entry mode. However, this is not always the case. Although the entrant may choose exporting over FDI, it still must maximise its expected profit as even after entry, the incumbent's cost type is not revealed (Saloner 1987). Hence, the entrant producers more than the complete information Cournot equilibrium output when facing a low cost incumbent.

The output of an entrant in a pooling equilibrium is,

$$q_2(\rho) = \frac{a - 2c_X + \rho c_H + (1-\rho)c_L}{3} \tag{3.35}$$

where the entrant uses exporting but estimates using its prior beliefs the marginal cost of the incumbent. Clearly, this will affect the low cost incumbent's profits as the entrant will produce more in the pooling equilibrium than it would in the separating equilibrium (i.e. $q_2(\rho) > q_2(0)$). Therefore, if a low cost incumbent produces at its monopoly output in the first period, the following inequality must hold for pooling to be worthwhile,

$$\pi_{1L}\left(\underline{q}\right) + \delta\pi_{1L}(0, c_X) < \pi_{1L} + \delta\pi_{1L}(\rho, c_X). \tag{3.36}$$

Inequality 3.36 defines a pooling equilibrium. However, we should check to see if a range of $\rho \in (0,1)$ exists such that inequality 3.36 holds. In other words, we need to show that for some range of ρ the incumbent will find it more profitable to pool than to separate. From the separating equilibrium, we require,

$$\pi_{1L}\left(\underline{q}\right) + \delta\pi_{1L}(0, c_X) > \pi_{1L} + \delta\pi_{1L}(1, c_Z) \tag{3.37}$$

Rearrange to get,

$$\delta\left(\pi_{1L}(0, c_X) - \pi_{1L}(1, c_Z)\right) > \pi_{1L} - \pi_{1L}\left(\underline{q}\right) \tag{3.38}$$

Now rearrange 3.36 in a similar way,

$$\pi_{1L} - \pi_{1L}\left(\underline{q}\right) > \delta\left(\pi_{1L}(0, c_X) - \pi_{1L}(\rho, c_X)\right) \tag{3.39}$$

We can now compare the two period profit of the incumbent in the separating and pooling equilibrium by equating 3.38 and 3.39 to get,

$$\pi_{1L}(0, c_X) - \pi_{1L}(1, c_Z) > \pi_{1L}(0, c_X) - \pi_{1L}(\rho, c_X) \tag{3.40}$$

This simplifies to,

$$\pi_{1L}(\rho, c_X) > \pi_{1L}(1, c_Z) \tag{3.41}$$

As $\pi_{1L}(\rho, c_X) > \pi_{1L}(1, c_X)$ because $\partial\pi_{1L}/\partial\rho < 0$ and $\pi_{1L}(1, c_X) > \pi_{1L}(1, c_Z)$ because $\partial\pi_{1L}/\partial c_2 > 0$, inequality 3.41 holds for all $\rho < 1$. Therefore, if prior beliefs are such that an entrant will always enter via technology X, the low cost incumbent will always pool.

The high cost incumbent must have an incentive to imitate the strategy of the low cost incumbent if there is to be pooling. Therefore, we require that,

$$\pi_{1H}(q_{1L}) + \delta\pi_{1H}(\rho, c_X) > \pi_{1H} + \delta\pi_{1H}(1, c_Z) \tag{3.42}$$

If this inequality is never the case, then there would be no limit pricing in the separating equilibrium: the low cost incumbent would never have to deviate from its first period monopoly output in order to separate from the high cost incumbent. However, inequality 3.42 is not exactly the reverse inequality of equation 3.23. Note that although the entrant enters via technology X, it chooses this technology given the prior beliefs that weight its expected post entry profits. Therefore, the prior beliefs fix the output that the firm produces in the second period. In the entry deterrence model of Milgrom and Roberts (1982) entry does not take place in the pooling equilibrium and so the entrant's output is zero.

This means that the low cost incumbent prefers to play some first period strategy that can be imitated by the high cost incumbent because this does not affect the choice of mode of entry. We can calculate the value of ρ needed for a pooling equilibrium, by substituting in the values for the profits in equation 3.34 and rearranging for ρ,

$$\frac{9\Delta - 4(a + c_L - 2c_Z - s - t)(s + t)}{4(s + t)(c_H - c_L)} \equiv \bar{\rho} > \rho \tag{3.43}$$

This indicates the upper bound on the prior probability that the incumbent has a low marginal cost. If this condition is satisfied, then the entrant will enter via technology X.

However, although the entrant produces with technology X, is it convinced with probability ρ that the incumbent has a low marginal cost. Remember, the entrant's expected profits under the two technologies are expressed in equation 3.34.

Our second important result is that pooling equilibria exist. The implications of this are that a high cost incumbent can lower its pre-entry price and as a consequence an inefficient entry mode is chosen. In the Smith-Motta model, the entry mode is always efficient in the absence of government policy. However, as we can show here, inefficient outcomes may occur due to incumbent behaviour, thus suggesting a need for state intervention.

3.5 Tariffs

So far we have not looked at the effect of the tariff t on the incumbent's first period strategy. We first need to look at the effect of the tariff on the entry mode decision: what effect does it have on the strategies of the incumbent and entrant.

First, let us consider the effect of a tariff on the incumbent's pre-entry strategy. The tariff is part of the exporter's marginal cost, hence $\pi_{1\theta}(\mu, c_X) = \pi_{1\theta}(\mu, c_Z + s + t)$ (i.e. $c_X = c_Z + s + t$), which is the incumbent's profit when exporting is the mode of entry. The least cost separating output is given by,

$$\underline{q} = \frac{a - c_H}{2} + \sqrt{\delta\left(\pi_{1H}\left(0, c_Z + s + t\right) - \pi_{1H}\left(1, c_Z\right)\right)} > q_{1L} \tag{3.44}$$

As a tariff raises the exporter's marginal cost, $\partial\pi_{1H}\left(0, c_Z + s + t\right)/\partial t > 0$. In turn, this implies that $\partial\underline{q}/\partial t > 0$. By increasing the tariff, the profits that a high cost incumbent earns, when exporting is the mode of entry, increases, increasing the firm's desire to imitate the low cost incumbent strategy.

However, this cannot be true for all levels of t. Clearly, an infinite tariff would make exporting impossible and as a result, the entrant would choose FDI. On the other hand, reducing the tariff may lead to a no-distortion separating equilibrium: pre-entry monopoly prices are sufficient to signal cost type. For example, it might be that for $t = 0$,

$$\underline{q} = q_{1L} > \frac{a - c_H}{2} + \sqrt{\delta\left(\pi_{1H}\left(0, c_Z + s\right) - \pi_{1H}\left(1, c_Z\right)\right)} \tag{3.45}$$

Therefore, an increasing tariff may have three effects. First, it may lead a low cost incumbent to price below its monopoly price in the first period in order to sustain the separating equilibrium. Secondly, as the tariff rises the limit price falls and third, at some point the tariff gets so high the entrant always chooses FDI: we obtain tariff jumping.

Nevertheless, if tariff jumping occurs what is left for the incumbent to do? Should it set monopoly prices in the first period? In fact, limit pricing may still continue for the simple reason that although the mode of entry cannot be affected by pre-entry prices, the entrant's output can still be limited. This is similar to Mailath (1989) where firms signal their cost types in order to enhance or protect their market share. The least cost separating output for the incumbent might now be,

$$\underline{q} = \frac{a - c_H}{2} + \sqrt{\delta \left(\pi_{1H} \left(0, c_Z \right) - \pi_{1H} \left(1, c_Z \right) \right)} > q_{1L} \tag{3.46}$$

Clearly, $\pi_{1H}(0, c_Z) > \pi_{1H}(1, c_Z)$ which means that as long as $q'' > q_{1L}$ distortionary prices may still be observed in the first period. Of course,

$$\pi_{1H}(0, c_Z + s + t) - \pi_{1H}(1, c_Z) > \pi_{1H}(0, c_Z) - \pi_{1H}(1, c_Z) \tag{3.47}$$

which means that the limit price suddenly rises when tariff jumping occurs. Figure 3.1 illustrates the relationship between the limit price and the tariff. As the tariff is increased, the limit price falls and exporting remains the mode of entry. However, at some point the tariff is so high that the entrant switches to exporting and the limit price jumps up. Figure 3.1 has been drawn to show the possibility of distortionary pre-entry prices even after tariff jumping will occur (i.e. $\bar{p} < p_{1L}$).

In the pooling equilibrium, we assume that the low cost incumbent plays its monopoly output in the first period and exporting takes place in the second period. A high cost incumbent will imitate this strategy, and hence we obtain limit pricing (where the high cost incumbent produces at the low cost monopoly output). Clearly, if the tariff does not affect the equilibrium, the limit price will remain the same: the low cost incumbent still plays its monopoly output.

However, what effect does the tariff have on the equilibrium that the incumbent chooses? We can now show how the tariff affects the range of prior beliefs that support the pooling equilibrium. In the pooling equilibrium, the entrant exports into

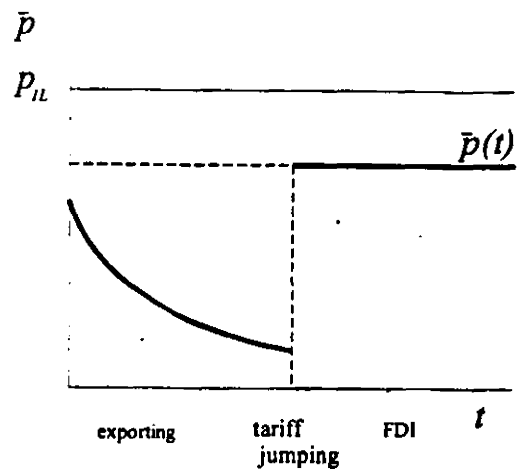

Figure 3.1: Change in Limit Price due to an increasing Tariff

the market because of the inequality,

$$\pi_2(\rho, c_Z + s + t) > \pi_2(\rho, c_Z) \tag{3.48}$$

(Note that $c_Z + s + t = c_X$). We know that by raising ρ we should find to $\bar{\rho}$ that yields equality (because $\pi_2(1, c_X) < \pi_2(1, c_Z)$). $\bar{\rho}$ represents the highest value ρ that supports the pooling equilibrium (note that it is possible for $\bar{\rho} = 0$). Therefore, in the pooling equilibrium, $\rho < \bar{\rho}$ i.e.

$$\pi_2(\bar{\rho}, c_Z + s + t) = \pi_2(\bar{\rho}, c_Z) \tag{3.49}$$

where $t, s, c_Z > 0$. Set $t = 0$. Now we obtain,

$$\pi_2(\bar{\rho}, c_Z + s) > \pi_2(\bar{\rho}, c_Z) \tag{3.50}$$

as exporting becomes more profitable. The new highest value of ρ that yields equality can be denoted as ρ' so that,

$$\pi_2(\rho', c_Z + s) = \pi_2(\rho', c_Z) \tag{3.51}$$

Again, it must be that $\rho' > \bar{\rho}$. Therefore, the range of prior beliefs that support the pooling equilibrium can be extended by reducing the tariff. If prior beliefs under the tariff were $\rho > \bar{\rho}$ then we would have a separating equilibrium as the entrant would enter via FDI if it is uncertain over the incumbent's true cost. By reducing the tariff, the government increases the entrant's profits under exporting. If as a result $\rho' > \rho$ then the incumbent pools with the result that the entrant always exports into the market.

As we can see, the government has considerable influence over the strategies of the incumbent. Not only can it affect the mode of entry but it can also influence the incumbent's first period strategy. A tariff policy can have two effects. By increasing a tariff a government reduces the range of beliefs that support the pooling equilibrium. If the incumbent is pooling, then a tariff increase may overturn the equilibrium and the incumbent may separate as a result. On the other hand, reducing a tariff increases the range of beliefs that support the pooling equilibrium and so we may observe a switch from separating to pooling in the first period. In order to understand which equilibrium is preferable, we need to look at the first and second period welfare that emerge in both types of equilibrium.

3.6 Welfare Implications

Let us now turn to the welfare effects of limit pricing in the mode of entry game. We need to consider welfare changes over the two periods, using the discount factor to weight second period welfare. Welfare is defined as the sum of local producer profit, consumer surplus and tariff revenue. Following Motta (1992) we ignore the profits earned by the multinational under FDI.

There are two cases to consider: what are the welfare effects of a tariff when exporting is the mode of entry and of tariff-jumping FDI. However, before considering the effect of the tariff we should consider first welfare under the two types of equilibria that emerge. In the separating equilibrium we have complete information in the first second period and firms produce at their Cournot outputs. In the pooling equilibrium, the entrant does not learn anything about the incumbent's cost and therefore is forced to use its prior beliefs. Given our definition of welfare above, we can state immediately the different welfare outcomes between the two types of equilibria. These results are quite standard to the literature on limit pricing (see Tirole 1988).

First, when the incumbent pools, the output of the entrant is the same regardless of the incumbent' s cost type. This is because the entrant maximises its expected profits according to its prior beliefs. Consequently, if a tariff were introduced, the resulting government tariff revenue would be the same regardless of the incumbent's actual type. However, the output of a high cost incumbent is lower than under complete information which means that profits and consumer surplus are lower. As for the high cost incumbent, its output is higher yielding higher profits and a larger consumer surplus. Now let us look at the effect on welfare from imposing a tariff.

3.6.1 A Small Tariff

First, let us consider exporting. An important paper here is that of Levy and Nolan (1992) where they show that in a simple duopoly where the entrant is an exporter, a small tariff unambiguously increases social welfare (also see Brander and Spencer 1984). There are two positive effects: a *terms of trade effect* and a *domestic firm output effect*. Intuitively, the tariff reduces the entrant's output and raises the domestic firms profits. Although consumers lose out on higher prices, this is compensated by the tariff revenue earned by the State (which could be redistributed to consumers or used to subsidize local production). We need to consider both the separating and pooling equilibrium in order to evaluate the effects of a tariff on welfare. As government policy is set before the first period, only prior beliefs can be used in the estimation of second period welfare. Writing second period welfare according to the definition above we have

$$W_2(\rho, c_X, t) = \pi_{1\theta}(\rho, c_\theta) + \int_{Q=0}^{q_1+q_2} P(Q)\, dQ - P(Q)\, Q + tq_2 \tag{3.52}$$

where the 3-tuple function $W_2(\rho, c_T, t)$ expresses expected welfare given the incumbent's cost type (expressed by ρ), the entrant's marginal cost (c_T — which includes the tariff when we consider exporting) and the tariff revenue (implied by $t > 0$). Using the equilibrium values obtained earlier, we obtain the expected welfare

$$W_2(\rho, c_X, t) = \left(\frac{a - 2(\rho c_H + (1-\rho) c_L) + c_T}{3}\right)^2$$

$$+\frac{1}{2}\left(\frac{2a-c_T-(\rho c_H+(1-\rho)c_L)}{3}\right)^2$$
$$+t\left(\frac{a-2c_T+(\rho c_H+(1-\rho)c_L)}{3}\right) \tag{3.53}$$

As we consider exporting, $c_T = c_X$ (where $c_X = c_Z + s + t$). Differentiate $W_2(\mu, c_X, t)$ with respect to t to obtain

$$\frac{dW_2(\rho, c_X, t^*)}{dt} = \frac{a-c_Z-s}{3} - t^* = 0 \tag{3.54}$$

for $\mu \in \{0,1\}, c_\theta \in \{c_H, c_L\}$. The second derivative is $\partial W_2/\partial t = -1 < 0$ which tells us that $t^* = (a-c_Z-s)/3$ is a maximum: the optimal tariff. For $t < (a-c_Z-s)/3$ welfare is always improving with the tariff (Levy and Nolan 1992). However, this is the situation under complete information where both firms are producing their optimal outputs. If the incumbent pools in the first period, then the entrant maximises its expected profits using its prior beliefs.

In the pooling equilibrium, the entrant uses its prior beliefs to maximise its expected output. However, what about the government? If the government knows the cost type of the incumbent, then a welfare maximising tariff might reveal the incumbent's cost (see Collie and Hviid 1994). Suppose the government knows the incumbent's cost type although pooling took place in the first period. The welfare maximising tariff for a high cost incumbent would be

$$\frac{\partial W_{2H}(\rho, c_X, t')}{\partial t} = \frac{a-c_Z-s}{3} - \frac{(c_H-c_L)(1-\rho)}{6} - t' = 0 \tag{3.55}$$

while for a low cost incumbent we would obtain

$$\frac{\partial W_{2L}(\rho, c_X, t'')}{\partial t} = \frac{a-c_Z-s}{3} + \rho\frac{c_H-c_L}{6} - t'' = 0 \tag{3.56}$$

We see that there are three optimal tariffs depending on the incumbent's actual cost i.e. $t'' > t^* > t'$. Therefore, if the government knew exactly the incumbent's cost in the pooling equilibrium it would choose a welfare maximising tariff that would be associated with a given cost type, thus revealing the incumbent's marginal cost. Of course, we must now ask ourselves the question as to whether welfare is improved by revealing the incumbent's cost ?(I.e. are there incentives constraints that satisfy a separating equilibrium.) This issue has been dealt with in considerable detail by Collie and Hviid (1994) where they show the existence of separating and pooling equilibria in a game where a government sets tariffs. We shall make the assumption that the government uses only the information it receives at the end of the first period. Therefore, the optimal tariff is the same as for the separating equilibrium, $t^* = (a - c_Z - s)/3$.[6] What we see here is that pooling will lead to lower second period welfare compared to the separating equilibrium because the estimated optimal tariff given the entrant's output will be either too high (when the incumbent has a high marginal cost) or too low (otherwise). However, as far as the government is concerned, the estimated change in welfare from a change in tariff is the same, regardless of whether we are in a separating or pooling equilibrium. Nevertheless, a pooling equilibrium may increase or decrease welfare depending on relative differences between the firms' marginal costs. The result is similar to that of Levy and Nolan (1992). They show that welfare has a U-shaped relationship with respect to the entrant's marginal cost. A similar relationship holds with respect to the incumbent's marginal cost and hence the prior beliefs in the pooling equilibrium. Thus, the second derivative can be written

$$\frac{\partial^2 W_2(\rho, c_X, t)}{\partial \rho^2} = (c_H - c_L)^2 > 0 \tag{3.57}$$

which tells us that the function is convex, and that a minimum exists at

$$\frac{\partial W_2(\rho', c_\theta, t)}{\partial \rho} = 0 \tag{3.58}$$

yielding

$$\rho' = \frac{1}{3}\frac{2a - 3c_L + c_T}{c_H - c_L} > 0 \tag{3.59}$$

However, $\rho' > 1$ which means that for $\rho \in [0,1]$ expected welfare is decreasing in ρ.[7] Therefore, expected welfare is highest when $\rho = 0$ and is the same as would be obtained under a separating equilibrium. As pooling yields lower expected welfare

[6] Under a separating equilibrium, the incumbent's cost is c_H or c_L. In the pooling equilibrium the government and entrant estimate it to be $c_\theta = \rho c_H + (1-\rho)c_L$.
[7] $1 > \frac{1}{3}\frac{2a-3c_L+c_T}{c_H-c_L} \Leftrightarrow -(a - c_H) > a - 2c_H + c_T$ which is a contradiction as the RHS is positive.

under the pooling equilibrium, the government might find it worthwhile forcing a separating equilibrium. This might be achieved by reducing or removing the tariff.

