Domestic R&D Policy in markets with Vertical Differentiation and Presence of Multinational Corporations

By

Abstract

This paper examines the strategic interaction between a Multinational Corporation (MNC) and a host country firm focused on its effect on product innovation by the host country's firm. To address this issue we analyse the channels through which Multinational corporations affect the incentives to invest in product innovation by host country firms. We consider a market for a vertically differentiated product that consist of a domestic firm, which produce only for domestic consumption, and a MNC, which can reach the local market by exporting or by establishing a subsidiary. To address these issues, in the context of an oligopolistic market, we build and analyse a three stages duopoly model. In the first stage the foreign firm chooses the mode of serving the domestic market. Then, the firms choose simultaneously product quality level in the second stage and prices (Bertrand competition) in the third stage. We also analyse the preferred mode of entry of the foreign firm from the host country's point of view. The model is then used to determine if there is scope for a domestic R&D policy. In this respect, our analysis suggests that any mechanism that provide an incentive for the domestic to increase its product quality would be welfare improving.

JEL: F2, L1, L5, O3.
Keywords: Foreign Direct Investment, Multinational's Entry Strategies, Vertical Differentiation, Research and Development.

1. Introduction

In recent years, the process of globalisation of production has assumed a number of new features. Two of these are very important from the point of view of developing countries[1]. First, FDI flows are increasingly important in global FDI. In particular, “Led by developing countries, global FDI flows resumed growth in 2004...” (UNCTAD, 2005, p. xix). As well, “…for the first time, TNCs are setting up R&D facilities outside developed countries that go beyond adaptation for local markets; increasingly, in some developing and South East European and CIS countries, TNCs R&D is targeting global markets and is integrated into the core innovation efforts of TNCs.” (UNCTAD, 2005, p. xxiv). This last phenomenon is very important from the host countries’ point of view, since it opens the door to develop not only technological know-how capabilities, but also to improve the ability of domestic firms to develop better products and/or production processes. This is the development of R&D capabilities (technological know-why).

Although there is significant theoretical literature on the impact of FDI on less developed economies, most of it analyses models where the decision of setting up a subsidiary in the host country has already been taken and/or where domestic firms don’t invest in R&D (see for instance, Findlay, 1978; Das, 1987; Wang and Blomstrom, 1992).

Hence, there is a lack of theoretical models that analyse the impact of FDI on developing countries in which simultaneously the mode of serving the domestic market is endogenous, the foreign firm set up R&D facilities when FDI is chosen, and domestic firms themselves undertake R&D investment. This chapter intends to fill this gap by developing a model of FDI in developing countries in which both the mode of foreign expansion and the incentives to innovate are endogenously determined.[2]

In particular, we intend to improve our understanding on the following issues:

1. First, on the impact of the different market structures on the incentives to innovate.
2. Second, on the preferred mode of entry of the foreign firm from the host country’s point of view.
3. Third, on the determinants of the optimal mode of entry of the foreign firm.
4. Fourth, to determine if there is scope for a domestic R&D policy

To address these issues, in the context of an oligopolistic market, we build and analyse a three-stage duopoly model. We consider a market for a vertically differentiated product that consists of a domestic firm, which produces only for domestic consumption, and a MNC, which can reach the local market either by exporting or by establishing a subsidiary. In the first stage, the foreign firm chooses the mode of serving the domestic market. Then, the firms simultaneously choose the quality level in the second stage and prices (Bertrand competition) in the third stage. The type of model we develop has been widely used in the literature about oligopoly models with vertically differentiated products, where firms compete in quality and then in price or quantity. This structure has been utilised to address a number of different

[1] Note however that to date only a small number of developing countries are participating in this process. However, it opens the possibility that more developing countries could be integrated into this process in the future.

[2] Petit and Sanna-Randaccio (2000) develop a model in which these two issues are endogenously determined. Their model, however, is formulated to explain FDI among developed countries. There are also a number of differences in the specific details between their and our model. For instance, they consider process R&D while our model allows product R&D.

issues such as minimum quality standards and R&D policy in international oligopolies. In these models firms compete in two stages, by simultaneously choosing product quality in the first stage and price or quantity in the second. The central idea behind this temporal structure is that quality is a long run decision variable, which can be taken as given when firms decide with respect to prices or quantity in the second stage. On the other hand, prices or quantity are a short run decision variable, which can be modified easily in a short period of time. The product quality level affects costs in two ways: firstly, as a sunk cost that follows from the expenditure in R&D to produce the required quality and, secondly, it affects production cost since it may increase with the quality of the product. Most of the models, however, consider just the first type of cost or none at all. In our model, both types of cost are considered. On the demand side, a common feature of these models is that consumers, who are heterogeneous, buy one or zero units of the product that is vertically differentiated. They differ in their valuations of quality and, therefore, in their willingness to pay for it. This feature allows that more than one quality is provided in equilibrium. Our model, however, compared with previous research using this type of set up differs in a number of key aspects. First, the type of issues we are interested in. In particular, we analyse, in the context of a market with a vertically differentiated product, the interaction between a MNC and a domestic firm, paying close attention to the incentives to firms' innovation. Second, we assume that product quality affects both development (fixed) and production costs. In our opinion, this type of set up seems more adequate if we consider a manufactured product, which seems to be the type of product with which emergent economies can compete with firms from developed countries.

The structure of this paper is as follows. In the following section we review the related literature. In section 3 we set up the model. In Section 4 we analyse the equilibrium of stages 2 and 3 in the two cases considered. First, the case in which the MNC serves the domestic market by exporting and, then when it creates a wholly owned subsidiary. Section 5 analyses the preferred mode of entry from the host country's point of view. Then, in section 6 we analyse the preferred mode of entry, but from the foreign firm's point of view. In section 7 we intend to shed some light on the issue if there is a scope for a domestic R&D policy. Finally, section 8 provides the main conclusions and suggests further research.

2. Related literature

This paper is closely related to two strands of literature, firstly, to the theoretical literature that focuses its analysis on the effects that the presence of MNC has on the technological development of the host country. Major contributions to the theoretical literature have been made by Findlay (1978), Das (1987) and Wang and Blomstrom (1992). A common element in them is the existence of productivity spillovers that are received by domestic firms from the MNC. A key difference, however, is that in Wang and Blomstrom there is an explicit recognition that the degree of spillovers depends on the expenditure made on learning activities (R&D) by domestic firms while in the other two models spillovers are costless[3]. A common weakness to these papers is that they undertake its analysis when the decision of setting up a subsidiary in the host country has already taken and/or where domestic firms don't invest in R&D. The model developed in this paper intends to fill this gap.

Secondly, this paper is related to the literature about oligopoly models with vertically differentiated products, where firms compete in quality and price or quantity, which is used to address a number of different issues such as minimum quality standards and R&D policy in international oligopolies. In these models, firms compete in two stages, by simultaneously choosing qualities in the first stage and price or quantity in the second. The central idea behind this temporal structure is that quality is a long run decision variable, which can be taken as given when firms decide with respect to prices or quantity in the second stage. On the other hand, prices or quantity are a short run decision variable, which can be modified easily in a short period of time. The quality chosen affects costs in two ways: firstly, as a sunk cost that follows from the expenditure in R&D to produce the required quality and, secondly, it affects production costs since it increases with the quality of the product. Most of the models, however, consider just the first type of cost or none at all. In our model both types of costs are considered. On the demand side, a common feature of these models is that consumers, who are heterogeneous, buy one or zero units of a product that is vertically differentiated. They differ in their valuations of quality and, therefore, in their willingness to pay for it. This feature allows that more than one quality is provided in equilibrium.

Ronnen (1991) analyses the effect of imposing a minimum quality standard (MQS from now on) in a local duopoly market where firms compete in quality and prices. His main result is that by establishing a MQS, which is not very stringent, social welfare is increased. A key feature of his model is that quality cost is sunk and doesn't affect variable production cost, which is zero. The intuition is that by establishing a MQS the quality chosen both by the high and low quality firm raise: the low quality firm to meet the MQS and the high quality firm to reduce the intensity of price competition that arises when the quality gap is reduced. The degree of product differentiation, however, decreases. Thus, in this model product qualities are strategic complements. Simultaneously, equilibrium prices measured in units of quality are reduced and, as a consequence, all consumers are better off in the regulated equilibrium: those who buy a unit and those who begin to buy. All of these results are in comparison to the unregulated equilibrium.

Ronnen's work is then extended in the context of an industry analysis in a number of directions. Motta (1993) builds a vertical differentiation model to compare the equilibrium product quality under Bertrand and Cournot competition in two different cases: quality costs

[3] See paper by Cohen and Levinthal, 1989, which introduces formally into the analysis of R&D spillovers.

are fixed and sunk with no impact on variable production cost and quality cost affect production cost with no fixed cost involved. He also evaluates its impact on welfare. There are two main results. First, the equilibrium product qualities are more differentiated in the case of price competition, a result that is independent on the quality cost type. The reason for that is straightforward, when firms compete in prices they anticipate a stronger competition in the second stage, so they tend to choose qualities that are more differentiated to soften price competition. Second, welfare is higher under Bertrand competition despite that it creates higher product differentiation.

Crampes et al. (1995) make a similar analysis to Ronnen, but assume that quality has an impact on production costs because “This appears to us the empirically more relevant case. Indeed, most quality standards in manufacturing pertain to materials and ingredients to be included or left out, packaging, thickness, flexibility, flammability, bio-degradability, etc. These seem to affect variable rather than fixed costs” (Crampes et al., page 72). They also show that in this case, when quality affects variable costs but fixed costs are equal to zero, a convex variable cost function is a necessary condition to have a stable and unique equilibrium. The main difference with Ronnen’s results is that in their model, when a MQS is established consumers may be better off or worse off depending on the response of the high quality producer to the increase in the quality chosen by the low quality producer. Consumer surplus increases if the high quality producer raises its quality slightly in response to the increase in quality of the other firm. Otherwise they are worse off.

Valletti (2000) also studies the consequences of imposing a MQS in the same context as Ronnen (1991) but assumes that firms in the second stage compete over quantities. Otherwise the models are the same. He finds that by establishing a mildly restrictive MQS both firms get lower profits, active consumers of both qualities are better off, but overall welfare decrease. The number of active consumers fall, so those consumers that stop buying the product are worse off. A key element to obtain this result is that when a firm increases its product quality the other firm’s profits are affected negatively. This assumption about second stage quantity competition appears to be reasonable in an industry characterized by capacity constraints. On the other hand, for industries where production can rapidly respond to increases in demand, the assumption of price competition seems to be more reasonable.

A different line of research is undertaken by Vandenbussche et al. (2001) where they look at the impact that the European Antidumping Policy may have in the context of a duopoly industry with vertically differentiated products. Their results rest on the assumption that both firms are symmetrical, which implies that there are two symmetric equilibrium in qualities in which the high quality firm chooses a quality equal to 1 and the low quality firm chooses a quality equal to 4/7. They also assume that both production and development costs are zero. In this context they show, in the case that in the free trade equilibrium the European firm produces the high quality product and the foreign firm the low quality one, that by establishing an antidumping policy, which is implemented as a price-undertaking, to protect the internal market can hurt domestic producers because it may cause a reversal of the qualities chosen by the domestic and foreign firms. When this happens, the qualities are still 1 and 4/7, so European consumers are not affected, but since profits earned by the high quality firm are higher than profits earned by the low quality firm, the European firm is hurt.

