QUALITY-IMPROVING R&D, TRADE BARRIERS, AND FOREIGN DIRECT INVESTMENT

by

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Abstract

This investigation pits Cournot oligopolists against each other in a model of quality and R&D choice. A firm gains a strategic advantage over its rival when it is able to sell in more countries due to the jointness of quality improvements across production locations. Trade barriers that restrict access to a market put the restricted firm at a disadvantage, the degree of disadvantage being stronger under a quota than under a tariff. Given that FDI (foreign direct investment) depends on this disadvantage, quotas present a stronger incentive to undertake FDI than a tariff. Also, in this model it is never possible for a quota to lead to quality upgrading of imports due to the associated disadvantage of the importing firm in quality-improving R&D.

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1. Introduction

Current theorizing on Multinational Enterprises (MNEs) places great weight on the possession of firm-specific, intangible assets by such firms [Caves (1996)]. The idea is that it is inherently difficult for a firm to serve countries aside from its host country because it is at a disadvantage relative to local firms. The intangible asset, often characterized as the result of R&D (such as a blueprint for a product or process) or learning-by-doing (such as managerial skills), compensates the MNE for these disadvantages and may in fact place the MNE at an advantage.

The theoretical trade literature often models this intangible asset simply as an exogenous sunk cost with no obvious implication for its impact on the structure of demand or production costs. Horstmann and Markusen (1987a, 1992) exemplify this approach. Theses studies focus on the strategic positioning of production sites and multi-plant economies of scale, and the decision to do FDI is motivated in large part by tariff jumping.[2] Motta (1994) goes a step further by showing that, in autarky, firms in a larger market will do more quality-improving R&D and are more likely to be the multinationals that emerge upon the opening of markets, but this is a short-run model that does not permit quality or R&D to adjust when markets open. While the exogeneity of the firm specific asset is useful for the purposes of these papers, they do not consider the change in incentives to perform R&D that enhanced market access brings and hence are unable to fully characterize the large R&D efforts by MNEs. In explaining the R&D/MNE link, the tongue-in-cheek answer of most economists would be economies of scale. Indeed, we show formally that it is multimarket economies of scale in quality-enhancing R&D that leads to large R&D efforts by firms with a significant international presence.

Braunerhjelm (1996) finds empirical support for this, noting that for a sample of Swedish MNEs, R&D is positively related to exports controlling for production abroad. Such insight could easily be formally illustrated in a monopoly setting. However, leaders of MNEs speaking on the prospects of their

[2] Exceptions include Ethier (1986) and Horstmann and Markusen (1987b) which focus on the internalization decision of firms relative to arm's length exploitation of the firm specific asset, and Helpman (1985) which focuses on the role of factor endowments in instigating FDI. The Ethier paper also provides a role for factor endowments, but comes up with very different conclusions from Helpman.

firms will more often than not let the words "strategy" or "competitiveness" slip their lips. Indeed, MNEs are frequently in industries characterized as oligopolistic. Thus to gain a full understanding of MNE behavior it would seem we must explicitly recognize the competitive environs surrounding multinationals. We conjecture that it is within an oligopolistic environment where R&D is a significant strategic choice variable that firms find additional motivation to seek multimarket economies of scale in R&D. Specifically, when R&D contributes to a strategic advantage over a rival, expanding sales into more markets than the rival constitutes a credible threat to expand R&D efforts at the expense of the rival in terms of both profits and R&D levels.[3] Veugelers and Vanden-Houte (1990) show this both theoretically and empirically using a sample of Belgian manufacturing firms, but their approach presumes the existence of an MNE which is something previous studies endogenized. Also, a critical factor in their model is the degree of substitutability between goods, and we enrich this approach by endogenizing the degree of substitutability.

A strategic R&D advantage does not necessarily imply FDI, however, and we follow the previous literature by focussing on the tariff jumping aspect of FDI. We illustrate the principle that under such conditions, different trade barriers have different impacts on the ability to exploit multimarket economies of scale in R&D and thus present different incentives to undertake FDI.