So far we have only looked at welfare in the second period of the game. However, to get a true estimate of the total welfare effect of a tariff, we need to consider first period welfare.

We illustrated earlier that a tariff can lower the limit price in the first period. Let us check the effect this has on first period welfare. Using the chain rule, the effect of a tariff on first period welfare is $\partial W_1/\partial t = \left(\partial W_1/\partial \underline{q}\right)\left(\partial \underline{q}/\partial t\right)$. We know that $\partial \underline{q}/\partial t > 0$ so we need only consider the effect of $\underline{q}$ on $W_1\left(\underline{q}(t)\right)$. First period welfare is given by

$$W_1\left(\underline{q}(t)\right) = \left[P\left(\underline{q}\right) - c_\theta\right]\underline{q} + \int_{q=0}^{\underline{q}} P\left(q(t)\right) dq - P\left(\underline{q}\right)\underline{q} \tag{3.60}$$

Taking the derivative with respect to $\underline{q}$ we obtain

$$\frac{\partial W_1(t)}{\partial \underline{q}} = a - c_\theta - \underline{q} > 0 \tag{3.61}$$

as $\underline{q} < a - c_\theta$.[8] Therefore,

$$\frac{\partial W_1\left(\underline{q}(t)\right)}{\partial t} = \frac{\partial W_1}{\partial \underline{q}}\frac{\partial \underline{q}}{\partial t} > 0 \tag{3.62}$$

Hence, a tariff which increases the least cost separating output above the incumbent's monopoly output, raises first period welfare. Therefore, a tariff policy that stimulates limit pricing behaviour increases first and second period welfare.

On the other hand, by increasing the tariff we reduce the range of beliefs that support a pooling equilibrium which eventually may lead to a switch to a separating equilibrium. As we have seen, this will lead to higher welfare in both periods. Nevertheless, in order to see whether separating leads to higher welfare we need to check welfare under FDI.

3.6.2 Tariff-Jumping FDI

Motta (1992) and Levy and Nolan (1992) also look at the welfare effects of tariff-jumping FDI. As Levy and Nolan (1992) consider firms with asymmetric costs under

[8] If $\underline{q} > a - c_\theta$ the incumbent would earn negative profits.

FDI, their analysis is similar to the one we follow here. They consider two cases for the entrant's marginal cost: tariff-induced FDI and cost-induced FDI, the former being where $s < 0$ such that $t > |s|$ and the latter where $s > 0$.[9] Their idea of tariff-induced entry assumes that exporting involves a lower marginal cost than FDI. The tariff reverses this relationship hence making FDI cheaper than exporting (thus tariff-induced FDI). Cost-induced FDI assumes $s > 0$ so that FDI is always cheaper than exporting, for all $t > 0$.

Their results are as follows. First, a necessary but not sufficient condition for FDI to be welfare enhancing is that the entrant's production cost be less than some critical value $\tilde{c}$. This emerges from the U-shaped relationship that exists between the entrant's marginal cost and welfare. This implies that the welfare effects of FDI are ambiguous and that inward FDI may be immiserizing unless the entrant operates at a lower cost than the incumbent. Secondly, when considering tariffs, they show that FDI is immiserizing unless the tariff being jumped was itself welfare enhancing. This simply means that if a tariff is being jumped because it's so high then consumers will enjoy lower prices in the market. Nevertheless, lowering the tariff in this situation would improve welfare. Finally, cost-induced FDI can be welfare-reducing.

Welfare under FDI is the sum of incumbent's profits and consumer surplus (Levy and Nolan 1992, Motta 1992). Initially, we set the tariff at zero to look at the effect of the welfare changes with respect to the entrant's marginal cost under FDI (i.e. $t = 0$). Similar to Levy and Nolan (1992) we can calculate the critical value of c_Z. The derivative of $W_2(\mu, c_Z, 0)$ with respect to the entrant's marginal cost is

$$\frac{\partial W_2(\mu, \tilde{c}_Z, 0)}{\partial c_Z} = \frac{\tilde{c}_Z - (\mu c_H + (1-\mu) c_L)}{3} = 0 \tag{3.63}$$

We see that $\partial^2 W_2(\mu, c_Z, 0) / \partial c_Z^2 = 1/3 > 0$ so that we have a minimum and the critical value is $\tilde{c}_Z = \mu c_H + (1-\mu) c_L$. This defines the U-shaped welfare relationship with respect to the entrant's marginal cost. Consider the first result of Levy and Nolan (1992). As $c_Z < c_X$, welfare will improve under FDI if and only if $c_Z < \mu c_H + (1-\mu) c_L$. If the entrant has a higher marginal cost than the incumbent, the

[9] $s < 0$ may arise if the home country of the entrant provides an export subsidy.

switch from exporting to FDI will lead to lower welfare. However, we should now compare welfare under FDI to that obtained with a tariff. We have seen above that a tariff enhances welfare so that a switch to FDI will lead to a loss in tariff revenue as well as reducing the incumbent's competitive advantage. Nevertheless, under FDI $s = 0$ so that the incumbent's production costs are even lower. If $c_Z < c_Z + s < c_L$ then welfare is improved by reducing the transport costs. Clearly welfare is influenced by two effects: the change in the tariff and the change in transportation costs. The change in welfare from a tariff is given by

$$\frac{\partial W_2(\mu, c_X, t)}{\partial t} = \frac{a - c_Z - s}{3} - t > 0 \tag{3.64}$$

while the change in welfare from a reduction in s is

$$\frac{\partial W_2(\mu, c_X, 0)}{\partial s} = \frac{c_Z + s - (\mu c_H + (1-\mu) c_L) - t}{3} < 0 \tag{3.65}$$

for $c_Z + s < \bar{c}_Z$. We can show than $\partial W_2(\mu, c_X, t)/\partial t > \partial W_2(\mu, c_X, 0)/\partial s$ as rearranging the above yields

$$a - 2(c_Z + s + t) + (\mu c_H + (1-\mu) c_L) > 0 \tag{3.66}$$

This tells us that a unit change in tariff has a greater effect on welfare than a unit change in transportation costs. Hence, if $t > s$ then FDI will always lead to lower welfare than can be obtained under a tariff.

Now consider the case where $s \leq 0$. Levy and Nolan (1992) argue that this will reduce welfare unless the tariff itself is immiserizing. Assume $s \leq 0$ and $t > 0$ such that $c_Z + s + t > c_Z > c_Z + s$ (i.e. $t > |s|$). Therefore, FDI is more profitable to the entrant only if the tariff is in place. The arguments above are now reversed. If $c_Z + s < \bar{c}_Z$ then a switch to FDI (by imposing a high tariff) will lower welfare. Simply, FDI means a loss in tariff revenue and the incumbent's competitive advantage i.e. $\partial W_2(\mu, c_Z + s, t)/\partial t > 0$ as well as raising the entrant's production cost by removing the exporting subsidy i.e. $\partial W_2(\mu, c_Z, 0)/\partial s < 0$. Of course, if $c_Z + s > \bar{c}_Z$ we might be able to obtain the opposite result, as long as s is sufficiently large. In other words, FDI is welfare improving if the incumbent has a considerable competitive advantage

$a = 24, c_L = 6, c_H = 8, t^* = 5$			
$c_Z = 0, s = 9, \Delta = 110, \delta = 1$			
q_{1L}	9.00	$q_2(0, c_Z + s + t^*)$	2.00
q_{1H}	8.00	t^*	5.000
$\underline{q}_1(t^*)$	15.85	$\bar{\Delta}(t^*)$	113.78
$\underline{q}_1(0)$	9.37	$\underline{\Delta}(t^*)$	100.00
$W_{1L}(\underline{q}(t^*))$	159.69	$W_2(0, c_X, t^*)$	122.00
$W_{1L}(\underline{q}(0))$	124.8	$W_2(0, c_Z)$	134.00

Table 3.2: Results of Separating Equilibrium (A) Caption

and that $t < s$. However, if $t > |s|$ welfare falls with FDI because the loss in tariff revenue is greater than the gain from raising the entrant's marginal cost.

We should now look at the differences that emerge due to incomplete information. First, it is clear from the Levy and Nolan (1992) analysis that FDI improves welfare only when the saving in transportation costs is considerable (for the case where $s > 0$). However, even this result may be reversed if we consider limit pricing behaviour. As we mentioned above, if an prohibitive tariff is imposed to induce FDI and that this improves second period welfare, first period welfare falls because $\partial W_1/\partial t > 0$. We can show that depending on the parameter values we use, first period welfare loss may or may not dominate second period welfare gains.

Consider a tariff t' such that the entrant will always choose FDI as the mode of entry i.e. $\pi_2(0, c_Z + s + t') < \pi_2(0, c_Z)$ although the optimal tariff t^* would yield $\pi_2(0, c_Z + s + t^*) > \pi_2(0, c_Z)$. In other words, under an optimal tariff exporting remains the mode of entry for a low cost incumbent while the prohibitive tariff $t' > t^*$ induces FDI for both types of incumbent.

We can see in Table 3.2, welfare is greater in the second period when FDI is the chosen mode of entry i.e. $W_2(0, c_Z) > W_2(0, c_X, t^*)$. In the symmetric information equilibrium, a government would want to set a high tariff to induce foreign direct investment, in order to benefit from the increased welfare. However, if we consider

$a = 24, c_L = 6, c_H = 8,$			
$c_Z = 2, s = 4, \Delta = 69.5, \delta = .5$			
q_{1L}	9.00	$q_2(0, c_Z + s + t^*)$	2.00
q_{1H}	8.00	t^*	6.00
$\underline{q}_1(t^*)$	12.35	$\bar{\Delta}(t^*)$	83.11
$\underline{q}_1(0)$	9.08	$\underline{\Delta}(t^*)$	71.11
$W_{1L}\left(\underline{q}(t^*)\right)$	146.06	$W_2(0, c_X, t^*)$	126.00
$W_{1L}^1\left(\underline{q}(0)\right)$	122.22	$W_2(0, c_X)$	111.11

Table 3.3: Results of Separating Equilibrium (B) Caption

first period welfare with signalling, we see that the welfare gains from imposing a high tariff may not be so beneficial after all, i.e.,

$$W_{1L}\left(\underline{q}(t^*)\right) + \delta W_2(0, c_X, t^*) > W_{1L}\left(\underline{q}(0)\right) + \delta W_2(0, c_Z)$$

$$159.69 + 122 > 124.8 + 134.00 \tag{3.67}$$

$$281.69 > 258.8 \tag{3.68}$$

Thus, the gains from signalling in the first period may outweigh the gains from FDI in the second period.[10] Nevertheless, this is not the only case. In Table 3.3 we see that for a different choice of parameter values, second period welfare may be lower when FDI is the chosen mode of entry. In the symmetric information equilibrium, a government would never set a high tariff to induce FDI as this would result in lower second period welfare, regardless of the gains from signalling in the first period. We can see that for the case where welfare might improve with FDI this is not always the case when limit pricing is present.

Let us now turn to the pooling equilibrium. According to Levy and Nolan (1992) a simple policy conclusion is that an investment project should only be accepted when the company is 'contributing' a superior technology. However, in a pooling equilibrium the true value of the incumbent's marginal cost is unknown. Posterior

[10]In the welfare analysis, the entrant's fixed cost Z of entry into the market has been ignored. It's inclusion would lead to even lower second period welfare if FDI is the chosen mode of entry.

beliefs are updated using priors i.e. $\mu = \rho$ and so the marginal costs might be as follows:

$$c_H > \rho c_H + (1 - \rho)\, c_L > c_X > c_Z > c_L$$

Given the government's beliefs about the incumbent's marginal cost, FDI might enhance welfare because the production technology is superior i.e. $\mu c_H + (1 - \mu)\, c_L > c_Z$. Unfortunately, it might be that the incumbent has a low marginal cost thus reversing the result. A simple solution to this would be to allow FDI only if $c_Z < c_X < c_L$. This ensures that we are always on the negative sloping part of the welfare function where a reduction in the entrant's marginal cost always leads to an increase in welfare.

Finally, what about using a tariff to force a change from the pooling to the separating equilibrium? The problem here is that a government that does not have complete information about the incumbent's cost cannot be sure about the final welfare outcome. If the incumbent has a low marginal cost, a tariff can be set which will induce a separating equilibrium. This will certainly improve first period welfare and if exporting yields higher welfare than FDI, second period welfare will also improve. On the other, if the incumbent has a high marginal cost, FDI will be the mode of entry and there will be no signalling in the first period. As a result, welfare will be lower.

3.7 An Alternative Interpretation

It is possible to re-interpret the exporting-FDI model as a choice between two types of technologies. It is not uncommon for plant sizes to differ within the same industry. One reason for this might be to do with size of the market. Consider an incumbent monopolist facing a single potential entrant. The entrant can either enter on a large scale or small scale depending on the residual demand it will face. For example, if the residual demand is small, the entrant's post-entry profits will be small and so it will be unwilling to make a large plant investment. If the plant size is small we might imagine that the firm is unable to exploit fully the possible economies of scale and so production costs might be quite high. On the other hand, if residual demand is large, post-entry profits will be high and so the firm might prefer to make a large fixed investment in order to exploit economies of scale. As a result, fixed costs might well be larger under larger scale production than under small scale production. On the other hand, the economies of scale obtained under large scale production mean that marginal costs may be lower than under small scale production. Clearly, large scale and small scale production resemble FDI and exporting respectively.

If informational asymmetries exist as in the exporting-FDI model, then the same results can be obtained. Limit pricing may emerge as an equilibrium strategy, influencing the scale of production of the entrant.

3.8 Conclusion

This chapter has been an attempt to integrate two areas of research. We have demonstrated how the Milgrom and Roberts (1982) limit pricing model common in Industrial Organisation can be adapted to explain the multinational firm's decision to invest directly in a country. Previous models from International Trade have formalised this decision under complete information (Motta 1992, Smith 1987, Buckley and Casson 1981), showing that cost-incentives can be used to distinguish between the different entry modes. These papers have done much to illustrate the relationship between exporting and FDI. However, their focus on the multinational has led them to ignore an important aspect: the domestic producer. Papers regarding dominant incumbent monopolists and their entry deterring capabilities are widespread in Industrial Organisation (see Martin 1995 for an overview of the most important). Being first in the market gives a firm certain advantages over those that follow, allowing them to make entry-deterring strategic investments (Fudenberg and Tirole 1983). We have shown that informational advantages can be used not to deter entry but to influence how it takes place.

Motta (1992) and Smith (1987) have shown the importance of residual demand and the entry mode. The larger the demand a firm faces, the more likely it is to choose foreign direct investment as the mode of entry. By combining this idea with the Milgrom and Roberts (1982) limit pricing model, we can show conditions where and incumbent can use pre-entry prices to signal information about future demand. If the signal tells the entrant that the post-entry demand is small, exporting is the chosen mode of entry. On the other hand, if the signal tells the entrant that post-entry demand is large, then FDI is the chosen mode of entry.

Furthermore, we have shown in this chapter that a domestic producer may have some influence over the mode of entry. Unlike previous papers where investment decisions are determined by parameter values, we show that the incumbent is able to actively affect the entry mode by manipulating market information. This is an important step as it emphasizes the effect that incumbent strategies may have on foreign investments.

We have also seen the effect of tariffs on the signalling behaviour of the incumbent. We see that trade policy may not only affect the entry mode but also the strategy of the incumbent. We saw that for small tariffs, the limit price fell. Moreover, if the separating equilibrium is supported by pre-entry monopoly prices, then a small tariff may lead to first period distortions, thus increasing welfare. If on the other hand, a large tariff is imposed, FDI becomes the dominant mode of entry and there will be no limit pricing in the first period. Although the tariff has a monotonic effect the choice of entry mode (as t increases we will always switch from exporting to FDI) this cannot be said of the incumbent's equilibrium strategy: an increasing tariff may lead to increased pre-entry price distortions as well as decreasing them. However, it must be noted that throughout the change in the incumbent's prices, we remain within the separating equilibrium.