Zhou et al. (2002) use the same model structure as Ronnen (1991) to study the optimal commercial policy: namely, subsidy or taxes applied on product development R&D for exported products. They analyse this in the context of two firms, based in two different countries, which export a vertically differentiated product to a third country. One firm, based in a LDC, exports a low quality product and the other firm, based in a DC, exports a high quality product. As in Ronnen (1991) firms face high R&D development cost (sunk) with no impact of quality level on variable production cost. In fact, they simplify the analysis by assuming that production cost is zero. Another important feature is that they assume asymmetric R&D cost. For a sufficiently high difference, in equilibrium the LDC's firm chooses to produce the low quality product and the DC's firm the high quality one. In consequence, their model avoids the problem of the indeterminacy of the chosen quality, which exists when firms are symmetric. As usual, firms choose R&D expenditure in stage one and then, in stage two, price or quantity. The central results obtained are dependant on the kind of competition in stage two. In the case of Bertrand competition, the optimal policy is a subsidy on R&D expenditure in the low quality product and a tax on the high quality product. In the case of Cournot competition, the optimal policy is reversed: R&D tax on the low quality product and subsidy on the high quality product. The authors also consider the case of jointly optimal policy. In this case, instead of shifting profits, the objective is to maximize total profits by extracting consumer surplus in the third country. They found that in the Bertrand case, the optimal policy calls for an R&D tax on the LDC's product and an R&D subsidy on the DC's product. In the case of Cournot competition, on the other hand, optimal policy calls for an R&D tax on both products.

With this model the authors add a new reason why governments may care about product quality. This is to maximize the domestic firm's profits (i.e. profit shifting strategic policy)[4].

In the next section we will develop a duopoly model to analyse the impact of a MNC on the host country R&D incentives.

[4] Other reasons are for example to improve product safety (in this case the government can establish a MQS) or to protect domestic industry from foreign competition.

3. The Model

In this section we describe the demand and supply side of the model developed in this chapter. We consider a vertically differentiated oligopolistic market, i.e. a market where consumers have the same ranking of preferences about products and, therefore, they would buy the product with the highest quality if all the varieties were sold at the same price. They differ, however, in their willingness to pay for quality, which follows in our model from differences in their income level.

We will use this model to explore, among other issues, how the incentives to improve product quality by a domestic firm (d) are affected when it faces the competition of a foreign firm, which can serve the domestic market by exporting (f) or by setting up a subsidiary (s). As a consequence, the analysis will be focused on the domestic market, where both firms compete over two periods by choosing product quality (μ_d, μ_j, j=f,s) in the first, and prices (P_d, P_j) in the second. In addition to that, we will study whether the product quality chosen by the domestic firm is optimal from a welfare perspective and, therefore, if there is scope for an industrial policy aimed at improving domestic welfare.

3.1 Preferences and Demand

Assume that each consumer can buy 0 or 1 unit of the product and that her preferences are represented by the function[5]

$$U = \begin{cases} u(I-P)+\mu & \text{If the consumer with income I buys one unit of a product with quality } \mu \text{ at price } P \\ u(I) & \text{if the consumer does not buy} \end{cases}$$

Assuming P is a small fraction of the consumer's income, by taking a first order Taylor's expansion, the utility function can be restated as

$$U = \begin{cases} \mu-(1/\theta)P & \text{If the consumer buys one unit of product with quality } \mu \text{ at price } P \\ 0 & \text{if consumer does not buy} \end{cases}$$

where $\theta = 1/u'(I)$, i.e. θ is equal to the inverse of the income marginal utility. Assume $u(.)$ is concave, then θ is higher, the higher is the consumer's income level. In particular, assume that $\theta \sim U[\overline{\theta}-1, \overline{\theta}]$[6] represents a distribution that is related to individual's incomes. Thus, in our model we interpret θ as depending on the consumer's income level.

For convenience, we make a monotonic transformation of the utility function. In this formulation, the utility function is represented as the difference between θ multiplied by the product quality (μ) and the price of the product. Thus, a consumer with a given income (and therefore θ) gets a gross utility equal to $\theta\mu$ if she purchases one unit of a product with

[5] This formulation follows Tirole (1988), chapter 2, pages 96-97.

[6] Note that if $\overline{\theta}$ increases to a certain amount, then all the distribution move in the same amount.

quality μ. Its net utility (surplus) is obtained by subtracting the price of the product (P) from $\theta\mu$. Hence, the utility function is:

$$U = \begin{cases} \theta\mu - P & \text{If the consumer buys one unit of the product with quality } \mu \text{ at price } P \\ 0 & \text{if the consumer does not buy} \end{cases}$$

A different and common interpretation of θ is that it represents taste or preference for quality. In that case, the higher is θ, the higher is the consumer's value given to a unit of a product of a given quality and therefore the higher is her willingness to pay. In our case, however, a higher willingness to pay reflects higher consumer income. Thus, if two consumers have the same income, they would have the willingness to pay for a product of a given quality.

We are now in a position to obtain the demand function faced by both firms. First, notice the following[7]:

1. A given consumer purchases a product only if she obtains a positive surplus, which requires that $\theta\mu - P > 0$. Otherwise, the consumer would be better off by making no purchase at all since in that case she would get its reservation surplus of zero.
2. Given prices and qualities, there is one consumer (θ^*) who is indifferent between buying one or the other product. For that consumer $\theta^*\mu_d - P_d = \theta^*\mu_j - P_j$, $j = f$ or s. Thus, from this condition it follows $\theta^* = (P_j - P_d)/(\mu_j - \mu_d)$. This implies that consumers with $\theta^* < \theta < \bar{\theta}$ buy the high quality product. Hence, the demand for the high quality product is given by $q_j = \bar{\theta} - \theta^*$ ($j = f$, s).
3. Finally, note that there is one consumer (θ_d) that gets zero net utility of consuming the low quality product, i.e. $\theta_d\mu_d - P_d = 0$. Then, for each consumer with $\theta > \theta_d$ the net utility she receives from consuming one unit of the low quality product is positive. As well, from 2, we know that consumers with $\theta > \theta^*$ prefer the high quality product. Therefore, consumers with θ in the range $[\theta_d, \theta^*]$ purchase the low quality product and, as a consequence, the demand for this product is given by $q_j = \theta^* - \theta_d$.

By using the previous information and assuming $\mu_d < \mu_j$[8] we can represent the low quality (domestic) demand function[9] as:

$$q_d = \theta^* - \theta_d = \frac{P_j - P_d}{\mu_j - \mu_d} - \frac{P_d}{\mu_d}$$

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[7] To obtain these conditions we assume the market is not necessarily fully covered, which implies the price charged for the low quality product is higher or equal than the valuation given to that good for the consumer with the lowest income ($(\bar{\theta} - 1)\mu_d \leq P_d$).

[8] This assumption is justified below.

[9] Note that if $P_d\mu_j > P_j\mu_d$ then $q_d = 0$ and, therefore, $q_j = \bar{\theta} - \theta_j$. Hence, in this case the foreign firm is the only active in the market and we would have a monopoly equilibrium. We will not consider this case however because as should be clear later it is always profitable for the domestic firm to be active in the market.

Hence, demand functions become,

$$q_d = \theta^* - \theta_d = \frac{P_j \mu_d - P_d \mu_j}{(\mu_j - \mu_d)\mu_d} \qquad \text{if } P_d \le P_j \frac{\mu_d}{\mu_j} \qquad j = f, s$$

$$q_j = \bar{\theta} - \theta^* = \bar{\theta} - \frac{P_j - P_d}{\mu_j - \mu_d} \qquad \text{if } P_d \le P_j \frac{\mu_d}{\mu_j} \qquad j = f, s$$

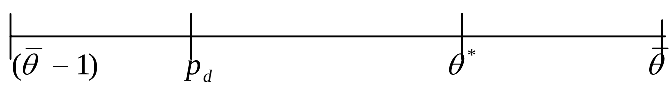
Note that when the firms choose prices in the last stage, qualities are given. By using this fact, we can define prices per unit of quality as the endogenous variables in the last stage of the game.

To do this, let us define $p_i = \frac{P_i}{\mu_i}$ (i=d,f,s). As well, let $r = \frac{\mu_j}{\mu_d}$ (j=f,s) be the ratio between the high quality and low quality products. This ratio is higher than one and reflects the degree of product differentiation. Then, the higher is *r*, the higher is the degree of product differentiation (higher quality gap). Of course, if *r* is equal to 1, it means that both products are identical or homogeneous.

Then, assuming that both firms are active and using the definitions above, the demand functions can be expressed as:

$$q_d = \frac{r}{r-1}(p_f - p_d) \qquad \text{and} \qquad q_j = \bar{\theta} - \frac{(rp_j - p_d)}{(r-1)} \qquad \textbf{(1)}$$

As well, when both firms are active, demand functions can be represented as:



where consumers in range $[(\bar{\theta} - 1), p_d]$ choose not to buy, consumers in range $[p_d,\ \theta^*]$ buy the domestic product, and consumers in range $[\theta^*,\ \bar{\theta}]$ buy the foreign firm product.

3.2 Cost of Quality

To this demand system we add now the quality cost structure to set up our model. There are two ways in which quality affect costs. First, firms need to invest resources in R&D to develop a product with the desired quality. This cost, which can be thought of as a sunk cost, is incurred in the second stage before the competition in the product market takes place. Second, production costs are also affected by the product quality. In particular, the higher is product quality, the higher is the variable cost of production. Therefore, by improving their product quality, firms face both sunk costs and higher variable production cost. The relative importance of these two channels has implications in terms of market structure[10]. For instance, if the burden of improving quality rests mainly on fixed cost and there is a low

[10] See for example Shaked and Sutton (1983) and Sutton (1986) for a discussion on this issue.

increase in the variable production cost, then markets tend to be relatively more concentrated than if the opposite happens.

The literature on vertical differentiation usually considers just one or the other type of quality cost, and in some cases no quality cost at all is considered. The intuition behind the fixed cost type of model is that to develop a product with the desired quality requires a high investment in R&D and then, when the desired quality is reached, production costs are affected only marginally by an increase in product quality. This kind of model, therefore, seems to be suited for industries like software and pharmaceuticals. The variable cost type of model, on the other hand, seems to be adequate for industries where increases in product quality rest basically, for example, in more expensive inputs or more qualified workers. This type of model seems to be adequate for manufacturing since in this type of industry quality rests mainly in the quality of materials or ingredients to be added (Crampes et al., 1995).

In our model we consider that cost quality has an impact both on fixed and variable cost. This is, therefore, an innovation with respect to the existing literature. It adds realism to our analysis, particularly in a context in which the host economy is a developing country. It seems to us the more relevant case since developing country firms appear to be more competitive with developed country firms in manufacturing rather than in industries such as software and pharmaceuticals. Another reason for this innovation is that it gives flexibility to our analysis since it allows analysing the implications on the equilibrium of different types of industries: namely, high development and low production costs and vice versa.

Since we are interested in studying the interaction between a developing country's firm in competition with a MNC based in a developed country, we assume there are asymmetric development costs. The way in which we introduce this in our model follows Zhou et al. (2002). To do this, let us define $FC(\mu)$ as the R&D cost incurred by the foreign firm when it develops a product with quality μ. On the other hand, to develop a product with the same quality, the domestic firm needs to invest $\gamma FC(\mu)$, where $\gamma > 1$. Thus, it implies that to develop a product with the same quality, the domestic firm needs to invest more. This reflects the idea that the domestic firm is less efficient in developing quality. This could happen for example because the subsidiary can draw on the experience of the parent firm and/or because the domestic firm’s R&D personnel have lower experience and professional qualifications.