We adopt a model that features duopolists engaging in a two-stage game of quality choice and then Cournot-Nash competition producing imperfect substitutes. The degree of substitutability is a function of the quality level chosen by each firm, with quality being a deterministic function of R&D levels. The quality chosen by each firm depends in part on the ability to capture sales from the rival, and quality reaction functions are downward-sloping. The results of quality-improving R&D are joint in production across production locations, so the ability to sell its output in more markets than a rival shifts a firm's quality reaction function out, increasing R&D and profits for that firm and reducing them for the rival. A firm would choose to export to avoid incurring the cost of setting up a foreign production

[3] In the terminology of Bulow, Geanakoplos and Klemperer (1985), it is required that the results of R&D function as strategic substitutes.

facility, but the presence of trade barriers may give rise to FDI. Quantitative restrictions which suppress the output response of quality enhancement also then reduce the R&D incentive more than an output-equivalent specific tariff, so tariff-jumping FDI is more likely under a quota than a tariff.

Spencer and Brander (1983) is a seminal work in the study of strategic R&D, particularly as regards R&D policy. The model features Cournot competition and cost-reducing R&D. A more recent extension by Reitzes (1991) examines the role of traditional trade policies in such an environment and finds that the strategic aspects of R&D become suppressed when the impact of R&D on output is weakened by qualitative restrictions, even if such restrictions are set at the free trade level of output. This effect manifests in the behavior of not just importers, but domestic firms as well. We present an extension of this work by allowing firms to consider FDI in the face of such trade barriers.

There is a substantial literature that considers the impact of trade policy on quality levels. Krishna (1987, 1990) and Das and Donnenfeld (1987) consider the case of a foreign monopolist and find under plausible conditions an increase in the quality of imports in response to a quota or specific tariff. This is largely due to the fact that consumers face a binary purchase decision, and the price increase associated with the trade barrier pushes consumers with the lowest intensity of quality preference out of the market, increasing the optimal quality level of the importing firm. Das and Donnenfeld (1989) considers a duopolistic industry structure and finds similar results, and additionally finds that the domestic firm may increase or decrease quality depending on whether that firm is the low or high quality firm.

The quality upgrading of imports is specifically impossible in this model, and this is not without precedent in the literature. Ries (1993) finds that a quota-restricted importer will not upgrade its product line as long as unconstrained competitors produce higher quality goods. Reitzes (1992) finds that the presence of set-up costs (such as R&D) gives rise to downward-sloping quality reaction functions that rule out upgrading, but he does not indicate any distinction between quotas and specific tariffs as we do.

This may seem at odds with the evidence. Feenstra (1988) argues for an increase in the quality of Japanese autos concurrent with the imposition of VERs in the early 1980's. The model presented here

offers the possibility that the VER led to less quality upgrading than would otherwise be the case. The increase in quality could be in response to increased production levels of Japanese auto manufacturers, possibly with a lag, and the existence of a quota might inhibit this effect and lead to less quality. It should also be noted that some Japanese auto models were being produced in the U.S. as early as 1982 and it is not clear if this is accounted for in Feenstra's study.[4]

Section 2 sets up the basic model in a single market with a domestic and foreign firm competing in the home market. Section 3 illustrates the strategic advantage described above by considering the possibility that the home firm will sell in a second market and examines the implication for quality levels that are set jointly for all markets a firm services. Section 4 considers symmetric access to both markets by both firms and the consequences of trade barriers around the home market. Section 5 concludes with discussion.

2. The Basic Model: The Home Country

The two firms, dubbed home (h) and foreign (f), are hypothesized to maximize profits in a two-stage game played out in the home market, where quality levels are chosen first and Cournot-Nash output levels are chosen second. It is routinely the case that manufacturers will display their newest models at annual trade shows before they are released on the open market. Based on the reception a given model receives at such shows, manufacturers get some idea of how competitive a model is and retailers can choose which merchandise to stock, presumably based on quality and other factors. Once in a showroom, consumers have the ability to inspect the goods on offer before purchase. This motivates the assumption that quality is chosen and revealed in an initial stage of the game. For many goods, such as durable consumer goods, many elements of non-price competition are employed so we forsake Bertrand conduct assumptions on the second stage in favor of a Cournot assumption.