In the pooling equilibrium, the entry mode is exporting for both incumbent cost types. We see therefore, that it is possible for an incumbent to manipulate information such that the entrant chooses a sub-optimal entry mode. A small tariff may overturn the pooling equilibrium forcing the low cost incumbent to separate. The entry mode then changes if the incumbent is revealed to have a high cost. However, a large tariff will lead to FDI being the mode of entry for all cost types. Nevertheless, a separating equilibrium still exists although it may no longer be distortionary in first period prices.

Finally, we looked at the effects on welfare. We saw that tariffs may lower the limit price and thus leads to first period welfare gains. By setting the tariff too high, FDI is encouraged and there may be no first period price distortions. However, although tariffs may lead to first period welfare gains, we must also consider their effect on second period welfare. The literature on optimal tariffs is abundant (see Levy and Nolan 1992), however, if a tariff forces a switch from exporting to FDI the welfare gains are not so clear. Switching to FDI implies that the incumbent will operate at a lower marginal cost than under exporting. Of course, this means that market prices in the domestic market may be lower but we must also remember that the profits of the domestic producer fall. Brander and Krugman (1983) and Levy and Nolan (1992) have both shown that the relationship between welfare and the marginal cost of the entrant is convex. Therefore, a fall in the entrant's marginal cost through FDI may increase or decrease welfare. What is also apparent is that by forcing FDI as a mode of entry, first period welfare as well as second period welfare may fall.

The conclusion of this chapter is that asymmetric information may lead to pre-entry signalling to influence the mode of entry. Furthermore, tariffs can be used to trigger or dampen these strategies which in turn leads to ambiguous welfare effects.

Chapter 4

Signalling for Entry

4.1 Introduction

Strategic entry deterrence is a subject that has interested industrial economists for years. The classic scenario of the incumbent monopolist faced by a potential entrant has been modeled in many different ways (see Gilbert 1987 for an overview). However, if we view firms operating in international markets, the scenario changes somewhat. For example, is it reasonable to consider the entrant as a new firm in the market or is it already an existing firm in some other market? Furthermore, should the incumbent be limited to its own market? The introduction of oligopoly theory to international trade and entry can be attributed primarily to Brander (1981) and Brander and Krugman (1983). By assuming that a potential entrant is an incumbent in a foreign market immediately leads to the possibility of reciprocal entry, whereby incumbent monopolists decide to simultaneously enter each other's markets. In this chapter we explore these issues, defining firms as both entrant and incumbent. By imposing incomplete information on certain parameters, we see that the firms use their pre-entry strategies not only to deter entry but to enhance their own entry in other markets. Using limit pricing as the vehicle for entry deterrence we are able to complement and contrast some of the results of Mailath (1989). Firms indeed use the limit price to deter entry but it also serves to enhance market share abroad.

4.1.1 Literature

The origins of limit pricing can be found in Bain (1949,1956). The informational link that we use in this paper is due to Milgrom and Roberts (1982). They focus on how an incumbent monopolist can use informational asymmetries to deter entry. However, Mailath (1989) extends their results by showing that signalling behaviour emerges even when entry is not deterred. He shows that two firms in a market who are uncertain over each other's costs will attempt to signal in an attempt to preserve their market share. For example, if a low cost incumbent does not signal it has a low cost, its rival will consider it have a high marginal cost and thus produce more. By signalling its cost type, the low cost incumbent is able to preserve its market share. A crucial difference in the set-up of the Mailath model is that information is not necessarily fully revealed in the second period, as is the case in the Milgrom and Roberts (1982) model. Milgrom and Roberts (1982) make the simplifying assumption that on entry all information is revealed. If this assumption was used in the Mailath model, the low cost incumbents would not signal their cost type for the simple reason that in the second period, the other firm will learn its cost type and produce accordingly.

Extensions of the Milgrom and Roberts (1982) model have been considerable. A multi-market model of limit pricing was formalised by Srinivasan (1991) and Bagwell (1993). It is interesting to note that Srinivasan (1991) also highlights the importance of foreign markets to the incumbent. In his model, the incumbent operates in two markets before the entry stage. If the markets are symmetric, independent and combined signalling yield the same results on the limit price. However, if differences do exist in terms of the demand parameter, combined signalling reduces the cost of signalling for the incumbent. However, we will show that the existence of another market enhances signalling behaviour, even if the markets are identical in terms of cost and market demand.

The reciprocal entry model that we use is similar to that of Brander (1981) and Brander and Krugman (1983) (from now on the B–K model). They modeled two monopolistic incumbents who simultaneously enter each other's home market. The interesting point is that trade takes place although the goods are identical. The upshot is that transportation costs raise costs and hence prices, resulting in lower firm profits. However, due to the Cournot conjectures where each firm assumes the other's output is given, reciprocal entry takes place. We can use this result to explain why incumbents would want to enter a foreign market only to compete with a firm producing exactly the same product. The introduction of incomplete information allows the incumbents to protect their home markets as well as enhancing their foreign market share. The final result is that the B–K result may still arise.

Initially, we assume, as B–K, two monopolists in two geographically separate markets which at some point in time are able to enter each other's home market simultaneously. Both incumbents have restricted information about the other firm's marginal cost, which is of either a high or low type. This game of two-sided asymmetric information closely resembles that of Mailath (1989). Similarly, we find that signalling for market share exists in the separating equilibrium as firms attempt to protect their own market and increase their market share in the foreign market. However, pooling behaviour represents a fall in market share for the low cost incumbent and therefore, a loss in profits. Therefore, a low cost firm in Mailath's model would never pool. In this paper, pooling might arise because of deterring entry from the home market. Although such behaviour will lead to a loss in expected market share in the foreign market for the low cost incumbent, the gains in the home market may be sufficient to compensate. If this is the case, a high cost incumbent is able to deter entry from the home market and increase its market share in the foreign market. If entry cannot be deterred from the home market, then no pooling equilibrium will exist. Furthermore, when conditions are such that a high cost incumbent cannot profitably imitate the strategy of a low cost incumbent in order to deter entry, a pooling equilibrium may still be possible if the gain in market share in the foreign market is significantly increased by the signal. In other words, signalling for entry may arise as an equilibrium strategy in the pooling equilibrium.

The importance of market share becomes more acute when we extend the model to $n+1$ markets and firms. In this scenario, the limit price might either rise or fall as the number of firms increases. If *a priori* beliefs are such that an incumbent believes all other firms to have a high marginal cost then the limit price falls. In fact, the fall might be so large that this leads to negative prices and hence the equilibrium breaks down. However, pricing below marginal cost is possible. On the other hand, if *a priori* beliefs are such that the incumbent believes all the other firms to have a low marginal cost, then the limit price increases towards the monopoly price. This is because expected market share gains fall over all the markets and hence the firm tries to maximise its pre-entry profits. Pooling still occurs in the $n+1$ firm case, although as n increases, the low cost type requires a lower discount factor in order to bind it to the pooling strategy. This is because a low cost incumbent loses market share across markets in the pooling equilibrium, but gains in the first period from not signalling. The opposite is the case for the high cost incumbent. It sacrifices first period profits in order to gain market share across markets in the second period. As a result, as the number of markets increases, the range of discount factors that bind it to imitating the low cost incumbent's first period strategy, increases.

The paper is organised as follows. In Section 4.2 the reciprocal entry model in a setting of incomplete information is outlined. In Section 4.3 the existence of the separating equilibrium is demonstrated for differing fixed costs. Section 4.4 shows the conditions required for the pooling equilibrium. In Section 4.5 we show the effect on the limit price by increasing the number of markets where entry can take place. Section 4.6 concludes.

4.2 The Model

Let us consider a two period game with two countries 1 and 2. In the first period, a homogenous good is produced by quantity setting incumbent monopolists 1 and 2 whose home markets are 1 and 2 respectively. The inverse demand function is assumed linear and is given by $p^i = a - Q^i$ where $Q^i = q_i^i + q_j^i$ for $q_i^i > 0$ and $q_j^i \geq 0$, $i, j \in \{1, 2\}$ (we use superscripts to denote market and subscripts for the firm identity, throughout). Each firm always produces in its own market but if entry takes place in the second period, then $q_j^i > 0$ and the firms compete as Cournot duopolists. The marginal cost of each incumbent is constant where $c_{i=1,2} \in \{c_L, c_H\}$, $c_H > c_L$. On entry into the other market, each incumbent must cover a fixed cost F_i (i.e. the fixed cost that i covers when entering a market—a firm's fixed cost is already covered for production in its own market).

In the second period, we have four possible outcomes:

1. 1 enters 2, 2 does not enter 1.

2. Both 1 and 2 enter the other's market.

3. 1 does not enter 2, 2 enters 1.

4. Neither 1 nor 2 enter the other's market.

However, neither of the firms knows the other's marginal cost (although they know their own marginal cost). Following Harsanyi (1967–68) we assign probabilities to the incumbents' cost types. At the beginning of the first period, incumbent 1 assigns a prior probability $\rho_2 \in [0,1]$ that the incumbent in market 2, namely firm 2, has a high cost type, c_H and probability $(1-\rho_2) \in [0,1]$ that firm 2 in market 2 has a low cost type, c_L. Milgrom and Roberts (1982) have shown how first period strategies may be linked to the marginal costs of the incumbents. At the end of the first period, these beliefs can be updated using Bayes' rule. Firm 1 is able to form posterior beliefs $\mu_2 \in [0,1]$.

4.2.1 Second Period Profits

Before we turn to the signalling game, we need to know the second period outputs and profits that result after trade has taken place. As neither firm knows the actual cost type of the other, they are forced to use their prior beliefs in deriving their expected profits. However, they know their own cost type and the cost type that the other firm will be believe they have at the end of the second period.

Let us now compute equilibrium outputs and profits when cost types are unknown. Firms have marginal costs c_H and c_L with prior probabilities ρ_i and $(1-\rho_i)$ and

$i\theta$	firm i of cost type θ, where $i \in \{1,2\}$ and $\theta \in \{H, L\}$.
$\hat{q}_{i\theta}$	first period output of firm $i\theta$
$q_{i\theta}$	monopoly output of firm i of cost type θ.
F_i	fixed entry cost of firm i.
$\pi^i_{i\theta}$	monopoly profits of $i\theta$ in market i.
$\pi^i_{i\theta}(q_i)$	first period profits of $i\theta$ in market i when producing q_i.
$\pi^i_{i\theta}(\mu_i, \rho_j)$	second period duopoly profits of $i\theta$ when beliefs are μ_i and ρ_j.
$\pi^i_j(\mu_i, \rho_j)$	i's expected second period duopoly profits of firm j in market i.
$E_{i\theta}(\mu_i, \rho_j)$	entry decision for i into j.
$E_j(\mu_i, \rho_j)$	i's expected entry decision for j into i.
ρ_i, μ_i	prior and posterior beliefs regarding i's cost type.

Table 4.1: Notation

posterior probabilities μ_i and $(1 - \mu_i)$ respectively. Firm i in market i maximises,

$$\pi^i_{i\theta} = \max_{q_{i\theta}} \left(a - c_\theta - q^i_{i\theta} - \mu_j q^i_{jH} - (1 - \mu_j)\, q^i_{jL}\right) q^i_{i\theta} \tag{4.1}$$

Incumbent i anticipates firm j to maximise,

$$\pi^i_{j\theta} = \max_{q_{j\theta}} \left(a - c_\theta - q^i_{j\theta} - \mu_i q^i_{iH} - (1 - \mu_i)\, q^i_{iL}\right) q^i_{j\theta} \tag{4.2}$$

The first order conditions for firm i are,

$$\frac{\partial \pi^i_{i\theta}}{\partial q_{i\theta}} = a - c_\theta - 2q^i_{i\theta} - \mu_j q^i_{jH} - (1 - \mu_j)\, q^i_{jL} = 0 \tag{4.3}$$

and for j,

$$\frac{\partial \pi^i_{j\theta}}{\partial q_{j\theta}} = a - c_\theta - 2q^i_{j\theta} - \mu_i q^i_{iH} - (1 - \mu_i)\, q^i_{iL} = 0 \tag{4.4}$$

We can then rearrange these into matrix format,

$$\begin{pmatrix} a - c_H \\ a - c_L \\ a - c_H \\ a - c_L \end{pmatrix} = \begin{pmatrix} 2 & 0 & \mu_j & (1-\mu_j) \\ 0 & 2 & \mu_j & (1-\mu_j) \\ \mu_i & (1-\mu_i) & 2 & 0 \\ \mu_i & (1-\mu_i) & 0 & 2 \end{pmatrix} \begin{pmatrix} q_{iH} \\ q_{iL} \\ q_{jH} \\ q_{jL} \end{pmatrix} \tag{4.5}$$

which yields equilibrium values,

$$q^i_{iH}(\mu_i,\mu_j) = \frac{2a - 3c_H + c_L + (c_H - c_L)(2\mu_j - \mu_i)}{6} \tag{4.6}$$

$$q^i_{iL}(\mu_i,\mu_j) = \frac{2(a - c_L) + (c_H - c_L)(2\mu_j - \mu_i)}{6} \tag{4.7}$$

$$q^i_{jL}(\mu_i,\mu_j) = \frac{2a - 3c_H + c_L + (c_H - c_L)(2\mu_i - \mu_j)}{6} \tag{4.8}$$

$$q^i_{jH}(\mu_i,\mu_j) = \frac{2(a - c_L) + (c_H - c_L)(2\mu_i - \mu_j)}{6} \tag{4.9}$$

This leads to equilibrium profits,

$$\pi^i_{iH}(\mu_i,\mu_j) = \left(\frac{2a - 3c_H + c_L + (c_H - c_L)(2\mu_j - \mu_i)}{6}\right)^2 \tag{4.10}$$

$$\pi^i_{iL}(\mu_i,\mu_j) = \left(\frac{2(a - c_L) + (c_H - c_L)(2\mu_j - \mu_i)}{6}\right)^2 \tag{4.11}$$

$$\pi^i_{jH}(\mu_i,\mu_j) = \left(\frac{2a - 3c_H + c_L + (c_H - c_L)(2\mu_i - \mu_j)}{6}\right)^2 \tag{4.12}$$

$$\pi^i_{jL}(\mu_i,\mu_j) = \left(\frac{2(a - c_L) + (c_H - c_L)(2\mu_i - \mu_j)}{6}\right)^2 \tag{4.13}$$

As we see, equilibrium outputs and profits are dependent on the firm's own cost type, the signal it sends and its beliefs about the other firm's cost. Therefore, the output of firm j is given by $q_j(\mu_i,\mu_j) = \mu_j q^i_{jH}(\mu_i,\mu_j) + (1-\mu_j) q^i_{jL}(\mu_i,\mu_j)$ which equals,

$$q^i_j(\mu_i,\mu_j) = \frac{(a - c_L) + (c_H - c_L)(\mu_i - 2\mu_j)}{3} \tag{4.14}$$

which yields expected equilibrium profits,

$$\pi^i_j(\mu_i,\mu_j) = \left(\frac{(a - c_L) + (c_H - c_L)(\mu_i - 2\mu_j)}{3}\right)^2 \tag{4.15}$$

We drop the subscript θ indicating j's cost type because the weighting is already given by μ_j.

4.2.2 The Entry Decision

The firms have two objectives: to increase profits in the domestic market and to enter the foreign market. If fixed entry costs for all firms are low (perhaps zero) then both firms will be able to enter each other's domestic market. Signalling will merely serve to increase each firm's market share, as in Mailath (1989). However, signalling may also deter entry from the domestic market and assist entry into the foreign market if fixed costs are considerable. For example, entry deterrence in the Milgrom and Roberts (1982) scenario would be represented by,

$$\pi_j^i(1,\mu_j) < F_j < \pi_j^i(0,\mu_j) \tag{4.16}$$

where the entrant's cost type is $c_j = \mu_j c_H + (1-\mu_j)c_L$. Hence, a low cost incumbent i, denoted iL can deter entry. Nevertheless, iH cannot deter entry. More generally, the entry condition requires that $i\theta$ will only enter market j when $\pi_{i\theta}^j(\mu_i,\mu_j) > F_i$ but i anticipates entry when $\pi_j^i(\mu_i,\mu_j) > F_j$.

However, this is not entirely the case in this chapter. One problem is that both incumbents i and j are forced to consider deterring entry or entering the market, respectively, in the first period, before any signalling has taken place. Indeed, the limit price they choose in the first period depends on their expected profits. As they don't know the other firm's cost, they must use their prior beliefs in estimating their expected profits. In other words, although the second period equilibrium may be a separating equilibrium, the firms do not know this when they consider their first period strategy. Therefore, incumbent i expects to earn profits $\pi_i^i(\mu_i,\rho_j)$ in the second period, using its prior beliefs to estimate the cost of the other firm. Similarly, firm i expects firm j to earn $\pi_j^i(\mu_i,\rho_j)$ on entering the market, even though firm j may expect to earn different profits on entering market i (firm j expects to earn $\pi_j^i(\rho_i,\mu_j)$ because it knows its own cost but not that of firm i). From now on, expected profits will be rewritten accordingly using the relevant prior beliefs.