If fixed cost of quality is symmetric, then under the conditions established until now, it can be shown that there are two Nash equilibriums in qualities: firm 1 choosing high quality and firm 2 choosing the low quality, and vice versa. However, by assuming asymmetric cost and that γ is great enough, then there is only one equilibrium, in which the domestic firm chooses to produce the low quality product[11].

As well, following Ronnen (1991) we will assume that $FC(\mu)$ has the following properties:

i. $FC(0) = FC'(0) = 0$
ii. $FC'(\mu) > 0$ and $FC''(\mu) > 0$ when $\mu > 0$
iii. $\lim_{\mu \to \infty} = \infty$ and $FC'''(\mu) \geq 0$

[11] The proof of this result can be found in Zhou et al. (2002)

Assumption i. ensure that both firms are active in the market because it implies that, provided the marginal benefit of μ (when $\mu = 0$) is positive[12], it is always profitable to enter to the market and offer a product with positive quality. Assumption ii. tells us that development costs are convex and, when variable costs are zero or concave in quality, it is a necessary condition to have an equilibrium that is unique and stable. Finally, assumption iii. ensures that the high quality producer chooses a quality lower than the maximum feasible. This is a necessary condition for the existence of equilibrium.

Finally, let us define $C(\mu)$ as the marginal (unit) cost of production of a product with quality μ, where $C'(\mu) \geq 0$. As a consequence, the firm's unit production cost will be higher the higher is its product quality. In particular, we assume that the unit cost function is $C_j = \alpha\mu_j$ ($\alpha > 0$, *j=d, f or* s), and therefore $C'(\mu) = \alpha > 0$. Thus, if both firms choose the same product quality, they have the same unit production cost[13]. Hence, the effect of product quality on production costs is the same for both firms. The idea behind this specification is that when a firm invests enough resources to produce a product with quality μ, then it has reached the knowledge required to produce its product with the best available technique and, therefore, the marginal (unit) cost of production ($\alpha\mu$) is the same independent of which firm reached that level of knowledge. Firms differ, however, in the amount of resources that they need to invest to reach a certain level of product quality.

[12] Below we show that the marginal benefit of μ evaluated at $\mu = 0$ is positive for both products, provided that there is some degree of product differentiation.

[13] It can be shown, however, that it is never profitable for both firms to choose the same quality level since in that case products become homogenous and therefore profits gross from quality development costs tend to zero (Bertrand competition with homogenous products).

4. *The Different Modes of Serving the Host Country Market and its Impact on the Incentives to Improve Product Quality*

The structure presented in the previous section will now be used to analyse two types of interaction in the domestic market. The first case emerges when the MNC serves domestic consumers through exports. The second case arises when the MNC creates a wholly owned subsidiary. In this section, we analyse stages 2 and 3 of the model, this is the simultaneous choice made by both firms of product quality in stage 2 and price in stage 3. The choice of the optimal mode of operation of the foreign firm is analysed in section 6.

4.1 First Case: The Foreign Firm Serves the Host Country Market by Exporting

In this case, the foreign firm serves the domestic market by exporting and, as a consequence, the foreign firm needs to pay transport costs to reach the domestic market with its product. Therefore, in addition to the marginal cost of production in the parent firm, the foreign firm also faces variable transport costs.

The sequence of decisions is: 1. In stage 2 both firms simultaneously choose product quality. Then, in stage 3, the firms simultaneously choose p_d and p_f, in a Bertrand fashion, taking qualities as given. However, the firms' maximisation problem is, as usual, solved backwards.

In summary, we can state the firms' problem as:

Stage 3:

Domestic firm Max p_d $\quad \pi^d = (P_d - C_d) * q_d = (p_d - \alpha)\mu_d * q_d$ **(2a)**

Foreign Firm Max p_f^* $\quad \pi^f = (P_f^* - C_f) * q_f = (p_f^* - \alpha)\mu_f * q_f$

where $P_i = \mu_i p_i$ and $C_i = \alpha\mu_i$, $i = d, f$.

Stage 2:

Domestic firm Max μ_d $\quad TP^d = \pi^d(\mu_d, \mu_f) - \gamma FC(\mu_d)$ **(2b)**

Foreign Firm Max μ_f $\quad TP^f = \pi^f(\mu_d, \mu_f) - FC(\mu_f)$

Third Stage: Price choice

Profits functions are

$$\pi^d = q_d(P_d - C_d) = \left[\frac{r}{(r-1)}(p_f - p_d)\right] * [p_d - \alpha]\mu_d \quad \textbf{(3a)}$$

$$\pi^f = q_f(P_f^* - C_f) = \left[\bar{\theta} - \frac{[r(p_f^* + \delta) - p_d]}{(r-1)}\right] * [p_f^* - \alpha]\mu_f \quad \textbf{(3b)}$$

where we use the demand functions defined by equation 1 and

t = transport cost per unit of output[14]

$P_f = P_f^* + t$ = Price paid by domestic consumers for each unit of q_f

$P_f^* =$ Price received by the foreign firm for each unit of q_f that they sell in the domestic market

$\delta = \dfrac{t}{\mu_f}$ = transport cost per unit of output divided by the foreign product quality.

Notice that at this stage the foreign product quality is exogenous, so if δ changes it should be interpreted as caused by a change in the transport cost per unit of output. In other words, we don't mean that the transport cost is per unit of quality, but per unit of output. Therefore, the transport cost per unit is the same independent of the product quality.

The f.o.c. of the maximisation problem (2a) is

$$\pi^d_{p_d} = \left[\frac{r}{r-1}(p_f - p_d)\right]\mu_d - \frac{r}{r-1}[p_d - \alpha]\mu_d = 0 \quad \textbf{(4a)}$$

$$\pi^f_{p_f^*} = \left[\bar{\theta} - \frac{\left[r(p_f^* + \delta) - p_d\right]}{(r-1)}\right]\mu_f - \frac{r}{r-1}\left[p_f^* - \alpha\right]\mu_f = 0 \quad \textbf{(4b)}$$

Therefore, the reaction functions are

$$p_d = \frac{1}{2}\left[p_f^* + \alpha + \delta\right] \quad \textbf{(5a)}$$

$$p_f^* = \frac{1}{2r}\left[\bar{\theta}(r-1) + p_d + r\alpha - r\delta\right] \quad \textbf{(5b)}$$

Note that prices are strategic complements. The reason is that if one firm increases its price, the other firm's demand increases and therefore it finds it profitable to increase its own price. The equilibrium prices is stable and unique if $\left|\dfrac{dp_i}{dp_j}\right| < 1,\ i, j = d, f\ ,\ i \neq j$. Taking into account that $r > 1$, this condition is met since
$\dfrac{dp_d}{dp_f^*} = \dfrac{1}{2}$ and $\dfrac{dp_f^*}{dp_d} = \dfrac{1}{2r}$.

Thus, by solving equations 5a and 5b we find the Nash equilibrium, which is:

$$p_d = \frac{1}{(4r-1)}\left[(r-1)\bar{\theta} + 3r\alpha + r\delta\right] \quad \textbf{(6a)}$$

$$p_f^* = \frac{1}{(4r-1)}\left[2(r-1)\bar{\theta} + (2r+1)\alpha - (2r-1)\delta\right] \quad \textbf{(6b)}$$

[14] In broader terms, the transport cost could be interpreted as including tariffs per unit of imports. However, to keep our analysis simple, we consider t as including only transport costs.

Hence, we find that the equilibrium values of each price increases with the level of $\bar{\theta}$ (related to the upper level of income distribution) and the marginal effect of product quality on unit production cost (α). However, the effect of transport cost has, as expected, an asymmetric effect. It increases the equilibrium domestic price and decreases the equilibrium foreign firm price.

By substituting 6a and 6b in equation 1, we obtain the firms' sales, which are:

$$q_d = \frac{r}{r-1}[p_f - p_d] = \frac{r}{r-1}\left\{\frac{(r-1))}{(4r-1)}[\bar{\theta} - \alpha] + \frac{r}{(4r-1)}\delta\right\} \quad \textbf{(7a)}$$

$$q_f = \frac{r}{r-1}\left\{\frac{2(r-1)}{(4r-1)}[\bar{\theta} - \alpha] - \frac{(2r-1)}{(4r-1)}\delta\right\} \quad \textbf{(7b)}$$

As well, from eq. 7b we have that a necessary condition for the foreign firm to face a positive demand is $\delta < \frac{2r-2}{2r-1}\left[\bar{\theta} - \alpha\right]$. Thus, if transport costs are high enough, it is never profitable for the foreign firm to export to the domestic market.

Second Stage: Quality choice

By introducing the Nash equilibrium in prices into the profit function we obtain the domestic and foreign firm profit functions in stage 2, which are:

$$\begin{aligned} TP^d &= \frac{r(r-1)}{(4r-1)^2}\mu_d\left\{\left[\bar{\theta} - \alpha\right] + \frac{r}{r-1}\delta\right\}^2 - \gamma FC(\mu_d) \\ &= \phi(r)\mu_d\left\{[\bar{\theta} - \alpha] + \phi_1(r)\delta\right\}^2 - \gamma FC(\mu_d) \end{aligned} \quad \textbf{(8a)}$$

$$\begin{aligned} TP^f &= 4\frac{r(r-1)}{(4r-1)^2}\mu_f\left\{\left[\bar{\theta} - \alpha\right] - \frac{2r-1}{2r-2}\delta\right\}^2 - FC(\mu_f) \\ &= 4\phi(r)\mu_f\left\{[\bar{\theta} - \alpha] - \phi_2(r)\delta\right\}^2 - FC(\mu_f) \end{aligned} \quad \textbf{(8b)}$$

where $\phi(r) = \frac{r(r-1)}{(4r-1)^2}$, $\phi_1(r) = \frac{r}{r-1}$ and $\phi_2(r) = \frac{2r-1}{2r-2}$.

As expected, quality choice affects the firms' profits through two different channels. Firstly, by increasing their product quality, the firms are able to charge higher prices, but they also face higher production and quality development costs. Simultaneously, if the domestic firm increases its product quality, then the degree of product differentiation shrinks, causing a more intense competition in the third stage of the game. In fact, note that if $r \to 1$, only the domestic firm would be active in the market. The reason is that with Bertrand competition and identical products, the domestic firm keeps the foreign firm out of the market by charging a little less than $(\alpha\mu + \delta)$.