[4] Honda began U.S. production of a few models in 1982, followed by Nissan in 1983 and Toyota (in a joint venture with GM) in 1984. Others followed in the late 1980's, but this is outside the time horizon considered by Feenstra (1988).

Labor L is the single factor of production, used as both the fixed and marginal input. There are potentially two differentiated goods, X and Y, and a numeraire good, Z. Good Z is produced in a perfectly competitive environment with constant returns to scale and is thus priced equal to its marginal cost, which with a suitable normalization of units can be set to unity. Thus, all costs and prices are expressed in terms of units of L or Z. Each differentiated good is produced by a single firm, with firm h producing X and firm f producing Y. Neither entry nor exit is permitted, an assumption consistent with a mature industry producing a mature good.

The literature tends to deal with consumer preferences under variable quality in two primary ways. The first is to suppose that consumers face a binary choice of whether or not to buy a product [e.g. Krishna (1987)]. Consumers must then be assumed to vary in their incomes or preferences for quality via some distribution function. A given consumer will buy the product if the utility of the good exceeds the utility of the money required to meet the good's price, and the maintenance of a quality preference distribution gives an interior solution. Such a specification under price competition often requires that firms produce different qualities (Shaked and Sutton, 1983). We wish to focus on firms producing near substitutes, and so choose the latter approach which permits consumers to buy a variable amount of the product, that quantity determined via utility maximization given prices and quality levels.

We postulate identical representative consumers with aggregate preferences expressed by the utility function U,

$$(1) \qquad U = x(aX - X^2/2) + y(aY - Y^2/2) - xyXY + Z,$$

where x is the quality level of good X, y is the quality level of good Y, and X, Y and Z are the quantities of those goods. The quality levels are constrained to exist in the range of [0, 1) in a manner that will be described when we present the production technology of the firm. Utility (1) can be seen to be quasilinear, and demand for the two differentiated goods is income inelastic for income ranges sufficiently large, which we assume to be the case.

Let p^x and p^y denote the prices of X and Y, respectively, and let π^i represent the profits of firm i, $i = (h, f)$. Consumers maximize utility (1) subject to the aggregate budget constraint

$$L + \pi^1 + \pi^2 = p^x X + p^y Y + Z$$

which yields the inverse demand functions

(2) $$p^x = x\,(a - X - yY)$$

(3) $$p^y = y\,(a - Y - xX)$$

These demand curves are seen to be linear. Increases in own quality rotate the own demand curve upward around a pivot that lies on the horizontal axis in quantity-price space. Increases in the rival's quality shift the demand curve in, the degree of shift increasing in the rival's quality level.

We next specify the firm's problem. Both differentiated firms choose quality levels first, fully aware of the implications of that choice on the second stage, and output levels second. A sub-game perfect equilibrium requires that quality choices must be consistent with profit maximization in the output stage. Thus we solve the game backwards, first determining the first-order conditions governing output choice and then incorporating these conditions into the firm's quality choice decision.

The quality level is determined by the amount of R&D undertaken by the firm, with R&D becoming a sunk cost by the time firms are making output decisions. Thus R&D is a non-production set-up cost that is endogenously chosen within the system. F^i is the R&D level undertaken by firm i, is a function of the chosen quality level, and is increasing in that level at an increasing rate. The quality level of a product is independent of the level of R&D conducted by the rival. This assumption excludes any inter-firm spillovers that knowledge created by R&D might have.[5] Thus, $F^h = F^h[x]$, $F^{h\prime}[x] > 0$, $F^{h\prime\prime}[x] > 0$. It is also assumed that $F^h[0] = 0$ and $F^h[1] = \infty$, $F'[0] = 0$ and $F'[\infty] = \infty$. We postulate a similar relationship between F^f, the R&D level of firm f, and firm f's chosen quality level y.