First, define $E_{i\theta} \in \{0,1\}$ as the entry decision for firm $i\theta \in \{1,2\}, \theta \in \{H,L\}$ where $E_{i\theta}(\mu_i,\rho_j) = 0$ and $E_{i\theta}(\mu_i,\rho_j) = 1$ denote no entry and entry, respectively. In order words,

$$E_{i\theta}(\mu_i,\rho_j) = \begin{cases} 1 \text{ when } \pi_{i\theta}^j(\mu_i,\rho_j) > F_i \\ 0 \text{ when } \pi_{i\theta}^j(\mu_i,\rho_j) \leq F_i \end{cases} \tag{4.17}$$

The value of $E_{i\theta}(\mu_i,\rho_j)$ depends implicitly on the incumbent's first period output q_i and the prior beliefs the firm holds regarding the other firm's marginal cost.

An important point to make is that $E_{i\theta}(\mu_i, \rho_j)$ represents expected entry. In fact, $E_{i\theta}(\mu_i, \rho_j) = 1$ may not lead to entry in the second period by firm i into market j. However, given the prior beliefs that i has about j it can form expectations about its future profits which it must make if it is to signal in the first period. As we shall see, this may lead to higher first period outputs than in the Milgrom and Roberts set-up.

Secondly, define $E_j(\mu_i, \rho_j) \in \{0, 1\}$ as firm i's expected entry decision for firm j. In other words, when $\pi_j^i(\mu_i, \rho_j) > F_j$ entry is expected and $E_j(\mu_i, \rho_j) = 1$. When $\pi_j^i(\mu_i, \rho_j) < F_j$ entry is not expected to take place and $E_j(\mu_i, \rho_j) = 0$.

We have a range of entry equilibria that might exist in the second period. Take firm 1 as an example. It can expect the following scenarios:

1. $E_2(0, \rho_2) = E_2(1, \rho_2) = 1$, free entry: $\pi_2^1(\mu_1, \rho_2) > F_2$

2. $E_2(0, \rho_2) = 0, E_2(1, \rho_2) = 1$, low cost entrant only: $\pi_2^1(1, \rho_2) > F_2 > \pi_2^1(0, \rho_2)$

3. $E_2(0, \rho_2) = E_2(1, \rho_2) = 0$, no entry: $F_2 > \pi_2^1(\mu_1, \rho_2)$

Note that $E_2(0, \rho_2) \leq E_2(1, \rho_2)$. In other words, $E_2(1, \rho_2) = 0$ and $E_2(0, \rho_2) = 1$ is not possible because it implies that entry is profitable for firm 2 in market 1 only when the incumbent 1 has a low cost type. However, as $\pi_{2\theta}^1(1, \rho_2) > \pi_{2\theta}^1(0, \rho_2)$, $E_2(1, \rho_2)$ may also equal 1.

In the foreign market, firm 1 will enter according to the following.

1. $E_{1\theta}(0, \rho_2) = E_{1\theta}(1, \rho_2) = 1$, free entry: $\pi_{1\theta}^2(\mu_1, \rho_2) > F_1$

2. $E_{1\theta}(0, \rho_2) = 1, E_{1\theta}(1, \rho_2) = 0$, signal low cost to enter: $\pi_{1\theta}^2(0, \rho_2) > F_1 > \pi_{1\theta}^2(1, \rho_2)$

3. $E_{1L}(\mu_i, \rho_2) = 1, E_{1H}(\mu_i, \rho_2) = 0$, low cost firm enters, only: $\pi_{1L}^2(\mu_1, \rho_2) > F_1 > \pi_{1H}^2(\mu_1, \rho_2)$

4. $E_{1\theta}(0, \rho_2) = E_{1\theta}(1, \rho_2) = 0$, no entry: $F_1 > \pi_{1\theta}^2(\mu_1, \rho_2)$

We see that $E_{1\theta}(0, \rho_2) \geq E_{1\theta}(1, \rho_2)$ because signalling a low cost will not reduce post-entry profits. Furthermore, as $E_{1L}(\mu_i, \rho_2) \geq E_{1H}(\mu_i, \rho_2)$ a low cost entrant will not expect to earn lower post-entry profits than a high cost entrant. As we see, there exist a considerable number of equilibria.

4.2.3 Optimal Strategies

In the first period the incumbents are monopolists. They are aware that in the second period entry is threatened and that they too can enter the other market. They must therefore find an optimal strategy that maximises expected profits. From Milgrom and Roberts (1982) the firms must consider whether entry can be deterred or not while from Mailath (1989) they must check to see whether they can enter the other market or not.

Incumbent $i\theta$ optimises the following:

$$\begin{aligned} \hat{q}_i \in \; & \operatorname{argmax}\left\{\pi_{i\theta}(q_i) + \delta\left\langle E_j(\mu_i,\rho_j)\,\pi^i_{i\theta}(\mu_i,\rho_j) + (1 - E_j(\mu_i,\rho_j))\,\pi^i_{i\theta}\right\rangle \right. \\ & \left. + E_{i\theta}(\mu_i,\rho_j)\,\delta\pi^j_{i\theta}(\mu_i,\rho_j)\right\} \end{aligned}$$

where $i,j \in \{1,2\}, i \neq j, \theta \in \{H,L\}$ and $\delta \in (0,1)$ represents the discount factor in each firm's expected future profit. Finally, we state Bayes' rule for consistency of beliefs,

$$\begin{aligned} \text{if } \hat{q}_{iL} &\neq \hat{q}_{iH} \text{ then } \mu_i = 0 \text{ and } \mu_i = 1 \\ \text{if } \hat{q}_{iL} &= \hat{q}_{iH} \text{ then } \mu_i = \rho_i \end{aligned}$$

Combining the incumbent's optimisation strategy and Bayes' rule we have defined the conditions necessary for a sequential equilibrium.

To summarise, the game unfolds as follows:

- Nature chooses all firms types.
- Period One: Firms choose their first period outputs.
- Firms observe the outputs across all markets.
- Period Two: Firms enter markets where they expect positive profits.

Entry may or may not be deterred in the second period, depending on the fixed cost of entry. In the following two sections, we consider the incentive constraints that lead to both separating and pooling equilibria.

4.3 Separating Equilibrium

Let us consider the separating equilibrium. This is when the low cost incumbents find it profitable to reveal their cost type to the entrants by finding a first period output (which implies the limit price) that cannot be imitated by a high cost incumbent. Initially, we assume that fixed costs are very small so that entry is always profitable both into the domestic market and into the foreign market. This is so that the model closely resembles that of B–K in the second period equilibrium.

The incentive constraint for the low cost incumbent $1L$ can be written,

$$\begin{aligned}
&\pi_{1L}^{1}(\hat{q}_i) + \delta E_2(0,\rho_2)\,\pi_{1L}^{1}(0,\rho_2) \\
&+\delta\left(1 - E_2(0,\rho_j)\right)\pi_{1L}^{1} + \delta E_{1L}(0,\rho_2)\left[\pi_{1L}^{2}(0,\rho_2) - F_1\right] \\
&\quad > \pi_{1L}^{1} + \delta E_2(1,\rho_2)\,\pi_{1L}^{1}(1,\rho_2) \\
&\quad +\delta\left(1 - E_2\right)(1,\rho_j)\,\pi_{1L}^{1} + \delta^2 E_{1L}(1,\rho_2)\left[\pi_{1L}^{2}(1,\rho_2) - F_1\right]
\end{aligned} \tag{4.18}$$

In order that all fixed costs can be considered in the model, the entry decision remains in the incentive constraints.[1] In the proof of Proposition 4.1 that follows, each case will be examined.

For $1H$, the incentive constraint is similarly,

$$\begin{aligned}
&\pi_{1H}^{1}(\hat{q}_i) + \delta E_2(0,\rho_2)\,\pi_{1H}^{1}(0,\rho_2) \\
&+\delta\left(1 - E_2(0,\rho_j)\right)\pi_{1H}^{1} + \delta E_{1H}(0,\rho_2)\left[\pi_{1H}^{2}(0,\rho_2) - F_1\right] \\
&\quad \leq \pi_{1H}^{1} + \delta E_2(1,\rho_2)\,\pi_{1H}^{1}(1,\rho_2) \\
&\quad +\delta\left(1 - E_2(1,\rho_j)\right)\pi_{1H}^{1} + \delta E_{1H}(1,\rho_2)\left[\pi_{1H}^{2}(1,\rho_2) - F_1\right]
\end{aligned} \tag{4.19}$$

although this time we require that imitating the low cost incumbent's first period output will lead to lower profits than playing the complete information monopoly

[1] Note that we write the first period output of firm $i\theta$ as $\hat{q}_i$ instead of $\hat{q}_{i\theta}$ as the cost type of the incumbent is indicated by the subscript on $\pi_{i\theta}$.

output in the first period.[2] Equations 4.18 and 4.19 are necessary conditions for a separating equilibrium.

For a separating equilibrium to exist, we need to show that the high cost incumbent finds it more expensive to deviate from its first period monopoly output than the low cost incumbent. This follows in fact from the concavity of the profit functions. However, the profitability of signalling must satisfy the two following conditions which are sufficient for obtaining a separating equilibrium. For the home market, we have,

$$\begin{aligned} &E_2(1,\rho_2)\left(\left[\pi_{1L}^1-\pi_{1L}^1(1,\rho_2)\right]-\left[\pi_{1H}^1-\pi_{1H}^1(1,\rho_2)\right]\right) \\ &\quad > E_2(0,\rho_2)\left(\left[\pi_{1L}^1-\pi_{1L}^1(0,\rho_2)\right]-\left[\pi_{1H}^1-\pi_{1H}^1(0,\rho_2)\right]\right) \end{aligned} \tag{4.20}$$

We can see that 4.20 suggests several sufficiency conditions. Remember that and $E_2(1,\rho_2) \geq E_2(0,\rho_2)$. Therefore, we require,

$$\pi_{1L}^1-\pi_{1L}^1(1,\rho_2) > \pi_{1H}^1-\pi_{1H}^1(1,\rho_2) \tag{4.21}$$

and

$$\pi_{1L}^1(0,\rho_2)-\pi_{1L}^1(1,\rho_2) > \pi_{1H}^1(0,\rho_2)-\pi_{1H}^1(1,\rho_2) \tag{4.22}$$

for $E_2(1,\rho_2) = 1, E_2(0,\rho_2) = 0$ and $E_2(1,\rho_2) = E_2(0,\rho_2) = 1$, respectively. Inequality 4.21 expresses the profitability of signalling when entry is deterred. This outcome is similar to that of Milgrom and Roberts (1982). Inequality 4.22 shows the profitability of increasing post-entry market share, similar to the result of Mailath (1989).

For the foreign market we have,

$$\begin{aligned} &E_{1L}(0,\rho_2)\left[\pi_{1L}^2(0,\rho_2)-F_1\right]-E_{1L}(1,\rho_2)\left[\pi_{1L}^2(1,\rho_2)-F_1\right] \\ &\quad > E_{1H}(0,\rho_2)\left[\pi_{1H}^2(0,\rho_2)-F_1\right]-E_{1H}(1,\rho_2)\left[\pi_{1H}^2(1,\rho_2)-F_1\right] \end{aligned} \tag{4.23}$$

For $E_{1\theta}(1,\rho_2) = E_\theta(0,\rho_2) = 1$ the following condition arises,

$$\pi_{1L}^2(0,\rho_2)-\pi_{1L}^2(1,\rho_2) > \pi_{1H}^2(0,\rho_2)-\pi_{1H}^2(1,\rho_2) \tag{4.24}$$

[2] We ignore case of equality.

Given the symmetry, this is identical to inequality 4.22. If $E_{1\theta}(1,\rho_2) = 0$. $E_{1\theta}(0,\rho_2) = 1$, then we obtain,

$$\pi^2_{1L}(0,\rho_2) > \pi^2_{1H}(0,\rho_2) \tag{4.25}$$

and finally, for $E_{1L}(\mu_i,\rho_2) = 1, E_{1H}(\mu_i,\rho_2) = 0$,

$$\pi^2_{1L}(0,\rho_2) > \pi^2_{1L}(1,\rho_2) \tag{4.26}$$

The last two conditions clearly hold because a low cost incumbent always earns higher profits than a high cost incumbent and signalling a low cost type will always enhance profits. The inequalities 4.21, 4.22, 4.24, 4.25 and 4.26 provide the conditions necessary for a separating equilibrium.

Proposition 4.1 *As long as $E_j(\mu_i,\rho_j) + E_{i\theta}(\mu_i,\rho_j) \geq 1$, there exists at least one separating equilibrium.*

Proof. See Appendix.

Proposition 4.1 requires that only one of the inequalities 4.21, 4.22, 4.24, 4.25 and 4.26 hold for a separating equilibrium to hold. If at least one of the conditions holds, then $E_j(\mu_i,\rho_j) + E_{i\theta}(\mu_i,\rho_j)$ can be no less than one because entry will take place somewhere. Indeed, this is what drives the separating equilibrium: either firm 1 will enter market 2 or firm 2 will enter market 1. Either way, this leads to limit pricing behaviour in the first period.

We have shown that whether or not entry takes place, limit pricing may emerge as an equilibrium strategy in the first period. In other words, we might find that pre-trade prices might be lower than the monopoly price levels. From Milgrom and Roberts (1982), limit pricing emerges to deter entry. However, Mailath (1989) has shown that this is not necessary for signalling behaviour to exist. Consequently, it is not surprising that limit pricing exists: if entry can be deterred, we have the model of Milgrom and Roberts (1982) and if it can't, we have the model of Mailath (1989). Indeed, if Milgrom and Roberts (1982) had made less simplistic assumptions about post-entry information, they would also have obtained the same result as Mailath (1989).

Let us look again at the possible entry scenarios.

1. $E_2(0,\rho_2) = E_2(1,\rho_2) = 1$, free entry: $\pi_2^1(\mu_1,\rho_2) > F_2$

2. $E_2(0,\rho_2) = 0, E_2(1,\rho_2) = 1$, low cost entrant only: $\pi_2^1(1,\rho_2) > F_2 > \pi_2^1(0,\rho_2)$

3. $E_2(0,\rho_2) = E_2(1,\rho_2) = 0$, no entry: $F_2 > \pi_2^1(\mu_1,\rho_2)$

This symbolizes the entry decision of firm 2 according to firm 1. In case 1 fixed costs are so low that firm 2 always enters market 1 whatever its cost. Nevertheless, a low cost incumbent may still limit price in order to protect its market share (Mailath 1989). In case 2 only a low cost firm 2 will enter market 1. As prior beliefs are such that $\pi_2^1(1,\rho_2) > F_2$ (as we are in the separating equilibrium) a low cost firm 1 will signal its cost in the first period (Milgrom and Roberts 1982). Finally, case 3 shows that entry is completely blockaded, whatever firm 1's cost. As a result there will be no limit pricing in the pre-entry stage.

However, this is half the story. We now have to consider firm 1's entry decision which is also dependent on it cost and first period strategy. In the foreign market, firm 1 will enter according to the following.

1. $E_{1\theta}(0,\rho_2) = E_{1\theta}(1,\rho_2) = 1$, free entry: $\pi_{1\theta}^2(\mu_1,\rho_2) > F_1$

2. $E_{1\theta}(0,\rho_2) = 1, E_{1\theta}(1,\rho_2) = 0$, signal low cost to enter: $\pi_{1\theta}^2(0,\rho_2) > F_1 > \pi_{1\theta}^2(1,\rho_2)$

3. $E_{1L}(\mu_i,\rho_2) = 1, E_{1H}(\mu_i,\rho_2) = 0$, low cost firm enters, only: $\pi_{1L}^2(\mu_1,\rho_2) > F_1 > \pi_{1H}^2(\mu_1,\rho_2)$

4. $E_{1\theta}(0,\rho_2) = E_{1\theta}(1,\rho_2) = 0$, no entry: $F_1 > \pi_{1\theta}^2(\mu_1,\rho_2)$

In the first case, firm 1 can always enter market 2 whatever its first period strategy and its cost type. However, signalling in the first period will enhance firm 1's market share in market 2, hence raising its profits. In case 2 we see that firm 1 can only enter the other market if it signals a low cost type, regardless of its actual cost. In other words, it must signal to enter, otherwise its market share will be too small to make sufficient profits to cover the fixed entry cost. In case 3 only the low cost firm can enter the other market signalling and finally, in the fourth case neither type of firm 1 can enter market 2 and so there will be no first period signalling.

If we compare the two sets of entry decisions, we see that limit pricing will not occur when entry is entirely deterred in both markets. Otherwise, the low cost firm will always want to separate from the high cost type. Therefore, it is possible that firm 2 will never enter market 1 because its fixed entry cost cannot be covered i.e. $F_2 > \pi_2^1(\mu_1, \rho_2)$. Under these circumstances, firm 1 does not need to signal to deter entry. On the other hand, if it is considering to enter market 2, signalling will both ensure profitable entry (case 2) and enhance market share (case 1,3). As we can see, limit pricing may be purely for entry, not only for entry deterrence.