Now both firms simultaneously choose their optimal product quality, taking the other firm's product quality as given. The first order conditions are:

$$TP_{\mu_d}^{d} = [\phi(r) - \phi'(r)r]\{(\overline{\theta} - \alpha) + \phi_1(r)\delta\}^2$$
$$+ 2\phi(r)\mu_d\left\{\left[(\overline{\theta} - \alpha) + \phi_1(r)\delta\right]\left[\phi_1^{'}(r)\frac{dr}{d\mu_d}\delta\right]\right\} - \gamma FC'(\mu_d) = 0 \quad \textbf{(9a)}$$

and

$$TP_{\mu_f}^{f} = 4[\phi(r) + \phi'(r)r]\{(\overline{\theta} - \alpha) - \phi_2(r)\delta\}^2$$
$$+ 8\phi(r)\mu_f\{(\overline{\theta} - \alpha) - \phi_2(r)\delta\} * \left\{- \phi_2^{'}(r)\frac{dr}{d\mu_f}\delta - \phi_2(r)\frac{d\delta}{d\mu_f}\right\} - FC'(\mu_f) = 0 \quad \textbf{(9b)}$$

which can be expressed as

$$TP_{\mu_d}^{d} = [\phi(r) - \phi'(r)r]\{(\overline{\theta} - \alpha) + \phi_1(r)\delta\}^2$$
$$+ \Omega(r)\{[(\overline{\theta} - \alpha)\delta + \phi_1(r)\delta^2]\} - \gamma FC'(\mu_d) = 0 \quad \textbf{(9c)}$$

$$TP_{\mu_f}^{f} = 4[\phi(r) + \phi'(r)r]\{(\overline{\theta} - \alpha) - \phi_2(r)\delta\}^2$$
$$+ \Omega_1(r)[(\overline{\theta} - \alpha)\delta - \phi_2(r)\delta^2] - FC'(\mu_f) = 0 \quad \textbf{(9d)}$$

$$\text{where } \Omega(r) = \frac{2r^2}{(4r - 1)^2(r - 1)} \text{ and } \Omega_1(r) = \frac{4r(2r^2 - 2r + 1)}{(4r - 1)^2(r - 1)} \quad \textbf{(10)}$$

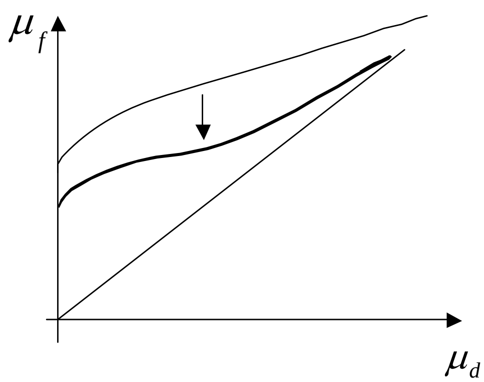
The optimal value for μ_d and μ_f is obtained from the solution to the system of equations (9c) and (9d). Since the second order and stability conditions are met, then the equilibrium is stable and unique (see proof in Appendix 2).

By totally differentiating Equations 9c and 9d we can observe that the equilibrium value for the domestic product quality is higher, the higher the domestic upper boundary of the income level ($\overline{\theta}$) and the lower is the domestic product development marginal cost ($\gamma FC'(\mu_d)$).

As well, it can be shown that $\frac{dTP_{\mu_d}^{d}}{d\mu_f} > 0$ and $\frac{dTP_{\mu_f}^{f}}{d\mu_d} > 0$ (see proof in Appendix 2). Then, the best response functions, which follow from the first order conditions, are positively sloped and therefore product quality levels are strategic complements. The intuition behind the slope of the reaction functions is as follows. If the foreign firm increases its product quality, both products become more differentiated (r increases), which increases the marginal benefit of increasing the domestic product quality and, as a consequence, the domestic firm find it profitable to increase its product quality. On the other hand, if the domestic firm increases its product quality, both products become less differentiated, the foreign firm's profits decreases and, to alleviate the intensity of the competition, the foreign firm finds it profitable to increase its product quality.

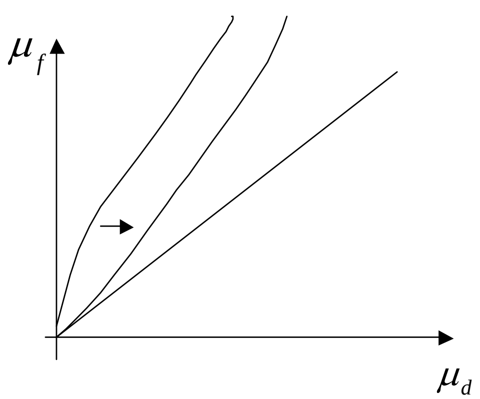
On the other hand, it can be shown that $\frac{dTP^{d}_{\mu_d}}{d\delta}\frac{\partial\delta}{\partial t} > 0$ and $\frac{dTP^{f}_{\mu_f}}{d\delta}\frac{\partial\delta}{\partial t} < 0$ (see proof in Appendix 2). This result tell us that if the domestic market's degree of protection (*t*) increases, then the incentives to improve its product quality increases for the domestic firm and decreases for the foreign firm. In other words, if the domestic market's degree of protection increases, the foreign firm's best response function moves down. It implies that given the domestic firm's product quality, the foreign firm's optimal quality level falls. The movement of the best response functions is illustrated in the following diagram:

Direction of the Movement of the Foreign Firm's Best Response Functions when the Degree of the Domestic Market Protection Increases



As well, if t increases, then the domestic firm's incentives to invest in product quality also increase. So, the domestic firm's best response function moves to the right. In other words, given the foreign firm's product quality, the domestic firm's product quality goes up. The following diagram illustrates this situation:

Direction of the Movement of the Domestic Firm's Best Response Functions when the Degree of the Domestic Market Protection Increases



4.2 Second Case: The Foreign Firm Serves the Host Country Market by Creating a Wholly Owned Subsidiary

In this case the foreign firm serves the domestic market by setting up a subsidiary (s). As well, we assume that the MNC's subsidiary undertakes its own R&D expenditure (R_s), which aims both to transfer its technology from the parent firm and to adapt its product to the conditions in the domestic market. The sequence of decisions, as in the previous case, is: both firms simultaneously choose qualities in the second stage and then, in the third stage they choose prices taking qualities as given.

Third Stage: Price choice

Profit functions in t=1 are:

$$\pi^d = q_d(P_d - C_d) == \left[\frac{r}{(r-1)}(p_s - p_d)\right][p_d - \alpha]\mu_d \tag{11a}$$

$$\pi^s = q_s(P_s - C_s) = \left[\bar{\theta} - \frac{[rp_s - p_d]}{(r-1)}\right][p_s - \alpha]\mu_s \tag{11b}$$

Nash equilibrium in prices at t=2 is:

$$p_d = \frac{(r-1)}{(4r-1)}\bar{\theta} + \frac{3r}{(4r-1)}\alpha \tag{12a}$$

$$p_s = \frac{2(r-1)}{(4r-1)}\bar{\theta} + \frac{(2r+1)}{(4r-1)}\alpha \tag{12b}$$

Note that both equilibrium prices increase with $\bar{\theta}$, and with the cost of production per unit of quality.

As well, we can obtain equilibrium quantities, which are:

$$q_d = \frac{r}{(r-1)}\left[\frac{(r-1)}{(4r-1)}(\bar{\theta} - \alpha)\right] \tag{13a}$$

$$q_s = \frac{r}{(r-1)}\left[\frac{2(r-1)}{(4r-1)}(\bar{\theta} - \alpha)\right] \tag{13b}$$

Both equilibrium quantities increase with $\bar{\theta}$, but decrease with the cost of production per unit of quality.

Second Stage: Quality choice

In this stage firms choose product quality levels. Before solving the firms' problem, note the following details of the foreign firm's profit function. First, by setting up a subsidiary, the foreign firm avoids transport costs. Additionally, the foreign firm incurs the cost of setting up a new production facility in the host country, which is given by $\bar{S}_s$. Then, by changing the mode of serving the domestic market, the foreign firm saves transport costs, but it faces additional plant specific fixed costs. As well, it has a new unit production cost (C_s), which depends on the product quality chosen by the subsidiary. Therefore, a necessary condition for this strategy to be profitable is $C_s < C_f + t$. In other words, the foreign firm needs to increase its variable profits to compensate its additional fixed cost. Finally, since in this case the subsidiary undertakes R&D in the host country, which aims to choose a product quality more suitable for the host economy, it incurs product development costs given by $FC(\mu_s)$. By undertaking its own R&D, the subsidiary has the opportunity of making a better choice of its product quality to serve the domestic market.

Hence, by using the demand functions given by equation (1) and the fact that $P_i = p_i \mu_i$ (i=d,s) the firms' profit function at t=1 can be expressed as:

$$TP^d = \left[\frac{r}{(r-1)}(p_f - p_d)\right][p_d - \alpha]\mu_d - \gamma FC(\mu_d) \qquad \textbf{(14a)}$$

$$TP^s = \left[\bar{\theta} - \frac{(rp_s - p_d)}{(r-1)}\right][p_s - \alpha]\mu_s - \bar{S}_s - FC(\mu_s) \qquad \textbf{(14b)}$$

By substituting in the Nash equilibrium prices into the profit function we obtain total profit functions, which are:

$$TP_d = \phi(r)\mu_d\left[\bar{\theta} - \alpha\right]^2 - \gamma FC_d(\mu_d) \qquad \textbf{(15a)}$$

$$TP_s = 4\phi(r)\mu_s\left[\bar{\theta} - \alpha\right]^2 - \bar{S}_s - FC_s(\mu_s) \qquad \textbf{(15b)}$$

where $\phi(r) = \dfrac{r(r-1)}{(4r-1)^2}$

Maximisation of profits with respect to μ_d and μ_s yields the following f.o.n.c.:

$$\left[\phi(r) - \phi'(r)r\right](\bar{\theta} - \alpha)^2 = \gamma FC'(\mu_d) \qquad \textbf{(16a)}$$

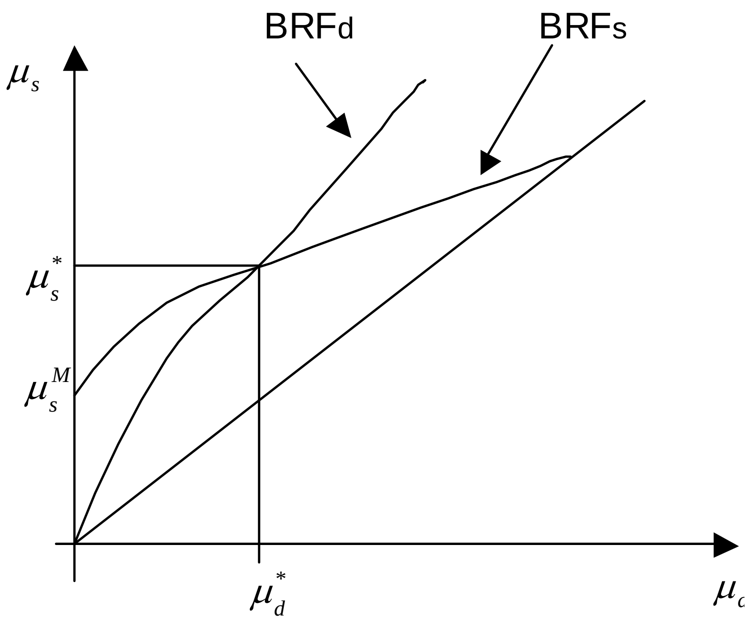
$$4\left[\phi(r) + \phi'(r)r\right](\bar{\theta} - \alpha)^2 = FC'(\mu_s) \qquad \textbf{(16b)}$$

The solution to the system of Equations (16.a) and (16.b) gives us the optimal value for μ_d and μ_s. From the f.o.n.c. we can obtain the reaction functions, which are positively sloped, making qualities strategic complements (See appendix 1 for the derivation of the best reaction functions). The intuition behind the slope of the reaction functions is the same as in case 1. If the foreign firm increases its product quality, then the products become more differentiated and therefore the marginal benefit of the domestic product quality increases and, as a consequence, the domestic firm finds it profitable to increase its product quality. On the other hand, if the domestic firm increases its product quality, the products became less differentiated, the foreign firm's profits decreases and, to alleviate the intensity of the competition, the foreign firm finds it profitable to increase its product quality.

The second order and stability conditions, which can be found in Appendix 1, are satisfied, so the solution to (16a) and (16b) is unique and stable.

The following diagram illustrates the equilibrium in this second stage of the game:

Best Response Functions and Nash Equilibrium in Qualities



BRF_d and BRF_s represent the best response functions of the domestic and subsidiary firms, respectively. They intersect above the 45^0 line because in equilibrium $\mu_s > \mu_d$, and the equilibrium qualities chosen by both firms are μ_d^* and μ_s^*. On the other hand, μ_s^M is the quality that the foreign firm would choose in case of being a monopoly.

5. Preferred Mode of Operation of the Foreign Firm from the Host Country's Point of View

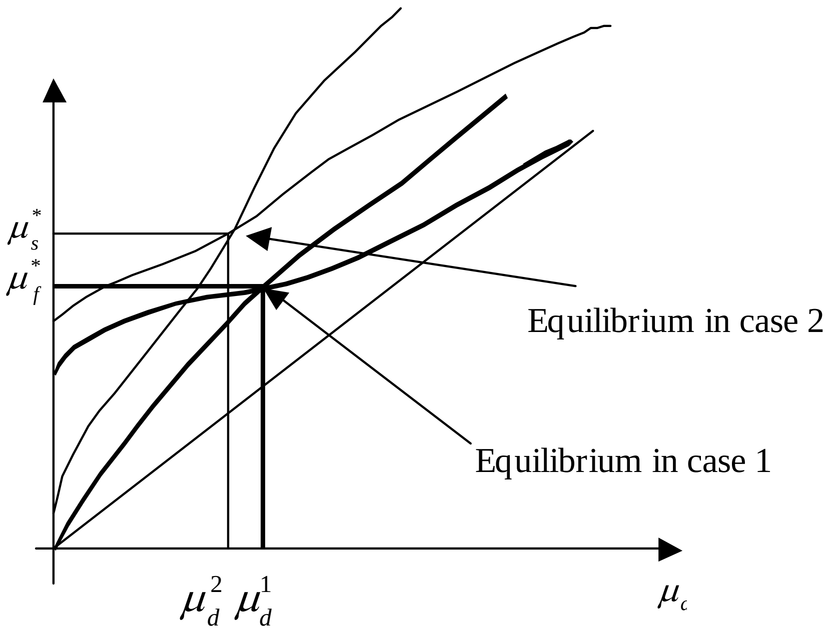
In this section we compare the equilibrium reached in the two cases analysed in section 4: namely, when the foreign firm serves the domestic market by exporting and when it sets up a wholly owned subsidiary. Our main aim in this section is to determine if there is a preferred mode of operation of the foreign firm from the host country's point of view. Alternatively, if there is one preferred mode, what are the determinants of preferring one or the other mode.

Remember that the main difference between the two scenarios analysed is that when the foreign firm exports to the domestic market (case 1) it faces not only production costs but also transport costs, while in the second case, it avoids transport costs but has to incur a plant specific fixed cost. Of course, it also changes the incentives to improve product quality faced both by the domestic and foreign firm. In particular, we know that $\frac{dTP_{\mu_d}^d}{d\delta}\frac{\partial\delta}{\partial t} > 0$ and $\frac{dTP_{\mu_f}^f}{d\delta}\frac{\partial\delta}{\partial t} < 0$. Thus, if the domestic market's degree of protection (t) decreases, then, given the domestic firm's product quality, the foreign firm's incentives to improve its product quality increases. As well, given the foreign firm's product quality, the domestic firm's incentives to improve its product quality falls. As we showed in the previous section, this situation changes both firms' best response functions: the foreign firm's best response function moves up and the domestic firm's best response function moves to the left.

A priori, however, the final effect on the equilibrium quality levels is ambiguous, since it depends on the relative movements of both best response functions. In other words, we need to know how sensitive both best response functions are to the transport costs. It is clear, however, that the equilibrium level of the foreign firm's product quality increases. On the other hand, the equilibrium level of the domestic firm's product quality can increase or decrease. The reason is that the domestic firm faces incentives in opposite directions. On the one hand, the reduction in the domestic market's degree of protection decreases its incentives (moves its best response function up and to the left), but also given that the subsidiary increases its product quality, it reduces the intensity of competition and therefore increases its incentives to invest resources to improve its product quality.

Thus, we have two possible cases. Firstly, the foreign firm's product quality rises and the domestic firm's product quality falls. Secondly, the product quality of both firms increases. Let us consider each case separately. The following diagram illustrates the first case:

Best Response Functions and Nash Equilibrium in Qualities in both Cases



Notice that compared with case 1, the relative qualities (r) increase. Thus, the quality gap is higher and therefore the intensity of competition is reduced. As well, from the equilibrium prices in case 1 (equations 6a and 6b) we have that

$$\frac{dp^d}{dr} = \left[\frac{3}{(4r-1)^2}(\bar{\theta}-\alpha) - \frac{1}{(4r-1)^2}\delta\right] > 0 \text{ and}$$

$$\frac{dp_f^*}{dr} = 2\left[\frac{3}{(4r-1)^2}(\bar{\theta}-\alpha) - \frac{1}{(4r-1)^2}\delta\right] > 0$$ [15]

Thus, if r increases so do both prices adjusted by its quality. Notice also that $\frac{dp_f^*}{dr} = 2\frac{dp_d}{dr} > 0$, so the foreign firm's price increases more (by two times) than the domestic firm's price increases.

On the other hand, the surplus obtained by each consumer when he buys one unit of one of the products is given by:

$$\theta\mu - P = \mu(\theta - p)$$

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[15] As we show above, a necessary condition for the foreign firm to have a positive demand is $\frac{(2r-2)}{(2r-1)}(\bar{\theta}-\alpha) > \delta$, which implies that $(\bar{\theta}-\alpha) > \delta$. Therefore, $3(\bar{\theta}-\alpha) > \delta$ and as a consequence $\frac{dp^d}{dr}$ and $\frac{dp_f^*}{dr}$ are greater than zero.

Hence, the effect on consumer welfare is:

- Consumers of the foreign firm product are worse off, since despite the foreign firm's product quality increases its price increases more.
- Consumers of the domestic product are also worse off since the domestic firm's product quality decreases and its price increases.
- Because the low quality price adjusted by quality increases, then there are consumers that leave the market. Remember that for the marginal consumer $\theta = \frac{P_d}{\mu_d} = p_d$, then if p_d increases so does θ for the marginal consumer. Then, there are fewer consumers active in the market.

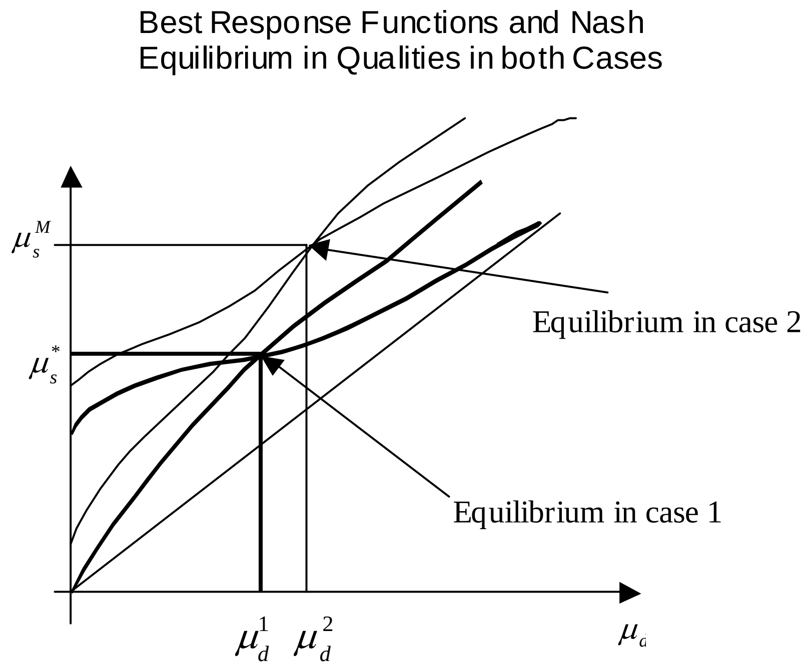
We can conclude therefore that consumers that remain in the market when equilibrium moves from case 1 to case 2 are worse off and that the number of active consumers decreases. The reason for these results is that *r* increases and therefore the intensity of competition falls since products become less differentiated. As a consequence of this, both prices are adjusted by a quality increase.

Regarding the firms' profits, we can conclude that:

- From equation 8b, we can see that the foreign firm's profits (gross from the plant specific fixed cost) increase since *r* rises and *t* falls. Thus, variable profits rise and the foreign firm would prefer FDI as a mode to reach the domestic market if its profits increase more than the plant specific fixed cost.
- On the other hand, from equation 8a we can observe that the domestic firm's profits can raise or fall. The reason is that if *t* and its product quality fall, then so do its profits. The effect is ambiguous however since if *r* increases it has a positive effect on its profits.

We can conclude what is the net effect on domestic welfare, but these results suggest that it is highly likely that domestic welfare decreases. What is clear in any case is that consumer welfare fall.

The following diagram illustrates the second case, in which the product quality of both firms increase:



The impact on consumer welfare is the same as in the first case since the quality of both products increases, but the foreign firm's product quality rises more than the domestic firm's product quality, so *r* increases. Therefore, both equilibrium prices move up and consumers of each product are worse off. As well, there are fewer active consumers in the market.

The qualitative effect on the foreign firm's profits is the same. There is, however, a quantitative effect since the product quality gap raises less. Therefore, we can expect in this case that the foreign firm's profits increases, but less than in the case in which the domestic firm's product quality falls.

On the other hand, since in this case the domestic firm's product quality moves up, it is more likely that its profits also do so. The net effect, of course, is still ambiguous since *t* falls. Notice however that even in the case that the domestic firm's profits increases, it increases less than the foreign firm's profits.

Finally, the effect on the domestic welfare is ambiguous, but it seems to be negative. These results suggest that the domestic economy is worse off when the foreign firm chooses to serve the domestic market through FDI instead of by exporting. The key reason for this is that the foreign firm increases its product quality and the product quality gap increases. Thus, intensity of competition falls since products become more differentiated. In that case, both product prices (per unit of quality) increases, which reduces consumers welfare. As well, it could reduce the domestic firm's profits.

6. Determinants of the Optimal Mode of Operation of the Foreign Firm

Let us study now the optimal mode of serving the domestic market from the foreign firm's point of view.