4.3.1 The Effect on Limit Price

It is worthwhile considering the effect on the limit price when the firm has the possibility of entering a foreign market. The least cost separating output $\underline{q}_1$ is the smallest output that the incumbent can choose for which the separating equilibrium still holds. We find this output defined by the level of production needed to set inequality 4.19 to equality. Thus we can rearrange 4.19 and define

$$\begin{aligned}
\pi_{1H}^1 - \pi_{1H}^1\left(\underline{q}_1\right) &= \Psi \\
&\equiv \left[E_2(0,\rho_2)\,\pi_{1H}^1(0,\rho_2) + (1 - E_2(0,\rho_2))\,\pi_{1H}^1\right] \qquad (4.27) \\
&\quad - \left[E_2(1,\rho_2)\,\pi_{1H}^1(1,\rho_2) + (1 - E_2(1,\rho_2))\,\pi_{1H}^1\right] \\
&\quad + E_{1H}(0,\rho_2)\left[\pi_{1H}^2(0,\rho_2) - F_1\right] \\
&\quad - E_{1H}(1,\rho_2)\left[\pi_{1H}^2(1,\rho_2) - F_1\right] \qquad (4.28)
\end{aligned}$$

as a proxy for the limit price. If Ψ increases then the least cost separating output increases. We can now compare this to the Milgrom and Roberts (1982) case without the foreign market (i.e. $E_{1H}(0,\rho_2) = E_{1H}(1,\rho_2) = 0$). We obtain

$$\begin{aligned}
\pi_{1H}^1 - \pi_{1H}^1(\hat{q}_1) &= \Psi_{\mathrm{M\&R}} \\
&\equiv \left[E_2(0,\rho_2)\,\pi_{1H}^1(0,\rho_2) + (1 - E_2(0,\rho_2))\,\pi_{1H}^1\right] \\
&\quad - \left[E_2(1,\rho_2)\,\pi_{1H}^1(1,\rho_2) + (1 - E_2(1,\rho_2))\,\pi_{1H}^1\right] \qquad (4.29)
\end{aligned}$$

Clearly, $\Psi_{M\&R} \leq \Psi$ which implies that the limit price (least cost separating output) in the Milgrom and Roberts model is higher (lower) than that obtained when the firm can enter a foreign market.

This result is driven by the larger profits available in the foreign market to the high cost incumbent if it is able to signal effectively that it has a low marginal cost.

4.4 Pooling Equilibrium

In the pooling equilibrium of Milgrom and Roberts (1982), the entrant learns nothing about the incumbent's marginal cost by observing its output and so updates its posterior beliefs using its priors. However, if beliefs are such that entry is deterred, the low cost incumbent has an incentive to pool deterring entry without using costly pre-entry price distortions. The high cost firm has an incentive to imitate this strategy, hence both firm types will deter entry in the second period. Unfortunately, Mailath (1989) is unable to show the existence of a pooling equilibrium for the reason that entry cannot be deterred. Consequently, the low cost firm will always separate in order to protect its market share and expected profits. In the present chapter, the low cost incumbents are faced with deterring entry and enhancing market share. By pooling, they can deter entry costlessly although at the expense of their foreign profits. Clearly, pooling has a double-edged effect: on the one hand it implies that entry can be deterred without costly pre-entry price distortions whilst on the other, profits in the foreign market are reduced.

In the following section we shall look at the incentives (and disincentives) of the low cost firm to pool. Furthermore, we need to check to see whether the high cost firm finds it profitable to imitate such a strategy. As we shall see, pooling equilibria do exist, although under more restrictive conditions than those provided by Milgrom and Roberts (1982). Indeed, we shall see that the decision to pool depends on the relative gains in the home and foreign markets.

4.4.1 Incentives of the Low Cost Firm

The incentive for a low cost incumbent to pool is that it can deter entry without having to signal in the first period (which is costly). Pooling equilibria are driven by the fixed cost of entry and the prior beliefs of the entrant. For example, firm 1 must believe that the profits earned by firm 2 in the post-entry game will be

$$F_2 > \pi_2^2(\rho_1, \rho_2) \tag{4.30}$$

In other words, given the fixed cost and the prior beliefs, entry will not take place (i.e. $E_2(\rho_1, \rho_2) = 0$). Therefore, given that in the pooling equilibrium firm 2 updates using its prior beliefs, firm 1 expects that this will lead to firm 2 not entering market 1. Of course, firm 1 does not know firm 2's true type, but it estimates it using its prior beliefs ρ_2.

Allowing imitation requires a reversal of the incentive constraints. If the pooling strategy deters entry, then the low cost incumbent will play its monopoly output in the first period q_{1L} (this is not the only pooling output, but it is the Pareto optimum for firm 1 as any other output would lead to lower profits). However, the incumbent's profit on entry into market 2 is reduced because $\pi_{1L}^2(0, \rho_2) > \pi_{1L}^2(\mu_1, \rho_2)$. In other words, pooling reduces its expected profits because firm 2 will produce a higher output than it would if it were producing against a low cost firm for certain.

Consequently, for a pooling equilibrium to exist, we require

$$\begin{aligned} &\pi_{1L}^1\left(\underline{q}_1\right) + \delta\pi_{1L}^1 + \delta E_{1L}(0, \rho_2)\left[\pi_{1L}^2(0, \rho_2) - F_1\right] \\ &\quad < \pi_{1L}^1 + \delta\pi_{1L}^1 + \delta E_{1L}(\rho_1, \rho_2)\left[\pi_{1L}^2(\rho_1, \rho_2) - F_1\right] \end{aligned} \tag{4.31}$$

This tells that pooling in the first period yields higher profits for the firm than could be obtained under a separating equilibrium (the separating equilibrium two-period profits being on the LHS of inequality 4.31).

$$\delta < \phi_L(\rho_1) \equiv \frac{\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right)}{E_{1L}(0, \rho_2)\left[\pi_{1L}^2(0, \rho_2) - F_1\right] - E_{1L}(\rho_1, \rho_2)\left[\pi_{1L}^2(\rho_1, \rho_2) - F_1\right]} \tag{4.32}$$

This defines an upper bound on the discount factor δ which supports the pooling equilibrium. If $\rho_1 = 0$ the denominator gets smaller (or remains unchanged) and so $\phi_L(0) \geq \phi_L(\rho_1)$. On the other hand, if $\rho_1 = 1$ then denominator gets bigger (or remains unchanged) and so $\phi_L(1) \leq \phi_L(\rho_1)$. We can conclude that $\partial\phi_L(\rho_1)/\partial\rho_1 \leq 0$. In other words, if δ gets bigger, we have a smaller range of beliefs over which the pooling equilibrium can be supported. Intuitively, the larger the discount factor, the higher the low cost firm's expected future profits are in the foreign market. Pooling lowers these profits and so the firm requires lower values of ρ_1 if it is to pool in the first period.

Let us consider the different entry decisions in order to get a full picture of what is going on. The entry decisions of the low cost firm are as follows:

1. $E_{1L}(0,\rho_2) = E_{1L}(\rho_1,\rho_2) = 1$
2. $E_{1L}(0,\rho_2) = 1, E_{1L}(\rho_1,\rho_2) = 0$
3. $E_{1L}(0,\rho_2) = E_{1L}(\rho_1,\rho_2) = 0$

We need to check under what conditions a pooling equilibrium exists for each entry decision.

If $E_{1L}(0,\rho_2) \geq E_{1L}(\rho_1,\rho_2) = 1$ then firm 1 will enter market 2 when it pools. Therefore, inequality 4.31 reduces to,

$$\delta < \phi'_L(\rho_1) \equiv \frac{\pi^1_{1L} - \pi^1_{1L}\left(\underline{q}\right)}{\pi^2_{1L}(0,\rho_2) - \pi^2_{1L}(\rho_1,\rho_2)} \tag{4.33}$$

for the low cost type incumbent, where $\underline{q}$ represents the least cost separating output.[3]

We see that inequality 4.33 imposes an upper bound on the range of the discount factors that support the pooling equilibrium. The numerator represents the first period profits lost from limit pricing while the denominator indicates the gain in profits in market 2 by signalling a low cost.

If the gains abroad from signalling are large, then pooling will only be supported by a small discount factor. This means that second period profits are relatively unimportant to firm 1 and so it is less concerned with the profits it might earn in the

[3] The least cost separating output $\underline{q}$ is a proxy of the limit price. It is the smallest output that a low cost type incumbent can produce at with out overturning the separating equilibrium.

foreign market. On the other hand, if separating is costly (i.e. $\underline{q}$ is relatively bigger than the monopoly output) then pooling becomes more attractive, despite the losses that might result abroad.

We can compare this result with that of Milgrom and Roberts (1982). They argue that if prior beliefs are such that entry is deterred in the pooling equilibrium, the incumbent will always find such a strategy possible. To see this, suppose $E_{1L}(\mu_1, \rho_2) = 0$ so that the incumbent's only strategy is to deter entry. Then inequality 4.31 reduces to

$$\pi_{1L}^1\left(\underline{q}_1\right) + \delta\pi_{1L}^1 < \pi_{1L}^1 + \delta\pi_{1L}^1 \tag{4.34}$$

which holds for all δ for $\underline{q}_1 > q_{1L}$. The impact of the foreign market on limit pricing behaviour is essentially Mailath's (1989) result. In his paper pooling equilibria do not exist because firms always find it profitable to protect market share. However, here we see the two forces at work: the desire to reduce costly pre-entry price distortions and the enhancement of market share abroad. It is interesting to note that if

$$\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right) > \pi_{1L}^2(0, \rho_2) - \pi_{1L}^2(\rho_1, \rho_2) \tag{4.35}$$

a pooling equilibrium always exists as this allows discount factors $\delta = 1$.

Now let us consider a second scenario. Suppose $E_{1L}(0, \rho_2) = 1, E_{1L}(\rho_1, \rho_2) = 0$. Firm 1 is only able to enter market 2 if it signals its cost type in the first period, hence in a pooling equilibrium it will not expect to enter market 2 (although it may once costs have been revealed). Inequality 4.31 reduces to,

$$\delta < \phi_L''(\rho_1) \equiv \frac{\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right)}{\pi_{1L}^2(0, \rho_2) - F_1} \tag{4.36}$$

As $\pi_{1L}^2(0, \rho_2) > F_1 > \pi_{1L}^2(\rho_1, \rho_2)$ implies $E_{1L}(0, \rho_2) = 1, E_{1L}(\rho_1, \rho_2) = 0$ then comparing this to inequality 4.33, $\phi_L'(\rho) < \phi_L''(\rho)$ can be written

$$\frac{\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right)}{\pi_{1L}^2(0, \rho_2) - \pi_{1L}^2(\rho_1, \rho_2)} < \frac{\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right)}{\pi_{1L}^2(0, \rho_2) - F_1} \tag{4.37}$$

Indeed, as F_1 increases to $\pi_{1L}^2(0, \rho_2)$, the upper bound of discount factors that support the pooling equilibrium goes to 1. When $E_2(\rho_1, \rho_2) = E_{1L}(0, \rho_2) = E_{1L}(\rho_1, \rho_2) = 0$

pooling will always occur for all $\delta > 0$. This is because firm 1 does not expect to make profits in market 2 and so concentrates on its own market where the pooling equilibrium is always preferable to the separating equilibrium (Milgrom and Roberts 1982).

4.4.2 Incentives for the High Cost Firm

We need to check whether the high cost incumbent finds it profitable to imitate the first period strategy of the low cost incumbent. In doing so, it deters entry from its home market and improves its position in the foreign market because $\pi_{1H}^{2}(\mu_1, \rho_2) > \pi_{1H}^{2}(1, \rho_2)$. The condition for pooling is thus,

$$\begin{aligned} \pi_{1H}^{1}(q_{1L}) + \delta\pi_{1H}^{1} + \delta E_{1H}(\rho_1, \rho_2)\left[\pi_{1H}^{2}(\rho_1, \rho_2) - F_1\right] \\ \geq \pi_{1H}^{1} + \delta\pi_{1H}^{1}(1, \rho_2) + \delta E_{1H}(1, \rho_2)\left[\pi_{1H}^{2}(1, \rho_2) - F_1\right] \end{aligned} \qquad (4.38)$$

On the LHS of inequality 4.38 we have the two period profits that $1H$ can expect to earn if it is able to imitate the pre-entry strategy of firm $1L$. On the RHS we have the profits that $1H$ would earn in a separating equilibrium i.e. it produces its monopoly output in the first period and reveals its cost as being high. Rewriting the above we get

$$\begin{aligned} \delta \geq \phi_H(\rho_1) \equiv \left[\pi_{1H}^{1} - \pi_{1H}^{1}(q_{1L})\right] / \Big(\pi_{1H}^{1} + E_{1H}(\rho_1, \rho_2)\left[\pi_{1H}^{2}(\rho_1, \rho_2) - F_1\right] \\ - \pi_{1H}^{1}(1, \rho_2) - \delta E_{1H}(1, \rho_2)\left[\pi_{1H}^{2}(1, \rho_2) - F_1\right]\Big) \end{aligned} \qquad (4.39)$$

which defines a lower bound on the range of the discount factors that support the pooling equilibrium. Let us look at the range of prior beliefs that support the pooling equilibrium. If $\rho_1 = 0$ the denominator gets bigger (or remains the same) so $\phi_H(0) \leq \phi_H(\rho_1)$. On the other hand, if $\rho_1 = 1$ the denominator gets smaller (or remains the same) thus $\phi_H(\rho_1) \leq \phi_H(1)$. We can conclude that $\partial\phi_H(\rho_1)/\partial\rho_1 \geq 0$ implying that if δ is large, a larger range of prior beliefs will support the pooling equilibrium. It is clear that if we are to show the existence of a pooling equilibrium we will need to show that $\phi_L(\rho_1) > \phi_H(\rho_1)$. We shall find later that this is indeed the case, leaving the proof to the appendix.

Let us write out the entry decisions of the high cost firm.

1. $E_{1H}(\rho_1, \rho_2) = E_{1H}(1, \rho_2) = 1$

2. $E_{1H}(\rho_1, \rho_2) = 1, E_{1H}(1, \rho_2) = 0$

3. $E_{1H}(\rho_1, \rho_2) = E_{1H}(1, \rho_2) = 0$

Let us see what happens when $1H$ is able to enter market 2. Suppose $E_{1H}(\rho_1, \rho_2) \geq E_{1H}(1, \rho_2) = 1$. Then 4.38 reduces to,

$$\delta\left[\pi_{1H}^1 - \pi_{1H}^1(1, \rho_2)\right] + \delta\left[\pi_{1H}^2(\rho_1, \rho_2) - \pi_{1H}^2(1, \rho_2)\right] \geq \pi_{1H}^1 - \pi_{1H}^1(q_{1L}) \tag{4.40}$$

The first term on the LHS represents the gains from pooling according to the Milgrom and Roberts model. Entry is deterred and hence $1H$ earns monopoly profits in the second period. This gain must be sufficiently large to compensate for first period losses. The second term on the LHS represents the gains from pooling by enhancing foreign market share. This is similar to the Mailath model in the sense that signalling increases market share although in his model this occurs only in the separating equilibrium. On the RHS we have the cost of pooling: the difference in profits between the separating and pooling equilibria. Rearranging we obtain

$$\delta \geq \phi'_H(\rho_1) \equiv \frac{\pi_{1H}^1 - \pi_{1H}^1(q_{1L})}{\left[\pi_{1H}^1 - \pi_{1H}^1(1, \rho_2)\right] + \left[\pi_{1H}^2(\rho_1, \rho_2) - \pi_{1H}^2(1, \rho_2)\right]} \tag{4.41}$$

Contrary to the low cost firm, we now define a lower bound on the discount factor $\phi'_H(\rho_1)$ which is again a function of ρ_1. Suppose

$$\delta\left[\pi_{1H}^1 - \pi_{1H}^1(1, \rho_2)\right] \leq \pi_{1H}^1 - \pi_{1H}^1(q_{1L}) \tag{4.42}$$

This is the Milgrom and Roberts (1982) incentive constraint for the separating equilibrium. We see that the high cost firm gets a higher discounted profit by playing its monopoly output in the first period and allowing entry rather than deterring entry by imitating the low cost monopoly output. Clearly, under these conditions the high cost firm will not pool (δ would have to be greater than 1). However, we must also consider the profits that the firm earns in the foreign market. By imitating the low cost firm's first period strategy the high cost firm earns higher profits than it would by revealing its cost type. If the profits gained in pooling in the foreign market are sufficiently large such that

$$\pi_{1H}^{2}(\rho_1,\rho_2)-\pi_{1H}^{2}(1,\rho_2)\geq\left[\pi_{1H}^{1}-\pi_{1H}^{1}(q_{1L})\right]-\left[\pi_{1H}^{1}-\pi_{1H}^{1}(1,\rho_2)\right] \tag{4.43}$$

pooling may still exist. In other words, although it may not be profitable for $1H$ to just deter entry by imitating $1L$'s first period output, the gains from increasing market share in market 2 may be enough to ensure a pooling equilibrium. Clearly, expected profits in 2 must be high in order to compensate for the loss in first period profits due to imitation of the low cost incumbent's output.

Nevertheless, it is interesting to see that the conditions for a Milgrom and Roberts (1982) pooling equilibrium may be violated but pooling exists because of Mailath's (1989) argument that firms will attempt to enhance their market share. The bizarre result is that pooling does not take place in the Mailath model because a low cost incumbent will always prefer to protect its market share. However, because the low cost incumbent is able to deter entry by pooling, it pools. The high cost incumbent is then able to use the profits its obtains in the foreign market in order to finance the first period signal.

Next, consider $E_{1H}(\rho_1,\rho_2)=1, E_{1H}(1,\rho_2)=0$ so that entry into 2 is only profitable if $1H$ pools. This leads to,

$$\begin{aligned}&\delta\left[\pi_{1H}^{1}-\pi_{1H}^{1}(1,\rho_2)\right]+\delta\left[\pi_{1H}^{2}(\rho_1,\rho_2)-F_1\right]\\&\geq\pi_{1H}^{1}-\pi_{1H}^{1}(q_{1L})\end{aligned} \tag{4.44}$$

Again, we see the two pooling criteria we mentioned before: the gains in the home market and the gains in the foreign market. Similarly, even if inequality 4.42 holds, we can still obtain a pooling equilibrium if,

$$\delta\geq\phi_H''(\rho_1)\equiv\frac{\pi_{1H}^{1}-\pi_{1H}^{1}(q_{1L})}{\left[\pi_{1H}^{1}-\pi_{1H}^{1}(1,\rho_2)\right]+\left[\pi_{1H}^{2}(\rho_1,\rho_2)-F_1\right]} \tag{4.45}$$

As $\pi_{1H}^{2}(\rho_1,\rho_2)>F_1>\pi_{1H}^{2}(1,\rho_2)$ it must also be that $\phi_H''(\rho_1)>\phi_H'(\rho_1)$. In other words, the lower the profits that are obtained in the pooling equilibrium, the higher the discount factor needed in order for the pooling equilibrium to be supported. This makes sense: if future profits are unimportant, the firm prefers to maximise its first period profits by setting price equal to monopoly price.