As we established before, by serving the domestic market through FDI, the foreign firm reduces variable costs but face higher fixed costs. From equations 8b and 15b we know that the foreign firm's profit functions in case 1 and case 2 are:

$$TP^{f} = 4\phi(r)\mu_{f}\left\{[\bar{\theta}-\alpha]-\phi_{2}(r)\delta\right\}^{2} - FC(\mu_{f})$$
$$TP^{s} = 4\phi(r)\mu_{s}\left\{[\bar{\theta}-\alpha]\right\}^{2} - \bar{S}_{s} - FC(\mu_{f})$$

As we know, when the equilibrium moves from case 1 to case 2, *r* increases and δ goes to zero. Thus, it is clear from these functions that the foreign firm's profits gross from the plant fixed cost increases since $\phi'(r)$ is positive and $\left[\bar{\theta}-\alpha\right]^{2} > \left\{[\bar{\theta}-\alpha]-\phi_{2}(r)\delta\right\}^{2}$. Thus, the foreign firm would prefer FDI if $\bar{S}_{s}$ is lower than the increase in profits.

Therefore, we can conclude that the choice of the mode of serving the domestic market depends on:

1. Level of transport cost (degree of domestic market protection): the higher the degree of market protection, the more likely that the foreign firm chooses FDI. The reason is that if the foreign firm switches the mode of serving the domestic market from exports to FDI, then its variable profits increase.
2. Level of plant specific fixed cost: the higher is $\bar{S}_{s}$ the more likely that the foreign firm chooses exports. The reason is that in this case the foreign firm needs a higher increase in variable profits to make it profitable to switch to FDI.
3. Difference in the level of efficiency in developing quality: the lower the domestic firm's R&D investment, the higher the probability that the foreign firm chooses FDI. This happens since in this case the increase in the product quality gap would be higher. Therefore, if the foreign firm switches to FDI, the increase in its variable profits is higher and therefore the higher the incentives to choose this mode to serve the domestic market.
4. The domestic income level: the higher is $\bar{\theta}$, the more likely that the foreign firm would serve the domestic market through FDI. The reason is that the amount that the foreign firm's variable profits increase when it moves from case 1 to case 2 is higher, the higher is $\bar{\theta}$. This result can be seen from the fact that $\frac{dTP^{f}}{d\bar{\theta}} = 4\phi(r)\mu_{f}\left\{(\bar{\theta}-\alpha)-\phi_{2}(r)\delta\right\} < \frac{dTP^{s}}{d\bar{\theta}} = 4\phi(r)\mu_{s}\left[\bar{\theta}-\alpha\right]$ since $\phi(r)>0$, $\mu_{s}>\mu_{f}$ and $\left\{(\bar{\theta}-\alpha)-\phi_{2}(r)\delta\right\} < \left[\bar{\theta}-\alpha\right]$. Therefore, the domestic income plays a role in the choice of the mode in which the foreign firm serves the domestic market.

7. Is there a Scope for a Domestic R&D Policy?

In this section we will analyse if there is scope for a domestic R&D policy. This would happen if the product quality chosen by the domestic firm does not maximise domestic welfare, defined as consumer surplus plus the domestic firm's profits. This analysis is undertaken for the case in which the foreign firm serves the domestic market by setting up a subsidiary. The main result is set in the following proposition:

Proposition 1. - When the foreign firm serves the domestic market by setting up a subsidiary, the quality chosen by the domestic firm does not maximize domestic welfare. In fact, there is an under-provision of quality.

Discussion: A sufficient condition to prove the proposition is to verify that $(dW \ / \ d\mu_d) \ > \ 0$ in the equilibrium without government intervention, where *W* is domestic social welfare.

Let us define the domestic country's welfare as:

$$W = \int_{p_d}^{\theta^*} \mu_d \left[\theta - p_d\right] d\theta + \int_{\theta^*}^{\bar{\theta}} \mu_s \left[\theta - p_s\right] d\theta + \left[\pi^d(\mu_d, \mu_s) - \gamma FC(\mu_d)\right]$$

where the first and second term to the right represent the net surplus obtained by consumers who buy the domestic and foreign product, respectively. The third term represents the domestic firm's profits less R&D cost. Then,

$$\frac{\partial W}{\partial \mu_d} = \left[\frac{\partial \int_{p_d}^{\theta^*} \mu_d (\theta - p_d) d\theta}{\partial \mu_d}\right] + \mu_s \left[\frac{\partial \int_{\theta^*}^{\bar{\theta}} \mu_s (\theta - p_s) d\theta}{\partial \mu_d}\right] \qquad \textbf{(17)}$$
$$+ \left[\frac{\partial \pi^d(\mu_d, \mu_s)}{\partial \mu_d} - \gamma FC'(\mu_d)\right] + \frac{\partial \pi^d}{\partial \mu_s}\frac{\partial \mu_s}{\partial \mu_d}$$

The first two terms in square brackets display the variation in the net consumer surplus derived from consuming the domestic and foreign product, respectively. On the other hand, the last two terms show the impact of marginally increasing μ_d on domestic firm profits. Because the domestic firm is maximizing profits, the third term in square brackets is zero. The last term shows the rent shifting strategic effect.

A key element to evaluate the sign of equation 17 is that $\frac{dr}{d\mu_d} > 0$, so if the domestic firm increases its product quality, the product quality gap decreases. This follows from the fact that the best response functions have a positive slope since product qualities are strategic complements.

Hence, if *r* falls, so do both prices since

i) $(dp_d / dr) > 0$ (by equation 12a)

ii) $(dp_s / dr) > 0$ (by equation 12b)

As well, we have that:

iii) $d\mu_s / d\mu_d > 0$ because qualities are strategic complements (see equation (A.16) in Appendix 1

iv) $\left[\frac{\partial \pi^d(\mu_d, \mu_s)}{\partial \mu_d} - \gamma FC'(\mu_d)\right] = 0$ because the domestic firm is maximising profits

v) $\frac{\partial \pi^d}{\partial \mu_s}\frac{\partial \mu_s}{\partial \mu_d} > 0$ because (A.17) in Appendix 1 and iii) above

By i) , ii) and iii) we have that consumer surplus of both products increases when the domestic product quality increases marginally. The reason is straightforward, when μ_d increases, there is a reduction in both the domestic and foreign equilibrium price measured in units of quality, as well as because the foreign firm finds it optimal to increase its product quality with the objective of reducing the intensity of competition. However, the domestic firm's product quality increases to a lower proportion than the foreign firm's product quality. As well, there is an additional benefit because $\frac{\partial \pi^d}{\partial \mu_s}\frac{\partial \mu_s}{\partial \mu_d} > 0$. Therefore, as in Zhou et al. (2002), there is a profit shifting strategic effect when domestic product quality increases.

These results imply that there is an under-provision of domestic product quality[16]. By increasing it marginally, consumers of both products are better off as a consequence of a reduction in both adjusted product prices. Adjusted prices, in turn, fall as a response to the increased competition that follows the reduction in the degree of product differentiation.

We can conclude therefore that evaluated at the optimum and without government intervention $\frac{\partial W}{\partial \mu_d} > 0$. Therefore, any mechanism that provides an incentive for the domestic firm to increase its product quality would be welfare improving. A mechanism could be, for example, a subsidy on the expenditure in R&D undertaken by the domestic firm or establish a mild minimum quality standard.

[16] Spence (1975) analyse the under-provision of quality in the context of a monopoly.

8. Main Conclusions and Policy Implications

In this chapter we analyse FDI in less developed countries in which both the mode of foreign expansion and the incentives to innovate are endogenously determined. This is the main contribution of the model developed since, to the best of our knowledge; it is the first model that analyses FDI in developing countries with a model of these characteristics. Our main objective is to shed some light on the impact of the different modes in which a foreign firm can reach a domestic market on the incentives to innovate and on the host country's welfare.

We analyse a three-stage game in which the foreign firm chooses the mode of serving the domestic market in the first stage. Then, in stages two and three firms simultaneously choose product quality and price level, respectively.

A key feature of our analysis is that we consider that product quality affects a firm's costs in two different ways. First, firms need to invest in R&D resources to develop a product with the desired quality, which can be thought of as a sunk cost. Second, the unit production cost increases with product quality. This is an innovation in relation to the existing literature. It adds realism to our analysis and seems more relevant in the context of developing countries.

The main results are that when the foreign firm moves from serving the domestic market by exporting to setting up a subsidiary:

- The foreign firm's product quality increases and the domestic firm's quality can increase or decrease. However, in any case the relative product qualities increase. As a consequence of this, both product prices per unit of quality rise.
- As prices increase, consumer surplus decreases. As well, the number of active consumers fall and therefore the size of the market shrinks.
- The foreign firm's gross profit from fixed plant costs increases, while the effect on the domestic firm's profit is ambiguous. In the case that the domestic firm's profits increases, it increases less for the foreign firm.
- The effect on domestic welfare is negative if the domestic firm's profits fall and it is likely negative in the case that domestic firm's profits raise.

As well, we found that in the case that the foreign firm chooses FDI to serve the domestic market; there is an under-provision of the domestic firm's product quality. Therefore, this suggests that mechanisms that increase the domestic firm's product quality could be welfare improving. This happens because by increasing the domestic product quality marginally there is a positive effect on consumers welfare because of the reduction in domestic and foreign prices measured in units of quality. As well, we could add a profit shifting strategic effect. This last result follows from the fact that product qualities are strategic complements. Examples of those mechanisms can be to establish a Minimum Quality Standard or a subsidy on the domestic R&D.

There are, however, a number of issues that deserve further research. For example, one major issue is the analysis of the optimal R&D policy from the host country's point of view. On the other hand, by undertaking a dynamic analysis we should be able to capture some other insights in a context where the firms' decisions are basically dynamic. Some other extensions that could be useful are to consider more than one domestic firm and to allow some other mode of serving the domestic market, for instance through mergers.

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Appendix 1

From section 3.4.2 we have that total profit functions in case 2 are,

$$TP_d = \frac{r(r-1)}{(4r-1)^2}\mu_d\left[\bar{\theta}-\alpha\right]^2 - \gamma FC_d(\mu_d) \qquad \textbf{(14a)}$$

$$TP_s = 4\frac{r(r-1)}{(4r-1)^2}\mu_s\left[\bar{\theta}-\alpha\right]^2 - \bar{S}_s - FC_s(\mu_s) \qquad \textbf{(14b)}$$

Note that total profits depend only on μ_d and μ_s ($r = \mu_s / \mu_d$). Hence, the previous equations can be expressed as production profits less quality development costs. Then,

$$TP_d = \pi^d(\mu_d, \mu_s) - \gamma FC_d(\mu_d) \qquad \textbf{(A.1)}$$

$$TP_s = \pi^s(\mu_s, \mu_d) - \bar{S}_s - FC_s(\mu_s) \qquad \textbf{(A.2)}$$

or alternatively as

$$TP_d = \phi(r)\mu_d\left[\bar{\theta}-\alpha\right]^2 - \gamma FC_d(\mu_d) \qquad \textbf{(A.3)}$$

$$TP_s = 4\phi(r)\mu_s\left[\bar{\theta}-\alpha\right]^2 - \bar{S}_s - FC_s(\mu_s) \qquad \textbf{(A.4)}$$

where

$$\phi(r) = \frac{r(r-1)}{(4r-1)^2}$$

Note also that $\phi'(r) = \dfrac{(2r+1)}{(4r-1)^3} > 0$ **(A.5)**

and $\phi''(r) = \dfrac{-2(8r+7)}{(4r-1)^4} < 0$ **(A.6)**

As well, from the maximisation of profits with respect to μ_d and μ_s we obtained in section 3.4.2 the following f.o.c. :

$$\left[\phi(r) - r\phi'(r)\right](\bar{\theta}-\alpha)^2 = \gamma FC'(\mu_d) \qquad \textbf{(17a)}$$

$$4\left[\phi(r) + r\phi'(r)\right](\bar{\theta}-\alpha)^2 = FC'(\mu_s) \qquad \textbf{(17b)}$$

which can be expressed as

$$\pi^d_{\mu_d}(\mu_d, \mu_s) - \gamma FC'(\mu_d) = 0 \qquad \textbf{(A.7)}$$

$$\pi^s_{\mu_s}(\mu_d, \mu_s) - FC'(\mu_s) = 0 \qquad \textbf{(A.8)}$$

where

$$\pi^d_{\mu_d}(\mu_d, \mu_s) = \frac{\partial \pi^d(\mu_d, \mu_s)}{\partial \mu_d} = \left[\phi(r) - r\phi'(r)\right](\bar{\theta}-\alpha)^2 \qquad \textbf{(A.9)}$$

and

$$\pi^s_{\mu_s}(\mu_s,\mu_d) = \frac{\partial \pi^s(\mu_s,\mu_d)}{\partial \mu_s} = 4[\phi(r) + r\phi'(r)](\overline{\theta} - \alpha)^2 \qquad \textbf{(A.10)}$$

Then from equations (A.5), (A.6), (A.9) and (A.10) we have that

$$\pi^d_{\mu_d}(\mu_d,\mu_s) = [\phi(r) - r\phi'(r)](\overline{\theta} - \alpha)^2 = \left[\frac{r^2(4r-7)}{((4r-1)^3}\right](\overline{\theta} - \alpha)^2 \qquad \textbf{(A.11)}$$

which is positive for $r > (7/4)$

$$\pi^s_{\mu_s}(\mu_s,\mu_d) = 4[\phi(r) + r\phi'(r)](\overline{\theta} - \alpha)^2 = \left[\frac{4r(4r^2 - 3r + 2)}{(4r-1)^2}\right](\overline{\theta} - \alpha)^2 \qquad \textbf{(A.12)}$$

expression that is always positive.

Thus, (A.11) and (A.12) prove that it is always profitable for the domestic and foreign firm to be active in the market because $\pi^d_{\mu_d}(\mu_d = 0,\mu_s) > \gamma FC'(\mu_d = 0)$ and $\pi^d_{\mu_d}(\mu_d,\mu_s = 0) > FC'(\mu_s = 0)$. In effect, the marginal benefit of investing one unit of R&D, when $R_i = 0$ (i=d,s), is higher than its marginal development cost.

Derivation of the Quality Best Response Function Slopes

By totally differentiating the f.o.c. given by equations (A.7) and (A.8) we get

$$\frac{\partial \pi^d_{\mu_d}(\mu_d,\mu_s)}{\partial \mu_d} * d\mu_d + \frac{\partial \pi^d_{\mu_d}(\mu_d,\mu_s)}{\partial \mu_s} * d\mu_s - \gamma FC''(\mu_d) * d\mu_d = 0 \qquad \textbf{(A.13)}$$

$$\frac{\partial \pi^s_{\mu_s}(\mu_d,\mu_s)}{\partial \mu_s} * d\mu_s + \frac{\partial \pi^s_{\mu_s}(\mu_d,\mu_s)}{\partial \mu_d} * d\mu_d - FC''(\mu_s) * d\mu_s = 0 \qquad \textbf{(A.14)}$$

Hence the slopes of the reaction functions are,

$$\frac{d\mu_d}{d\mu_s} = \frac{-\left[\partial \pi^d_{\mu_d}(.\mu_d,\mu_s)/\partial \mu_s\right]}{\left[\frac{\partial \pi^d_{\mu_d}(\mu_d,\mu_s)}{\partial \mu_d} - \gamma FC''(\mu_d)\right]} > 0 \qquad \textbf{(A.15)}$$

$$\frac{d\mu_s}{d\mu_d} = \frac{-\left[\partial \pi^s_{\mu_s}(\mu_s,\mu_d)/\partial \mu_d\right]}{\left[\frac{\partial \pi^s_{\mu_s}(\mu_s,\mu_d)}{\partial \mu_s} - FC''(\mu_s)\right]} > 0 \qquad \textbf{(A.16)}$$

The positive sign of the domestic reaction function slope (A.15) follows from

$$\frac{\partial \pi^{d}_{\mu_d}(\mu_d,\mu_s)}{\partial \mu_s} = \frac{\partial \pi^{d}_{\mu_d}}{\partial r}\frac{\partial r}{\partial \mu_s} = \left[\left[\phi'(r) - \phi'(r) - r\phi''(r)\right](\overline{\theta} - \alpha)^2\right]\left[\frac{1}{\mu_d}\right]$$

$$= -\left[r\phi''(r)\right]\left[\frac{1}{\mu_d}\right](\overline{\theta} - \alpha)^2 > 0 \qquad \textbf{(A.17)}$$

$$\frac{\partial \pi^{d}_{\mu_d}(\mu_d,\mu_s)}{\partial \mu_d} = \frac{\partial \pi^{d}_{\mu_d}}{\partial r}\frac{\partial r}{\partial \mu_d} = \left[-r\phi''(r)\right](\overline{\theta} - \alpha)^2\left(\frac{-\mu_s}{\mu_d^2}\right)$$

$$= \left[r^2\phi''(r)\right](\overline{\theta} - \alpha)^2\left(\frac{1}{\mu_d}\right) < 0 \qquad \textbf{(A.18)}$$

and the fact that $FC''(\mu_d) > 0$ (also note that $\phi''(r) < 0$ by A.6).
Analogously, the positive slope of the subsidiary reaction function follows from

$$\frac{\partial \pi^{s}_{\mu_s}(\mu_s,\mu_d)}{\partial \mu_d} = \frac{\partial \pi^{s}_{\mu_s}}{\partial r}\frac{\partial r}{\partial \mu_d} = 4\left[\phi'(r) + \phi'(r) + r\phi''(r)\right](\overline{\theta} - \alpha)^2\left(-\frac{\mu_s}{\mu_d^2}\right)$$

$$= 4\left[2\phi'(r) + r\phi''(r)\right](\overline{\theta} - \alpha)^2\left(-\frac{\mu_s}{\mu_d^2}\right) \qquad \textbf{(A.19)}$$

$$= \left[\frac{-8(5r+1)}{(4r-1)^4}\right]\left(-\frac{r}{\mu_d}\right)(\overline{\theta} - \alpha)^2 > 0$$

$$\frac{\partial \pi^{s}_{\mu_s}(\mu_s,\mu_d)}{\partial \mu_s} = \frac{\partial \pi^{s}_{\mu_s}}{\partial r}\frac{\partial r}{\partial \mu_s} = 4\left[2\phi'(r) + r\phi''(r)\right](\overline{\theta} - \alpha)^2\left(\frac{1}{\mu_d}\right)$$

$$= \left[\frac{-8(5r+1)}{(4r-1)^4}\right]\left(\frac{1}{\mu_d}\right)(\overline{\theta} - \alpha)^2 < 0 \qquad \textbf{(A.20)}$$

and from the fact that $FC''(\mu_s) > 0$.

Second Order and Stability Conditions

Second order conditions are,

$$\frac{\pi^{d}_{\mu_d}(\mu_d,\mu_s)}{\partial \mu_d} - \gamma FC''(\mu_d) < 0 \qquad \textbf{(A.21)}$$

$$\frac{\pi^{s}_{\mu_s}(\mu_d,\mu_s)}{\partial \mu_s} - FC''(\mu_s) < 0 \qquad \textbf{(A.22)}$$

which can be easily shown are satisfied because (A.18) and (A.20) coupled with the facts that by assumption about development costs $\gamma FC''(\mu_d) > 0$ and $FC''(\mu_s) > 0$.

Finally, the stability condition requires

$$\frac{\partial TP_d^2}{\partial \mu_d \partial \mu_d} * \frac{\partial TP_s^2}{\partial \mu_s \partial \mu_s} - \frac{\partial TP_d^2}{\partial \mu_d \partial \mu_s} * \frac{\partial TP_s^2}{\partial \mu_s \partial \mu_d} > 0 \qquad \textbf{(A.23)}$$

which by using (A.1), (A.2), (A.9) and (A.10) become

$$\left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_d} - \gamma FC''(\mu_d)\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_s} - FC''(\mu_s)\right]$$
$$-\left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_s} - \gamma \frac{\partial FC'(\mu_d)}{\partial \mu_s}\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_d} - \frac{\partial FC'(\mu_s)}{\partial \mu_d}\right] > 0 \qquad \textbf{(A.24)}$$

We do not consider the existence of R&D spillover, then development costs do not depend on the other product quality, so

$$\left[\frac{\partial FC'(\mu_d)}{\partial \mu_s}\right] = \left[\frac{\partial FC'(\mu_s)}{\partial \mu_d}\right] = 0$$

then (A.24) can be expressed as

$$\left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_d} - \gamma FC''(\mu_d)\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_s} - FC''(\mu_s)\right]$$
$$-\left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_s}\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_d}\right] \qquad \textbf{(A.25)}$$

and by expanding the first two terms in square brackets (A.25) become

$$\left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_d}\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_s}\right] - \left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_s}\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_d}\right]$$
$$-\left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_d}\right]\left[FC''(\mu_s)\right] - \left[\gamma FC''(\mu_d)\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_s}\right]$$
$$+\left[\gamma FC''(\mu_d)\right]\left[FC''(\mu_s)\right] \qquad \textbf{(A.26)}$$

By using (A.17) to (A.20) we have that

$$\left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_d}\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_s}\right] - \left[\frac{\partial \pi_{\mu_d}^d(\mu_d, \mu_s)}{\partial \mu_s}\right]\left[\frac{\partial \pi_{\mu_s}^s(\mu_s, \mu_d)}{\partial \mu_d}\right] = 0$$

So, what we need now to satisfy the stability condition is

$$-\left[\frac{\partial \pi^{d}_{\mu_d}(\mu_d,\mu_s)}{\partial \mu_d}\right][FC''(\mu_s)]-[\gamma FC''(\mu_d)]\left[\frac{\partial \pi^{s}_{\mu_s}(\mu_s,\mu_d)}{\partial \mu_s}\right]+[\gamma FC''(\mu_d)][FC''(\mu_s)]>0$$

which can be easily verified since as we show before $\left[\frac{\partial \pi^{d}_{\mu_d}(\mu_d,\mu_s)}{\partial \mu_d}\right]<0$, $\left[\frac{\partial \pi^{s}_{\mu_s}(\mu_s,\mu_d)}{\partial \mu_s}\right]<0$, $\gamma FC''(\mu_d)>0$ and $FC''(\mu_s)>0$. Hence, we can conclude that since both the second order and stability conditions are met the equilibrium in product qualities obtained in case 2 is both stable and unique.

Appendix 2

Effect of Transport Costs (t) on the Incentives to Improve Product Quality

First note that

$\frac{\partial TP^d_{\mu_d}}{\partial t} = \frac{\partial TP^d_{\mu_d}}{\partial \delta}\frac{\partial \delta}{\partial t} = \frac{\partial TP^d_{\mu_d}}{\partial \delta}\frac{1}{\mu_f}$ and $\frac{\partial TP^f_{\mu_f}}{\partial t} = \frac{\partial TP^f_{\mu_f}}{\partial \delta}\frac{\partial \delta}{\partial t} = \frac{\partial TP^f_{\mu_f}}{\partial \delta}\frac{1}{\mu_f}$. Then, the effect of t on the best response functions depend on the sign of both $\frac{\partial TP^d_{\mu_d}}{\partial \delta}$ and $\frac{\partial TP^f_{\mu_f}}{\partial \delta}$.