In the final case, $E_{1H}(\rho_1, \rho_2) = E_{1H}(1, \rho_2) = 0$ which means that the high cost firm can never enter the other market. Consequently, we obtain the pooling equilibrium of Milgrom and Roberts (1982) where

$$\delta \geq \phi_H''' \equiv \frac{\pi_{1H}^1 - \pi_{1H}^1(q_{1L})}{\pi_{1H}^1 - \pi_{1H}^1(1, \rho_2)} \tag{4.46}$$

We see that ϕ_H''' is not function of ρ_1. It is easy to see that $\phi_H''' > \phi_H''(\rho_1) > \phi_H'(\rho_1)$ because the denominator in ϕ_H''' is the smallest of the three. We see that foreign market entry allows for a larger range of discount factors that support the pooling equilibrium for the high cost incumbent. The possibility of foreign market profits increases expect future profit and as a consequence we can allow for lower levels of δ. On the other hand, we could fix δ and look at the range of prior beliefs that support the pooling equilibrium.

So far we have discussed restrictions on the incentives of the two different cost type firms to pool. However, we should also check to see whether such incentives are plausible. For the low cost firm there must be some $\phi_L(\rho_1) > \delta$ while for the high cost firm we need some $\phi_H(\rho_1) < \delta$. If this is the case for all the different entry decisions then beliefs exist for all pooling equilibria. We prove this in the following proposition.

Proposition 4.2 *There always exists a range of prior beliefs ρ that support the pooling equilibrium for all foreign market entry decisions.*

Proof. See Appendix.

The proof is rather long but essentially shows that we can always find conditions for which a pooling equilibrium will exist. In other words, we can always find incentives for both cost types to pool i.e. there exists some ρ such that $\phi_L(\rho) > \phi_H(\rho)$. Thus, all the equilibria discussed above may exist.

To conclude this section, we have shown the existence of a pooling equilibrium when entry can be deterred from the home market. However, pooling behaviour also enhances the expected market share of the high cost firm in the foreign market. Although the low cost incumbent loses profit in the foreign market, the gains in the home market may compensate. If this is the case (as it is for low enough δ), pooling may be an equilibrium strategy.

4.5 $n+1$ Markets

We have seen that the limit price is indeed influence by the existence of a foreign market. In this section we explore the extent of this effect. Before we were able to show that the existence of another market leads to a fall in the limit price. The question we ask ourselves now is whether this is true if we increase the number of markets and firms.

The problems of extending the Cournot model to n markets is illustrated briefly in Friedman (1977) and in more detail by Ruffin (1971) and Okuguchi (1973). Obtaining stability and uniqueness in the equilibrium if the number of firms is increased to infinity can create problems and for this reason we assume a simplified, more specific modeling for the following analysis. Hence, from now on consider that,

$$P^i(q) = 1 - \sum_{i=1}^{n+1} q_i \tag{4.47}$$

is the linear inverse demand function for market $i \in \{1, n+1\}$. Indeed, this is exactly the same for all the other n markets as the number of firms equals the number of markets. Therefore, if we increase the number of markets that a firm can enter, we increase the number of firms in those markets, simply because of reciprocal entry. The beliefs that each firm i holds regarding the other incumbents can be given by the vector $\rho_{-i} = \{\rho_1, \rho_2, ..., \rho_{i-1}, \rho_{i+1}, ..., \rho_{n+1}\}$.

4.5.1 Separating Equilibrium

The incentive constraint for iL can be written,

$$\begin{aligned} &\pi^i_{iL}(q_L) + \delta\pi^i_{iL}(0, \rho_{-i}) + \delta \sum_{i \neq j} \left[\pi^j_{1L}(0, \rho_{-i}) - F_i\right] \\ &> \pi^i_{iL} + \delta\pi^i_{iL}(1, \rho_{-i}) + \delta \sum_{i \neq j} \left[\pi^j_{iL}(1, \rho_{-i}) - F_i\right] \end{aligned} \tag{4.48}$$

and similarly for iH,

$$\begin{aligned} &\pi^i_{iH}(q_L) + \delta\pi^i_{iH}(0,\rho_{-i}) + \delta\sum_{i\neq j}\left[\pi^j_{iH}(0,\rho_{-i}) - F_i\right] \\ &\quad\leq \pi^i_{iH} + \delta\pi^i_{iH}(1,\rho_{-i}) + \delta\sum_{i\neq j}\left[\pi^j_{iH}(1,\rho_{-i}) - F_i\right] \end{aligned} \tag{4.49}$$

Note that the profit that i earns in the foreign markets is the same for each market regardless of the prior beliefs as each firm enters the others' market.

It is easy to show that there exists a separating equilibrium. In the proof of Proposition 4.1 we see that the output of 2 is dependent only on μ_i and not on the actual cost type of 1. As long as signalling increases the residual demand that 1 faces in the second period in all markets, then a separating equilibrium will exist. However, we shall show below that conditions exist where signalling breaks down because a low enough limit price can no longer be found.

Effect on the Limit Price

We can see how the limit price is affected by the increase in the number of firms that can enter i and the number of markets that i can enter. Assume that the limit price is the highest price that iL can charge without upsetting the separating equilibrium. In the Cournot setting, this means the lowest equilibrium output $\underline{q}$. This can be obtained by finding the point at which inequality 4.48 reaches equality, i.e.,

$$\Psi_i(n) \equiv \pi^i_{iH} - \pi^i_{iH}\left(\underline{q}\right) = \delta\sum_{i=1}^{n+1}\left[\pi^i_{iH}(0,\rho_{-i}) - \pi^i_{iH}(1,\rho_{-i})\right] \tag{4.50}$$

Therefore, the least cost separating output in i is a function of the expected profits of iH if it were able to successfully imitate the strategy of iL. To see the effect of increasing the number of firms on the limit price, it is necessary to use the parameterised example. Assume firms have marginal costs c_H and c_L with prior probabilities ρ_i and $(1-\rho_i)$ and posterior probabilities μ_i and $(1-\mu_i)$ respectively. Each firm maximises,

$$\pi^i_{i\theta} = \max_{q_{i\theta}}\left(a - c_\theta - q_{i\theta} - \sum_{i\neq j}\left(\rho_j q_{jH} + (1-\rho_j)\, q_{jL}\right)\right) q_{i\theta} \tag{4.51}$$

However, first period outputs influence the outputs of the other firms in the market. Therefore, the expected residual demand that each firm faces is dependent on prior beliefs μ_i. Therefore, incumbent i anticipates firm j to maximise,

$$\pi^i_{j\theta} = \max_{q_{j\theta}} \left(a - c_\theta - q_{j\theta} - \sum_{i \neq j \neq k} \left(\rho_k q_{kH} + (1-\rho_k) q_{kL}\right) - \mu_i q_{iH} - (1-\mu_i) q_{iL} \right) q_{j\theta} \tag{4.52}$$

The first order conditions for firm i are,

$$\frac{\partial \pi^i_{i\theta}}{\partial q_{i\theta}} = a - c_\theta - 2q_{i\theta} - \sum_{i \neq j} \left(\rho_j q_{jH} + (1-\rho_j) q_{jL}\right) = 0 \tag{4.53}$$

and for j,

$$\frac{\partial \pi^i_{j\theta}}{\partial q_{j\theta}} = a - c_\theta - 2q_{j\theta} - \sum_{i \neq j \neq k} \left(\rho_k q_{kH} + (1-\rho_k) q_{kL}\right) - \mu_i q_{iH} - (1-\mu_i) q_{iL} = 0 \tag{4.54}$$

To simplify, suppose $\rho_k = \rho_i = \rho_j = \rho$ so we can the write the first order conditions for $j\theta$ as,

$$\frac{\partial \pi^i_{j\theta}}{\partial q_{j\theta}} = a - c_\theta - 2q_{j\theta} - (n-1)\left(\rho q_{jH} + (1-\rho) q_{jL}\right) - \mu_i q_{iH} - (1-\mu_i) q_{iL} = 0 \tag{4.55}$$

The first order conditions can be rearranged and solved for output. The results for both output and profit are indicated in the appendix. Ψ, the profitability of signalling is now given by,

$$\begin{aligned} \Psi &= \delta(n+1)\left[\left(\frac{2(a-c_H) - n(c_H - c_L)(1-2\rho)}{2(n+2)}\right)^2 \right. \\ &\quad \left. - \left(\frac{2(a-c_H) - 2n(c_H - c_L)(1-\rho)}{2(n+2)}\right)^2\right] \end{aligned} \tag{4.56}$$

ρ is an estimate of the other firms' cost types. This is because i maximises its expected profits given that it knows that it can send a signal μ_i to the other firms. However, i must wait till the second period to receive the signal μ_j. Therefore, i is forced to use its prior beliefs in estimating the cost type of the other n firms. A change in Ψ infers a change in the least cost separating output and hence a change in the limit price. If Ψ rises, the least cost separating output falls (to retain the equality) and hence the limit price rises. We are interested in how the limit price changes as n changes. We can now make the following proposition.

Proposition 4.3 *If $\rho > 3/4$ the limit price will fall with large enough n. If $\rho < 3/4$ the limit price will rise with large enough n.*

Proof. Remember that we proxy the limit price by Ψ knowing that as Ψ increases, the limit price increases. We need to see whether the limit price increases or decreases with respect to n. By differentiating Ψ we get,

$$\begin{aligned}\frac{\partial \Psi}{\partial n} &= \delta\frac{(-c_H + c_L)}{4(n+2)^3} - 18c_L n^2 + 16nc_L\rho - 12nc_L - 3c_L n^3 + 4c_L n^3\rho \\ &+24c_L n^2\rho - 4c_H n^3\rho + 24nc_H + 18n^2 c_H - 12an - 16nc_H\rho \\ &+8c_H - 24c_H n^2\rho + 3n^3 c_H - 8a \qquad (4.57)\end{aligned}$$

Then, we take the limit of the derivative,

$$\lim_{n\to\infty}\left(\frac{\partial \Psi}{\partial n}\right)\frac{1}{4}\delta(-c_H + c_L)^2(4\rho - 3) \qquad (4.58)$$

This tells us that for a large enough number of markets and firms, the slope will be either positive or negative depending on whether ρ is greater or less than 3/4. ■

Increasing the number of firms and markets has two effects. First, the number of firms in a market reduces the profits a firm can expect to earn. However, the number of markets that a firm can enter increases and so total profits across markets rises. If all the firm have exactly the same cost type and they have complete information about this, the total profits of each firm would be,

$$\Pi_i = (n+1)\left(\frac{a-c}{n+2}\right)^2 \qquad (4.59)$$

where we assume that $c_i = c_j = c$ for all firms. Differentiating this with respect to n yields,

$$\frac{\partial \Pi_i}{\partial n} = -\frac{n(n+2)(a-c)^2}{(n+2)^2} < 0 \qquad (4.60)$$

which tells us that as the number of countries and firms increases, total profits across markets will fall. However, this result arises because all firms have equal marginal costs. If marginal costs are different, the result will also be quite different. Suppose firm i has marginal costs c_i while all the other firms have the same marginal cost, c. The output in each market for firm i is,

$$q_i^k = \left(\frac{a-(n+1)c_i + nc_j}{n+2}\right)^2 \qquad (4.61)$$

Taking the limit of this function gives us,

$$\lim_{n\to\infty}\left(\frac{a-(n+1)c_i+nc_j}{n+2}\right)=c_j-c_i \tag{4.62}$$

so we see that as long as $c_i < c_j$, firm i will still produce a positive output. If the firms have equal marginal costs, then output is zero, as we would expect in the case of perfect competition. Clearly, a positive output (and hence positive profits) over an infinite number of markets implies an infinite profit. Nevertheless, we see that when cost asymmetries exist, increasing the number of firms and markets may lead to higher profits.

Similarly, for the case of incomplete information, the output of the incumbent iL in the second period is given by,

$$q_{iL}=\frac{2(a-c_L)-n(c_H-c_L)(\mu_i-2\rho)}{2(n+2)} \tag{4.63}$$

When firm iL signals it has a low marginal cost, $\mu_i=0$. The limit of this output as n goes to infinity is,

$$\lim_{n\to\infty}\frac{2(a-c_L)+2\rho n(c_H-c_L)}{2(n+2)}=\rho(c_H-c_L) \tag{4.64}$$

which clearly states that the low cost firm will always have a positive output when there are an infinite number of firms in the market. It is for this reason that the limit price rises with n as long as there is a sufficiently high probability that the other firms have a higher marginal cost.

Using parameter values, we can show how the least cost separating output depends on ρ. Find some $\underline{q}$ which equalises inequality 4.48. This gives us,

$$\begin{aligned}\delta(n+1)&\left[\left(\frac{2(a-c_H)-n(c_H-c_L)(1-2\rho)}{2(n+2)}\right)^2\right.\\&\left.-\left(\frac{2(a-c_H)-2n(c_H-c_L)(1-\rho)}{2(n+2)}\right)^2\right]\\&=\left(\frac{a-c_H}{2}\right)^2-\left(a-c_H-\underline{q}\right)\underline{q}\end{aligned} \tag{4.65}$$

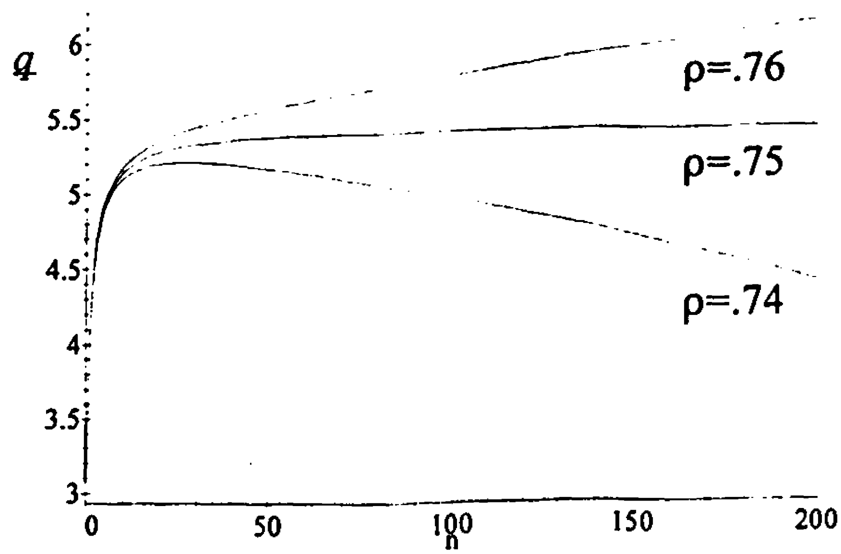

Figure 4.1: Least Cost Separating Output for Increasing n.

Solving for $\underline{q}$ yields,

$$\underline{q} = \frac{a - c_H}{2} + \frac{1}{2(n+2)}\left[\delta n (c_H - c_L)(n+1)\right.$$
$$\left.(4nc_H\rho - 3nc_H - 4nc_L\rho + 3nc_L - 4c_H + 4a)\right]^{1/2} \tag{4.66}$$

For the following parameter values $a = 24, c_H = 18, c_L = 16, \delta = .5, \rho \in \{.74, .75, .76\}$, we can plot the least cost separating output for $n \in [1, 200]$ (figure 4.1). As we can see, for $\rho = .75$ the least cost separating output settles at around 5.4 while it is increasing for $\rho > .75$ and decreasing for $\rho < .75$.

4.5.2 Pooling Equilibrium

In the pooling equilibrium, the entrant learns nothing about the true cost type of the incumbent by observing its first period output. For a low cost incumbent to find pooling profitable, we require a non-trivial fixed cost or a considerable difference in marginal costs, so that a pooling strategy will deter entry in the second period. In the pooling equilibrium, entry is deterred from market i when,

$$\pi_j^i(\rho_i, \rho_j) \leq F_j \tag{4.67}$$

This states that any potential entrant j will expect non-positive duopoly profits when entering market i given ρ_i. If duopoly profits are non-positive, then tripoly profits must be negative.

However, can i enter the other markets? Two scenarios arise.

1. $E_{iH}(1,\rho_j) = 1$, free entry: $\pi^j_{iH}(1,\rho_j) > F_i$

2. $E_{iH}(\rho_i,\rho_j) = 1, E_{iH}(\rho_i,\rho_j) = 0$, entry when pooling occurs, only: $\pi^j_{iH}(\rho_i,\rho_j) > F_i \geq \pi^j_{iH}(1,\rho_j)$

These assumptions have considerable implications. First, if i can deter all entry into its own market and yet enter the other markets, it seems reasonable that i will be the only entrant in all the other n markets. Quite simply, if duopoly profits do not cover the fixed entry cost, then tripoly profits (this is the maximum profit possible in each market because i enters for sure) certainly cannot cover this cost, hence i is the only entrant. The only way to change this would be to allow for differing fixed costs among the other n firms. However, this would mean that i may not be able to deter all firms from entering its home market. If entry were sequential although production remains simultaneous, this scenario could exist. However, this is beyond the scope of this chapter.

We saw that in the separating equilibrium entry deterrence was not essential for signalling as the limit price can also be used to establish market share. However, this kind of strategy cannot be supported in the pooling equilibrium because a low cost incumbent will always do better by signalling. Nevertheless, when the fixed cost of the entrant is such that pooling will deter entry, then the following condition ensures that the low cost incumbent will pool. Assume that priors are the same for all the firms, denoted ρ_j. The incentive constraint for iL is,

$$\begin{aligned}\pi^i_{iL}\left(\underline{q}\right) + \delta\pi^i_{iL} + n\delta\left[\pi^j_{iL}(0,\rho_j) - F_i\right] \\ < \pi^i_{1L} + \delta\pi^i_{1L} + n\delta\left[\pi^j_{iL}(1,\rho_j) - F_i\right]\end{aligned} \tag{4.68}$$

which reduces to

$$\delta < \delta_L \equiv \frac{\pi_{1L} - \pi_{1L}\left(\underline{q}\right)}{n\left[\pi^j_{iL}(0,\rho_j) - \pi^j_{iL}(1,\rho_j)\right]} \tag{4.69}$$

Note that the LHS of equation 4.69 will eventually increase in n as we saw above in Proposition 4.3 and that $1L$ pools at its Pareto optimal complete information monopoly output, q_{iL}. Note that as n increases, the denominator gets smaller and thus the range of $\delta < \delta_L$ that support pooling behaviour gets smaller. The reason for this is simple: as n increases, the profits made from increasing market share by signalling become more important. The profits from deterring entry get relatively small compared to the expected profits in the foreign markets. For the low cost incumbent, market share is lost by pooling and consequently, an increase in its importance reduces the desire to pool. Note that as $n \to \infty$, $\delta_L \to 0$ which means no pooling equilibrium can exist.

For iH let us first assume that $E_{iH}(1, \rho_j) = 1$. The necessary condition for the high cost incumbent is similarly,

$$\begin{aligned} &\pi_{iH}^{i}(q_{iL}) + \delta\pi_{iH}^{i} + n\delta\left[\pi_{iH}^{j}(\rho_i, \rho_j) - F_i\right] \\ &\quad \geq \pi_{1H}^{i} + \delta\pi_{1H}^{i}(1, \rho_{-i}) + n\delta\left[\pi_{iH}^{j}(1, \rho_j) - F_i\right] \end{aligned} \tag{4.70}$$

which rearranges to,

$$\delta \geq \delta_H \equiv \frac{\pi_{1H}^{i} - \pi_{iH}^{i}(q_{iL})}{\left[\pi_{iH}^{i} - \pi_{1H}^{i}(1, \rho_{-i})\right] + n\left[\pi_{iH}^{j}(\rho_i, \rho_j) - \pi_{iH}^{j}(1, \rho_j)\right]} \tag{4.71}$$

As n increases, the denominator increases defining a lower value of δ_H. In other words, increasing the number of markets a firm can enter increases the incentive to pool.

Now consider $E_{iH}(1, \rho_j) = 0, E_{iH}(\rho_i, \rho_j) = 1$. The incentive constraint for iH is now,

$$\begin{aligned} &\pi_{iH}^{i}(q_{iL}) + \delta\pi_{iH}^{i} + n\delta\left[\pi_{iH}^{j}(\rho_i, \rho_j) - F_i\right] \\ &\quad \geq \pi_{1H}^{i} + \delta\pi_{1H}^{i}(1, \rho_{-i}) \end{aligned} \tag{4.72}$$

Similarly, we can rearrange to get,

$$\delta \geq \delta_H \equiv \frac{\pi_{1H}^{i} - \pi_{iH}^{i}(q_{iL})}{\left[\pi_{iH}^{i} - \pi_{1H}^{i}(1, \rho_{-i})\right] + n\left[\pi_{iH}^{j}(\rho_i, \rho_j) - \pi_{iH}^{j}(1, \rho_j)\right]} \tag{4.73}$$

Again, as we increase n, we obtain a wider range of discount factors that support the pooling equilibrium. Indeed, as $n \to \infty$, $\delta_H \to 0$ implying that if a low cost incumbent can deter entry by pooling, a high cost incumbent will always imitate its strategy (because $\delta > 0$). However, as shown above, a low cost incumbent will not pool when n is infinitely large.

Proposition 4.4 *We can find parameters $\{\delta, \rho, F, n\}$ for which pooling equilibria exist. However, for finite n^*, the pooling equilibrium breaks down and the low cost incumbent will separate.*

Proof. We see that inequalities 4.43 and 4.45 are virtually identical to inequalities 4.71 and 4.73 and so following Proposition 4.2 we can find conditions under which a pooling equilibrium exists. However, we saw that as $n \to \infty$, $\delta_L \to 0$ and $\delta_H \to 0$. Choosing some $\delta' > 0$ there must exist some n for which $\delta_L < \delta'$. Hence, the low cost incumbent will prefer to separate rather than pool, overturning the pooling equilibrium. ■

The rationale behind this result is that the low cost incumbent incurs a loss in the foreign markets by pooling. It is giving up market share that it could win if it separated in the first period. As the number of foreign markets increases, this loss gets bigger. What is interesting when we compare the results to the previous section is that $n > 1$ i.e. we need at least two foreign markets otherwise pooling remains the dominant equilibrium. Of course, it should be pointed out that this result relies on the fact that when firms pool, information about their cost type is not revealed on entry into a market. This is the assumption that Milgrom and Roberts (1982) use to simplify their model of entry deterrence. If it were retained here, Mailath's result would collapse and limit pricing would serve no purpose in enhancing foreign market share.

Overall, the extension to $n + 1$ markets does change some of the previous results. We see that the limit price in the separating equilibrium may not always fall in the presence of foreign markets and that there may not always exist a pooling equilibrium, even if prior beliefs are such that entry will always be deterred.

4.6 Conclusion

In this chapter, we have shown how the B–K model can be adapted to a model of limit pricing by restricting the cost information available to the incumbents. We see that the limit price may not only be used to deter entry but also to increase market share in the target country. The existence of the foreign market increases the willingness of the high cost incumbent to imitate the strategy of a low cost firm. As a result, the low cost incumbent is forced to choose a lower limit price in order to signal its cost type. This is similar to the results of Srinivasan (1991) who finds that combining signals across markets may lower the limit price in one of the markets. However, we do not require market demand or cost differences to drive this result.

We were also able to show the existence of pooling equilibria despite the fact that this reduced foreign market profits for the low cost incumbent. However, the gains from not deviating from the monopoly output level in the first period always compensate for the foreign loss. What is interesting is that even under conditions where pooling would not exist in the Milgrom and Roberts (1982) model, the equilibrium is supported because of foreign market profits. This is unusual as pooling equilibria do not exist in Mailath (1989) because entry deterrence is not a feasible strategy. However, because pooling raises foreign market profits for the high cost firm, it helps to finance the first period deviation from the monopoly output.

Increasing the number of markets and firms we see that the limit price either increases or decreases depending on the size of the prior beliefs. If a firm believes that all the other firms have a high marginal cost, the expected profits of a low cost incumbent will increase with n and hence the limit price falls. However, when the firm believes that all the other firms have a low marginal cost, its expected profits fall with n and therefore the limit price rises. Moreover, for certain n, the limit price may be negative and hence the equilibrium breaks down.

For finite n we see a break down in the pooling equilibrium: the low cost incumbent's losses in the foreign market from pooling are so high that it prefers to incur first period losses and limit price in the first period. Hence, although priors may deter entry, limit pricing may still occur. This is contrary to all results so far seen in the literature on limit pricing.

This chapter has shown that in an international context we can see two aspects of limit pricing: its ability to deter entry and its ability to enhance market share. Indeed, we have shown that the type of equilibrium that emerges may depend on which of these two effects dominates.

Appendix

4.6.1 Complete Information

Assume an inverse linear demand function for $n+1$ firms, $p(q) = a - \sum_{i=1}^{n+1} q_i$, where firms have marginal cost $c_i \in \{c_1, c_2, ..., c_{n+1}\}$. Firm i maximises profit in each market k,

$$\pi_i^k = \max_{q_i} \left(a - c_i - q_i - \sum_{i \neq j} q_j \right) q_i \tag{4.74}$$

for $i, k, j \in \{1, ..., n+1\}$. To simplify things, assume that all firms $j \neq i$ have marginal cost c_j. As all the other n firms of cost type c_j are the same, their outputs will be the same. The first order condition for i is,

$$\frac{\partial \pi_i^k}{\partial q_i} = a - c_i - 2q_i - nq_j = 0 \tag{4.75}$$

and for the other n firms,

$$\frac{\partial \pi_j^k}{\partial q_j} = a - c_j - (n+1)\, q_j - q_i = 0 \tag{4.76}$$

We can solve these two first order conditions for the equilibrium outputs,

$$q_i = \frac{a - (n+1)\, c_i + nc_j}{n+2} \tag{4.77}$$

$$q_j = \frac{a - 2c_j + c_i}{n+2} \tag{4.78}$$

This yields equilibrium profits for the both types,

$$\pi_i^k = \left(\frac{a - (n+1)\, c_i + nc_j}{n+2} \right)^2 \tag{4.79}$$

$$\pi_j^k = \left(\frac{a - 2c_j + c_i}{n+2} \right)^2 \tag{4.80}$$

The total profits of firm i over the $n+1$ markets is simply, $(n+1)\pi_i^k$. If all firms have equal marginal costs, i.e. $c_i = c_j = c$ then the profits are,

$$\pi_i^k = \left(\frac{a-c}{n+2}\right)^2 \tag{4.81}$$

4.6.2 Incomplete Information

Let us now compute similar equilibria when costs types are unknown. Firms have marginal costs c_H and c_L with prior probabilities ρ_i and $(1-\rho_i)$ and posterior probabilities μ_i and $(1-\mu_i)$ respectively. Each firm maximises,

$$\pi_{i\theta}^i = \max_{q_{i\theta}} \left(a - c^\theta - q_{i\theta} - \sum_{i\neq j} (\rho_j q_{jH} + (1-\rho_j) q_{jL})\right) q_{i\theta} \tag{4.82}$$

However, first period outputs influence the outputs of the other firms in the market. Therefore, the expected residual demand that each firm faces is dependent on prior beliefs ρ_i. Therefore, incumbent i anticipates firm j to maximise,

$$\pi_{j\theta}^i = \max_{q_{j\theta}} \left(a - c^\theta - q_{j\theta} - \sum_{i\neq j\neq k} (\rho_k q_{kH} + (1-\rho_k) q_{kL}) - \mu_i q_{iH} - (1-\mu_i) q_{iL}\right) q_{j\theta} \tag{4.83}$$

The first order conditions for firm i are,

$$\frac{\partial \pi_{i\theta}^i}{\partial q_{i\theta}} = a - c^\theta - 2q_{i\theta} - \sum_{i\neq j} (\rho_j q_{jH} + (1-\rho_j) q_{jL}) = 0 \tag{4.84}$$

and for j,

$$\frac{\partial \pi_{j\theta}^i}{\partial q_{j\theta}} = a - c^\theta - 2q_{j\theta} - \sum_{i\neq j\neq k} (\rho_k q_{kH} + (1-\rho_k) q_{kL}) - \mu_i q_{iH} - (1-\mu_i) q_{iL} = 0 \tag{4.85}$$

To simplify, suppose $\rho_k = \rho_j = \rho$ so we can the write the first order conditions for $j\theta$ as,

$$\frac{\partial \pi_{j\theta}^i}{\partial q_{j\theta}} = a - c^\theta - 2q_{j\theta} - (n-1)(\rho q_{jH} + (1-\rho) q_{jL}) - \mu_i q_{iH} - (1-\mu_i) q_{iL} = 0 \tag{4.86}$$

We can then rearrange these into matrix format,

$$\begin{pmatrix} a-c_H \\ a-c_L \\ a-c_H \\ a-c_L \end{pmatrix} = \begin{pmatrix} 2 & 0 & n\rho & n(1-\rho) \\ 0 & 2 & n\rho & n(1-\rho) \\ \mu_i & (1-\mu_i) & 2+(n-1)\rho & (n-1)(1-\rho) \\ \mu_i & (1-\mu_i) & (n-1)\rho & 2+(n-1)(1-\rho) \end{pmatrix} \begin{pmatrix} q_{iH} \\ q_{iL} \\ q_{jH} \\ q_{jL} \end{pmatrix} \tag{4.87}$$

yielding equilibrium outputs,

$$q_{iH} = \frac{2(a-c_H) - n(c_H-c_L)(1+\mu_i-2\rho)}{2(n+2)} \tag{4.88}$$

$$q_{iL} = \frac{2(a-c_L) - n(c_H-c_L)(\mu_i-2\rho)}{2(n+2)} \tag{4.89}$$

$$q_{jH} = \frac{2(a-c_H) + (c_H-c_L)(n(\rho-1)-2(\rho-\mu_i))}{2(n+2)} \tag{4.90}$$

$$q_{jL} = \frac{2(a-c_L) + (c_H-c_L)((n-2)\rho+2\mu_i)}{2(n+2)} \tag{4.91}$$

This leads to equilibrium profits,

$$\pi_{iH}^{i}(\mu_i,\rho) = \left(\frac{2(a-c_H) - n(c_H-c_L)(1+\mu_i-2\rho)}{2(n+2)}\right)^2 \tag{4.92}$$

$$\pi_{iL}^{i}(\mu_i,\rho) = \left(\frac{2(a-c_L) - n(c_H-c_L)(\mu_i-2\rho)}{2(n+2)}\right)^2 \tag{4.93}$$

$$\pi_{jH}^{i}(\mu_i,\rho) = \left(\frac{2(a-c_H) + (c_H-c_L)(n(\rho-1)-2(\rho-\mu_i))}{2(n+2)}\right)^2 \tag{4.94}$$

$$\pi_{jL}^{i}(\mu_i,\rho) = \left(\frac{2(a-c_L) + (c_H-c_L)((n-2)\rho+2\mu_i)}{2(n+2)}\right)^2 \tag{4.95}$$

The profitability of signalling is given by,

$$\begin{aligned} \Psi &= \delta\left(\frac{2(a-c_H) - n(c_H-c_L)(1-2\mu_j)}{2(n+2)}\right)^2 \\ &\quad -n\delta\left(\frac{2(a-c_H) - n(c_H-c_L)(2-2\mu_j)}{2(n+2)}\right)^2 \end{aligned} \tag{4.96}$$

If we differentiate Ψ we obtain,

$$\begin{aligned} \frac{\partial\Psi}{\partial n} &= \delta(n+1)(c_H-c_L)\frac{n(c_H-c_L)(4\mu_j-3) - (n-2)(a-c_H)}{(n+2)^3} \\ &\quad +n\delta(c_H-c_L)\frac{4(a-c_H) + n(c_H-c_L)(4\mu_j-3)}{2(n+2)^2} \end{aligned} \tag{4.97}$$

This tells us something about the way the limit price changes with respect to the number of firms and industries which a firm can enter.

Proof of Proposition 4.1: We can divide the proof into two parts. In the first part we demonstrate the single crossing condition. In the second part a separating equilibrium is shown to exist for zero fixed costs.

(i) Considering the case of limit pricing (i.e. strategies where $\hat{q}_1 > q_{1L}$) the single crossing condition (Spence 1974) shows that it is more costly for a high cost firm to increase its output than it is for a low cost firm. Essentially, this requires that the slope of the low cost incumbent's profit when producing above the monopoly output is greater (less negative) than that of the high cost firm.

Show that $\pi_{1L} - \pi_{1L}(\hat{q}_1) < \pi_{1H} - \pi_{1H}(\hat{q}_1)$ for $\hat{q}_1 > q_{1L}$. Monopoly profits are given by $\pi_{1L} = \max(a - c_\theta - q_{1\theta})\, q_{1\theta}$ which yields equilibrium output $q_{1\theta} = (a - c_\theta)/2$ and profits $\pi_{1\theta} = (a - c_\theta)^2/4$. Therefore,

$$\pi_{1L} - \pi_{1L}(\hat{q}_1) < \pi_{1H} - \pi_{1H}(\hat{q}_1) \tag{4.98}$$

yields,

$$\left(\frac{a - c_L}{2}\right)^2 - (a - c_L - \hat{q}_1)\,\hat{q}_1 < \left(\frac{a - c_H}{2}\right)^2 - (a - c_H - \hat{q}_1)\,\hat{q}_1 \tag{4.99}$$

and rearranging gives us,

$$\frac{1}{4}(c_H - c_L)(2a - c_H - c_L - 4q_1) < 0 \tag{4.100}$$

for $(2a - c_H - c_L)/4 \equiv (q_{1L} + q_{1H})/2 < \hat{q}_1$. Therefore, a sufficient condition is that $\hat{q}_1 > q_{1L}$.