As well, from equation 9c we have that

$$\frac{dTP^d_{\mu_d}}{d\delta} = \begin{bmatrix} 2[\phi(r) - r\phi'(r)]\{(\bar{\theta} - \alpha) + \phi_1(r)\delta\}\phi_1(r) \\ + 2\phi(r)\phi_1(r)\left(\frac{1}{r-1}\right)\{(\bar{\theta} - \alpha) + 2\phi_1(r)\delta\} \end{bmatrix} \qquad \textbf{(A.27)}$$

By definition $\phi(r)$ and $\phi_1(r)$ are positive. As well, provided that $r > (7/4)$, then $[\phi(r) - r\phi'(r)] > 0$ (by A.11). So, unambiguously,

$$\frac{dTP^d_{\mu_d}}{d\delta} > 0$$

In turn, from equations 9d

$$\frac{dTP^f_{\mu_f}}{d\delta} = \begin{bmatrix} -8[\phi(r) + \phi'(r)r]\{(\bar{\theta} - \alpha) - \phi_2(r)\delta\}\phi_2(r) \\ + 8\phi(r)\left\{\frac{2r}{(2r-2)^2} + \phi_2(r)\right\}[(\bar{\theta} - \alpha) - 2\phi_2(r)\delta] \end{bmatrix}$$

Let $z = (\bar{\theta} - \alpha) - \phi_2(r)\delta$, then

$$\frac{dTP^f_{\mu_f}}{d\delta} = \left[8\phi(r)\left\{\frac{2r}{(2r-2)^2} + \phi_2(r)\right\}(z - \phi_2(r)\delta\right] - 8[\phi(r) + r\phi'(r)]z\phi_2(r)$$

$$==> \frac{dTP^f_{\mu_f}}{d\delta} = 8\begin{bmatrix} \phi(r)\frac{2r}{(2r-2)^2}z - \phi(r)\frac{2r}{(2r-2)^2}\phi_2(r)\delta \\ +\phi(r)\phi_2(r)z - \phi(r)[\phi_2(r)]^2\delta \\ -\phi(r)\phi_2(r)z - r\phi'(r)\phi_2(r)z \\ \end{bmatrix}$$

which, after cancelling equal terms, converges to

$$\frac{dTP^f_{\mu_f}}{d\delta} = 8\begin{bmatrix} \phi(r)\frac{2r}{(2r-2)^2}z - \phi(r)\frac{2r}{(2r-2)^2}\phi_2(r)\delta \\ -\phi(r)[\phi_2(r)]^2\delta - r\phi'(r)\phi_2(r)z \end{bmatrix}$$

which can be expressed as

$$\frac{dTP^f_{\mu_f}}{d\delta} = 8\begin{bmatrix} \left[\phi(r)\frac{2r}{(2r-2)^2} - r\phi'(r)\phi_2(r)\right]z \\ -\left[\phi(r)\frac{2r}{(2r-2)^2}\phi_2(r) + \phi(r)[\phi_2(r)]^2\right]\delta \end{bmatrix}$$

After replacing $\phi(r)$, $\phi'(r)$ and $\phi_2(r)$ by their functions in the first term of the right hand side of the previous equation, we obtain

$$\left[\left\{\phi(r)\frac{2}{(2r-2)^2} - \phi'(r)\phi_2(r)\right\}\right] = \left[\frac{r(r-1)}{(4r-1)^2}\frac{2}{(2r-2)^2} - \frac{(2r+1)}{(4r-1)^3}\frac{(2r-1)}{(2r-1)}\right]$$
$$= -\frac{1}{2(4r-1)^3} < 0$$

So

$$\frac{dTP^f_{\mu_f}}{d\delta} = 8\begin{bmatrix} -\left[\frac{r}{2(4r-1)^3}\right]z \\ -\left[\frac{2r}{(2r-2)^2} + \phi_2(r)\right](\phi(r)\phi_2(r))\delta \end{bmatrix}$$

As well, by definition $\phi(r)$ and $\phi_2(r)$ are positive, so the last term of the right hand side of the previous equation is negative. Then, we can conclude that

$$\frac{dTP^f_{\mu_f}}{d\delta} < 0$$

Second Order and Stability Conditions

Second order conditions require that

$$TP^{d}_{\mu_d \mu_d} = \frac{\partial \pi^{d}_{\mu_d}}{\partial r} \frac{\partial r}{\partial \mu_d} - \gamma FC''(\mu_d) < 0$$

And

$$TP^{f}_{\mu_f \mu_f} = \frac{\partial \pi^{f}_{\mu_f}}{\partial r} \frac{\partial r}{\partial \mu_f} - FC''(\mu_f) < 0$$

where $\frac{\partial r}{\partial \mu_d} = -\frac{r}{\mu_d} < 0$, $\frac{\partial r}{\partial \mu_f} = \frac{1}{\mu_d} > 0$.

As well, by assumption $\gamma FC''(\mu_d) < 0$ and $FC''(\mu_f) < 0$.

Then, we need to examine $\frac{\partial \pi^{d}_{\mu_d}}{\partial r}$ and $\frac{\partial \pi^{f}_{\mu_f}}{\partial r}$ to verify if the second order conditions are satisfied.

First, let us analyse $\frac{\partial \pi^{d}_{\mu_d}}{\partial r}$.

From equation 9c we get

$$\begin{aligned} \frac{\partial \pi^{d}_{\mu_d}}{\partial r} = & -\phi''(r)\left[(\overline{\theta} - \alpha) + \phi_1(r)\delta\right]^2 \\ & + 2\left[\phi(r) - r\phi'(r)\right]\left\{(\overline{\theta} - \alpha) + \phi_1(r)\delta\right\}\phi_1'(r)\delta \\ & + \Omega'(r)\left\{(\overline{\theta} - \alpha) + \phi_1(r)\delta\right\}\delta \\ & + \Omega(r)\left\{\phi_1'(r)\delta^2\right\} \end{aligned}$$

then if we factorise the second and third term by $\left\{(\overline{\theta} - \alpha) + \phi_1(r)\delta\right\}\delta$ we get

$$\begin{aligned} \frac{\partial \pi^{d}_{\mu_d}}{\partial r} = & -\phi''(r)\left[(\overline{\theta} - \alpha) + \phi_1(r)\delta\right]^2 \\ & + \left[2\left[\phi(r) - r\phi'(r)\right]\phi_1'(r) + \Omega'(r)\right]\left\{(\overline{\theta} - \alpha) + \phi_1(r)\delta\right\}\delta \qquad \textbf{(A.28)} \\ & + \Omega(r)\left\{\phi_1'(r)\delta^2\right\} \end{aligned}$$

where

$$\Omega(r) = 2\phi(r)\phi_1(r)\left(\frac{1}{r-1}\right) = \frac{2r^2}{(4r-1)^2(r-1)}$$ and

$$\Omega'(r) = -\frac{2r(4r^2 + r - 2)}{(4r-1)^3(r-1)^2}$$

by introducing the definition of the different functions of r into equation A.28, it becomes

$$\begin{aligned}\frac{\partial \pi^d_{\mu_d}}{\partial r} = {} & \frac{2(8r+7)}{(4r-1)^4}\left[(\overline{\theta} - \alpha) + \phi_1(r)\delta\right]^2 \\ & - \left[\frac{4r(4r-1)}{(4r-1)^3(r-1)^2}\right]\left\{(\overline{\theta} - \alpha) + \phi_1(r)\delta\right\}\delta \\ & - \frac{2r^2}{(4r-1)^2(r-1)^3}\delta^2\end{aligned}$$

by developing the first term of the right hand side and simplifying we get

$$\begin{aligned}\frac{\partial \pi^d_{\mu_d}}{\partial r} = {} & \frac{2(8r+7)}{(4r-1)^4}\left[(\overline{\theta} - \alpha)^2 + 2(\overline{\theta} - \alpha)\phi_1(r)\delta + \left[\phi_1(r)\right]^2\delta^2\right] \\ & - \left[\frac{4r}{(4r-1)^2(r-1)^2}\right]\left\{(\overline{\theta} - \alpha)\delta + \phi_1(r)\delta^2\right\} \\ & - \frac{2r^2}{(4r-1)^2(r-1)^3}\delta^2\end{aligned}$$

rearranging terms and using the definition of $\phi_1(r)$ we get

$$\begin{aligned}\frac{\partial \pi^d_{\mu_d}}{\partial r} = {} & \frac{2(8r+7)}{(4r-1)^4}\left[(\overline{\theta} - \alpha)^2\right] \\ & + \left[\frac{2(8r+7)}{(4r-1)^4}2\frac{r}{(r-1)} - \left[\frac{4r}{(4r-1)^2(r-1)^2}\right]\right]\left\{(\overline{\theta} - \alpha)\delta\right\} \\ & + \left[\frac{2(8r+7)}{(4r-1)^4}\left(\frac{r}{(r-1)}\right)^2 - \frac{4r}{(4r-1)^2(r-1)^2}\frac{r}{(r-1)} - \frac{2r^2}{(4r-1)^2(r-1)^3}\right]\delta^2\end{aligned}$$

By simplifying the previous equation we obtain

$$\frac{\partial \pi^{d}_{\mu_d}}{\partial r} = \frac{2(8r+7)}{(4r-1)^4}\left[(\bar{\theta}-\alpha)^2\right]$$
$$-\left[\frac{4r(8r^2-7r+8)}{(4r-1)^4(r-1)^2}\right](\bar{\theta}-\alpha)\delta$$
$$+\left[\frac{2r^2(8r^2-r-10)}{(4r-1)^2(r-1)^3}\right]\delta^2$$

As we established before, $(\bar{\theta}-\alpha) > \frac{(2r-1)}{(2r-2)}\delta$, so $(\bar{\theta}-\alpha) > \delta$. Therefore, we can infer that $\left[(\bar{\theta}-\alpha)^2\right] > (\bar{\theta}-\alpha)\delta > \delta^2$.

On the other hand,

$$\frac{2(8r+7)}{(4r-1)^4} - \left[\frac{4r(8r^2-7r+8)}{(4r-1)^4(r-1)^2}\right] + \left[\frac{2r^2(8r^2-r-10)}{(4r-1)^2(r-1)^3}\right]$$
$$= 2\frac{128r^6-80r^5-125r^4+92r^3-37r^2+29r-7}{(4r-1)^4(r-1)^3} > 0$$

By using numerical methods, we find that the last expression is positive for $r > (7/4)$, which is the range of values that r can have.

Therefore, we can conclude that $\frac{\partial \pi^{d}_{\mu_d}}{\partial r} > 0$ and that $\frac{\partial \pi^{d}_{\mu_d}}{\partial r}\frac{\partial r}{\partial \mu_d} < 0$ since $\frac{\partial r}{\partial \mu_d} = -\frac{r}{\mu_d} < 0$.

Therefore,

$TP^{d}_{\mu_d \mu_d} = \frac{\partial \pi^{d}_{\mu_d}}{\partial r}\frac{\partial r}{\partial \mu_d} - \gamma FC''(\mu_d) < 0$ and, as a consequence, the second order conditions are met for the domestic firm.