(ii) Rearrange the incentive constraints to obtain:

$$\begin{aligned}
&\delta \Big\langle E_2(0,\rho_2)\left[\pi_{1L}^1(0,\rho_2) - \pi_{1H}^1(0,\rho_2) - \pi_{1L}^1 + \pi_{1H}^1\right] \\
&\quad - E_2(1,\rho_2)\left[\pi_{1L}^1(1,\rho_2) - \pi_{1H}^1(1,\rho_2) - \pi_{1L}^1 + \pi_{1H}^1\right]\Big\rangle \\
&\quad + \delta\Big\langle\Big[E_{1L}(0,\rho_2)\left[\pi_{1L}^2(0,\rho_2) - F_1\right] - E_{1L}(1,\rho_2)\left[\pi_{1L}^2(1,\rho_2) - F_1\right]\Big] \\
&\quad - \Big[E_{1H}(0,\rho_2)\left[\pi_{1H}^2(0,\rho_2) - F_1\right] - E_{1H}(1,\rho_2)\left[\pi_{1H}^2(1,\rho_2) - F_1\right]\Big]\Big\rangle \\
&\quad > \left[\pi_{1L} - \pi_{1L}(q_L)\right] - \left[\pi_{1H} - \pi_{1H}(q_L)\right]
\end{aligned} \tag{4.101}$$

From the single crossing condition in (i),

$$\pi_{1L} - \pi_{1L}(\hat{q}_1) < \pi_{1H} - \pi_{1H}(\hat{q}_1) \tag{4.102}$$

for $\hat{q}_1 > q_{1L}$ which means that the RHS is negative. The profitability of separating is greater for the low cost type than it is for the high cost type. The conditions for a separating equilibrium are:

$$\begin{aligned} &E_2(1,\rho_2)\left(\left[\pi_{1L}^1 - \pi_{1L}^1(1,\rho_2)\right] - \left[\pi_{1H}^1 - \pi_{1H}^1(1,\rho_2)\right]\right) \\ &\quad > E_2(0,\rho_2)\left(\left[\pi_{1L}^1 - \pi_{1L}^1(0,\rho_2)\right] - \left[\pi_{1H}^1 - \pi_{1H}^1(0,\rho_2)\right]\right) \end{aligned} \tag{4.103}$$

and

$$\begin{aligned} &E_{1L}(0,\rho_2)\left[\pi_{1L}^2(0,\rho_2) - F_1\right] - E_{1L}(1,\rho_2)\left[\pi_{1L}^2(1,\rho_2) - F_1\right] \\ &\quad > E_{1H}(0,\rho_2)\left[\pi_{1H}^2(0,\rho_2) - F_1\right] - E_{1H}(1,\rho_2)\left[\pi_{1H}^2(1,\rho_2) - F_1\right] \end{aligned} \tag{4.104}$$

for domestic and foreign investment, respectively. There are several cases to prove.

First, for the domestic market. We know that $E_2(0,\rho_2) \leq E_2(1,\rho_2)$ because an incumbent signalling a low cost cannot raise the entrant's post-entry profits.

1. $E_2(0,\rho_2) = E_2(1,\rho_2) = 1$, free entry.

2. $E_2(0,\rho_2) = 0, E_2(1,\rho_2) = 1$, low cost entrant only.

3. $E_2(0,\rho_2) = E_2(1,\rho_2) = 0$, no entry.

(i) If $E_2(0,\rho_2) = E_2(1,\rho_2) = 1$, (entry always takes place), inequality 4.103 reduces to,

$$\pi_{1L}^1(0,\rho_2) - \pi_{1L}^1(1,\rho_2) > \pi_{1H}^1(0,\rho_2) - \pi_{1H}^1(1,\rho_2) \tag{4.105}$$

Substituting in the parameter values, this can be rewritten as,

$$\begin{aligned} &\left(\frac{2(a-c_L)+(c_H-c_L)(2\rho_2)}{6}\right)^2 - \left(\frac{2(a-c_L)+(c_H-c_L)(2\rho_2-1)}{6}\right)^2 \\ &\quad > \left(\frac{2a-3c_H+c_L+(c_H-c_L)(2\rho_2)}{6}\right)^2 \\ &\quad - \left(\frac{2a-3c_H+c_L+(c_H-c_L)(2\rho_2-1)}{6}\right)^2 \end{aligned} \tag{4.106}$$

which reduces to,

$$\frac{1}{6}(c_H - c_L)^2 > 0 \tag{4.107}$$

(ii) If $E_2(0,\rho_2) = 0, E_2(1,\rho_2) = 1$, then 4.103 rearranges to,

$$\pi^1_{1L} - \pi^1_{1L}(1,\rho_2) > \pi^1_{1H} - \pi^1_{1H}(1,\rho_2) \tag{4.108}$$

Again, substituting in the equilibrium values yields,

$$\left(\frac{a-c_L}{2}\right)^2 - \left(\frac{2(a-c_L)+(c_H-c_L)(2\rho_j-1)}{6}\right)^2$$
$$> \left(\frac{a-c_H}{2}\right)^2 - \left(\frac{2a-3c_H+c_L+(c_H-c_L)(2\rho_j-1)}{6}\right)^2 \tag{4.109}$$

which reduces to,

$$\frac{1}{6}(c_H - c_L)(a - 2c_L + c_H - 2\rho_j(c_H - c_L)) > 0 \tag{4.110}$$

which is positive.[4]

(iii) Finally, suppose $E_2(0,\rho_2) = E_2(1,\rho_2) = 0$. Inequality 4.103 no longer holds and the equilibrium fails.

For the foreign market, similar equilibria occur. Firm 1's investment into market 2 is given by inequality 4.104. Clearly, $E_{1\theta}(0,\rho_2) \geq E_{1\theta}(1,\rho_2)$ because signalling a low cost type cannot lower a firm's own post-entry profits. Furthermore, $E_{1L}(\mu_i,\rho_2) \geq E_{1H}(\mu_i,\rho_2)$ because a low cost incumbent will always be able to enter a market when it is profitable for a high cost firm, although the opposite may not be the case.

1. $E_{1\theta}(0,\rho_2) = E_{1\theta}(1,\rho_2) = 1$, free entry.

2. $E_{1\theta}(0,\rho_2) = 1, E_{1\theta}(1,\rho_2) = 0$, signal low cost to enter.

3. $E_{1L}(\mu_i,\rho_2) = 1, E_{1H}(\mu_i,\rho_2) = 0$, low cost firm enters, only.

4. $E_{1\theta}(0,\rho_2) = E_{1\theta}(1,\rho_2) = 0$, no entry.

[4] For $q_{1L} > 0$ and $q_{1H} > 0$, $\rho_2 = 1$, $a - c_H > 0$ and $\rho_2 = 0$, $a - 2c_L + c_H > 0$.

(i) If $E_{1\theta}(0,\rho_2) = E_{1\theta}(1,\rho_2) = 1$, i.e. entry always takes place. Inequality 4.104 reduces to,

$$\pi_{1L}^2(0,\rho_2) - \pi_{1L}^2(1,\rho_2) > \pi_{1H}^2(0,\rho_2) - \pi_{1H}^2(1,\rho_2) \tag{4.111}$$

We know that $\pi_{1\theta}^2(\mu_i,\rho_2) = \pi_{1\theta}^1(\mu_i,\rho_2)$ and so by 4.105 we obtain,

$$\frac{1}{6}(c_H - c_L)^2 > 0 \tag{4.112}$$

(ii) If $E_{1\theta}(0,\rho_2) = 1, E_{1\theta}(1,\rho_2) = 0$. Then 4.104 reduces to,

$$\pi_{1L}^2(0,\rho_2) > \pi_{1H}^2(0,\rho_2) \tag{4.113}$$

which holds for all $c_H > c_L$.

(iii) If $E_{1L}(\mu_i,\rho_2) = 1, E_{1H}(1,\rho_2) = 0$ then we get,

$$\pi_{1L}^2(0,\rho_2) > \pi_{1L}^2(1,\rho_2) \tag{4.114}$$

From the equilibrium profits, we know that $\pi_{1\theta}^1(\mu_1,\rho_2) = \pi_{1\theta}^2(\mu_1,\rho_2)$ which means that the same holds for inequality 4.104.

(iv) Finally, suppose $E_{1\theta}(0,\rho_2) = E_{1\theta}(1,\rho_2) = 0$ then 4.103 no longer holds and the equilibrium fails. ■

Proof of Proposition 4.2: We need to check that a range of discount factors exists such that both the high and low cost firms will want to pool. The low cost incumbent finds pooling profitable when we have the following inequality:

$$\begin{aligned} &\pi_{1L}^1\left(\underline{q}_1\right) + \delta\pi_{1L}^1 + \delta E_{1L}(0,\rho_2)\left[\pi_{1L}^2(0,\rho_2) - F_1\right] \\ &\quad < \pi_{1L}^1 + \delta\pi_{1L}^1 + \delta E_{1L}(\rho_1,\rho_2)\left[\pi_{1L}^2(\rho_1,\rho_2) - F_1\right] \end{aligned} \tag{4.115}$$

Rearranging for δ we obtain

$$\delta < \phi_L(\rho_1) \equiv \frac{\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right)}{E_{1L}(0,\rho_2)\left[\pi_{1L}^2(0,\rho_2) - F_1\right] - E_{1L}(\rho_1,\rho_2)\left[\pi_{1L}^2(\rho_1,\rho_2) - F_1\right]} \tag{4.116}$$

We define the upper bound on the discount factor $\phi_L(\rho_1)$ as a function of ρ_1. For the high cost firm, the conditions for a pooling equilibrium are

$$\begin{aligned} &\pi_{1H}^1(q_{1L}) + \delta\pi_{1H}^1 + \delta E_{1H}(\rho_1,\rho_2)\left[\pi_{1H}^2(\rho_1,\rho_2) - F_1\right] \\ &\quad > \pi_{1H}^1 + \delta\pi_{1H}^1(1,\rho_2) + \delta E_{1H}(1,\rho_2)\left[\pi_{1H}^2(1,\rho_2) - F_1\right] \end{aligned} \tag{4.117}$$

which can be rearranged to give

$$\delta \geq \phi_H(\rho_1) \equiv \left[\pi_{1H}^1 - \pi_{1H}^1(q_{1L})\right] / \left(\pi_{1H}^1 + E_{1H}(\rho_1,\rho_2)\left[\pi_{1H}^2(\rho_1,\rho_2) - F_1\right]\right.$$
$$\left. - \pi_{1H}^1(1,\rho_2) - E_{1H}(1,\rho_2)\left[\pi_{1H}^2(1,\rho_2) - F_1\right]\right) \tag{4.118}$$

where $\phi_H(\rho_1)$ defines the lower bound on the discount factor. We need to find some ρ_1 such that $\phi_L(\rho_1) > \phi_H(\rho_1)$ to see under which entry decisions pooling equilibria exist. For the low cost firm, the following entry decisions yield the subsequent upper bounds on the discount factor.

1. $E_{1L}(0,\rho_2) = E_{1L}(\rho_1,\rho_2) = 1$, yielding $\phi_L(\rho_1) = \phi_L'(\rho_1)$
2. $E_{1L}(0,\rho_2) = 1, E_{1L}(\rho_1,\rho_2) = 0$, yielding $\phi_L(\rho_1) = \phi_L''(\rho_1)$
3. $E_{1L}(0,\rho_2) = E_{1L}(\rho_1,\rho_2) = 0$, yielding $\phi_L(\rho_1) = \phi_L'''(\rho_1)$

Similarly, lower bounds on the discount factor exist for the high cost firm.

1. $E_{1H}(\rho_1,\rho_2) = E_{1H}(1,\rho_2) = 1$, yielding $\phi_H(\rho_1) = \phi_H'(\rho_1)$
2. $E_{1H}(\rho_1,\rho_2) = 1, E_{1H}(1,\rho_2) = 0$, yielding $\phi_H(\rho_1) = \phi_H''(\rho_1)$
3. $E_{1H}(\rho_1,\rho_2) = E_{1H}(1,\rho_2) = 0$, yielding $\phi_H(\rho_1) = \phi_H'''(\rho_1)$

First, we need to check that $\phi_\theta'''(\rho_1) > \phi_\theta''(\rho_1) > \phi_\theta'(\rho_1)$ and that $\phi_L'(\rho_1) > \phi_H'''(\rho_1)$ for some range of beliefs. This can be written as:

$$\begin{aligned} & \frac{\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right)}{0} \\ > \; & \frac{\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right)}{\pi_{1L}^2(0,\rho_2) - F_1} \\ > \; & \frac{\pi_{1L}^1 - \pi_{1L}^1\left(\underline{q}_1\right)}{\pi_{1L}^2(0,\rho_2) - \pi_{1L}^2(\rho_1,\rho_2)} \end{aligned} \tag{4.119}$$

The first term is clearly the largest, and the second term dominates the last because $\pi_{1L}^2(\rho_1,\rho_2) < F_1$ which proves that $\phi_L'''(\rho_1) > \phi_L''(\rho_1) > \phi_L'(\rho_1)$ for all ρ. Next, let's do the same for $1H$.

$$\frac{\pi_{1H}^1 - \pi_{1H}^1 (q_{1L})}{\pi_{1H}^1 - \pi_{1H}^1 (1, \rho_2)}$$
$$> \frac{\pi_{1H}^1 - \pi_{1H}^1 (q_{1L})}{\pi_{1H}^1 + \pi_{1H}^2 (\rho_1, \rho_2) - F_1 - \pi_{1H}^1 (1, \rho_2)}$$
$$> \frac{\pi_{1H}^1 - \pi_{1H}^1 (q_{1L})}{\pi_{1H}^1 + \pi_{1H}^2 (\rho_1, \rho_2) - \pi_{1H}^1 (1, \rho_2) - \pi_{1H}^2 (1, \rho_2)} \tag{4.120}$$

which proves that $\phi_H''' (\rho_1) > \phi_H' (\rho_1) > \phi_H'' (\rho_1)$ for all ρ_1. We can now prove the existence of a pooling equilibrium for each of the cases.

Now, we can show that for some ρ_1, such that we can find some δ^* where $\phi_L' (\rho_1) > \delta^* > \phi_H''' (\rho_1)$. Thus, suppose

$$\frac{\pi_{1L}^1 - \pi_{1L}^1 \left(\underline{q}_1\right)}{\pi_{1L}^2 (0, \rho_2) - \pi_{1L}^2 (\rho_1, \rho_2)} \geq \delta^* > \frac{\pi_{1H}^1 - \pi_{1H}^1 (q_{1L})}{\pi_{1H}^1 - \pi_{1H}^1 (1, \rho_2)} \tag{4.121}$$

Let $\rho_1 \to 0$, $\phi_L (\rho_1) \to \infty, \phi_H''' (\rho_1)$ is an unchanged positive number. Clearly, $\phi_L' (0) > \phi_H''' (0)$. If $\phi_L' (1) > \phi_H''' (1)$ then there exists a range of δ^* which supports the pooling equilibrium for all ρ_1. If $\phi_L' (1) < \phi_H''' (1)$ we can find ρ_1' such that $\phi_L' (\rho_1') = \phi_H''' (\rho_1')$ hence, $\phi_L' (\rho_1' - \epsilon) > \phi_H''' (\rho_1' - \epsilon)$ which again provides a range of $\delta^* \in [\phi_L' (\rho_1' - \epsilon), \phi_L' (0)]$ that supports the separating equilibrium. ■

Chapter 5

Conclusion

The aims of this thesis were analyse the effects of trade policy on the strategic behaviour of firms. Overall, we can see that extending IO models to an international context, deepens our analysis in two areas. First, it allows us to look at the effects of a multinational entrant on the strategic behaviour of an incumbent monopolist and secondly, we can see the impact of trade policies on firms' actions.

We have seen how an domestic producer can use informational advantages to deter or reduce the extent of entry. In Chapter 2 we looked at the entry decision of a multinational entrant faced with two similar markets. This scenario allowed us to look at the effects of a national and joint quota on the pre-entry strategy of the domestic incumbents. From a strategic point of view, we saw how joint quotas link the actions of the domestic producers. Although tariffs and quotas generally had opposite effects on the actions of an incumbent, certain conditions were found where a very small joint quota could lead to similar incumbent behaviour as with a joint tariff. The welfare effects were ambiguous. First period welfare gains from lower pre-entry prices may or may not outweigh possible welfare losses resulting from entry deterrence. The welfare results complement rather than contrast those of Levy and Nolan (1992) showing that under certain conditions, quotas may enhance two-period welfare.

In Chapter 3 the analysis focused on the mode of entry. A multinational has a choice of two entry strategies: either exporting or foreign direct investment. We were able to show conditions under which it is advantageous for an incumbent to signal its cost type in order to affect the mode of entry. We saw that first period welfare increases with the limit price and that a small tariff decreases the limit price. Indeed, a tariff (or subsidy) may affect the type of equilibrium that emerges. The welfare effects of the second period were again similar to those of Levy and Nolan (1992).

Finally, Chapter 4 looked at reciprocal entry, where incumbents in separate markets were also able to enter each others' markets. The model brought together two aspects of limit pricing models, that of entry deterrence (Milgrom and Roberts 1982) and market share protection (Mailath 1989). The existence of foreign markets enhanced limit pricing behaviour although as the number of markets grew pooling equilibria disappeared for certain prior beliefs.

Clearly, when we consider firms in an international environment, their strategic behaviour differs from that of the standard closed economy. This provides a more realistic picture of firm behaviour, as well as illustrating the greater effect of government trade policy. There are no clear-cut conclusions that can be made regarding trade policy except that the effects of such policies may have more profound effects than usually considered. The sensitivity of partial equilibrium analysis to changes in parameter values is a considerable problem in estimating effects. Moreover, empirical analysis supporting limit pricing behaviour is rather weak. On the other hand, evidence of limit pricing might be easier to obtain when considering an international context. For example, one of the problems with the closed-economy entry-deterrence models is that potential entrants are not observed. However, if we consider the case of Chapter 3, exporting and FDI are observed and so we should be able to see if there is a link between pre-entry prices and the mode of entry chosen. If this could be achieved, it may be possible to measure the extent of strategic firm behaviour on prices in the economy and hence the possible effects of trade policy.

Future research may focus on other types of entry-deterring behaviour such as investment into excess capacity (Dixit 1980) within an international context. This may lead to a more general formalisation of strategic firm behaviour in international markets as well as clarifying the clearly extensive effects of trade policy.

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