[5] We might allow for a firm's own quality level to be increasing in the amount of R&D conducted by the rival to allow for the possibility of knowledge spillovers, but this would complicate the model without contributing significantly to the basic insight and is left to future research.

Both firms have identical marginal cost structures. Marginal costs are assumed to be constant for all ranges of output, but increasing in the quality level of the firm. Each unit of output, while not any more costly for the firm to produce than any other unit, is more costly if it is to have a higher quality level in that it requires more labor time to produce. For simplicity we posit that the relationship between unit marginal cost and quality is linear. This will be seen to be useful in highlighting the strategic effects at work in this model. If κ is the unit cost, then we assume $\kappa(x) = mx$ where m is some positive constant, $m < a$.

Substituting for prices from (2) and (3), we state the profit functions of firm h and firm f, respectively, as

(4) $$\pi^h = x(a - X - yY)X - mxX - F^h[x],$$

(5) $$\pi^f = y(a - Y - xX)Y - myY - F^f[y].$$

We henceforth focus on the problem for firm h where this does not create confusion, noting that the problem for firm f is symmetric.

Monopoly Benchmark

A useful benchmark is obtained by briefly exploring the model when we exogenously exclude firm f setting $Y = 0$ and treat firm h as a monopolist in the home market. Firm h maximizes its profit (4) with respect to output giving us the monopoly level of output

(6) $$X^M = \frac{a - m}{2}.$$

The monopoly level of output, which we henceforth refer to as the pure market power component of output behavior, is invariant to the quality level. This is due to the various linearities imposed by our choice of functional forms that force marginal revenue and marginal cost to rise or fall in tandem with the quality level. Note that this is the result for the familiar textbook monopolist where x is fixed at unity.

Inserting (6) into the profit function (4) and maximizing with respect to the quality level x gives us (where subscripts denote partial derivatives)

$$(7) \qquad F_x^h = \frac{(a-m)^2}{4}.$$

Condition (7) gives us an implicit optimal quality level for the monopolist, and via the function $F^h[x]$ implicitly gives the optimal R&D effort of the monopolist. The second term in (7) is the marginal contribution of quality increases to profits gross of R&D expenses. This is constant as is the difference between marginal revenue and marginal cost, which depends only on the parameters a and m. The optimal choice of quality will be such that the second term in (7) is equal to the first term which is the marginal cost of quality improvements, as expressed by the relation between quality and R&D levels.

It is a useful feature of the model that monopoly behavior is so simple, depending only on demand and cost parameters and the quality-improving technology. The actual level of quality has no impact on the monopolist's level of output. As we will see, a firm will only adjust its output in strategic response to the behavior of a rival. What our model lacks in generality it makes up for in focus on the strategic behavior of firms.

Duopoly Solution

We now presuppose the existence of the foreign firm in the home market. Maximizing firm h's profits (4) with respect to its output, assuming it maintains Cournot conjectures on the response of the rival firm, yields a first order condition

$$(8) \qquad \pi_X^h = x(a-m-2X-yY) = 0$$

and the second order conditions

$$\pi_{XX}^h = -2x \le 0; \qquad \pi_{XX}^h \pi_{YY}^f - \pi_{XY}^h \pi_{YX}^f = xy(4-xy) \ge 0$$

consistent with a maximum and a stable equilibrium, respectively. Solving (8) for firm h's output yields firm h's output reaction function,

$$(9) \qquad R^X[Y] = \frac{a - m - yY}{2}.$$

This reaction function is independent of own quality for the same reasons monopoly output is. It is sensitive to the foreign firm's quality level and is further evidence of how the model is structured to highlight the strategic interaction of the oligopolists.

An identical procedure gives a similar equation for the output reaction function of firm *f*, R^Y. The reaction functions are represented in Figure 1 and are consistent with a stable equilibrium. Plugging such an R^Y into (9) gives us an explicit solution for the output level of X as a function of quality levels and parameters,

$$(10) \qquad X = X^M S^X = \frac{a - m}{2}\left(\frac{2(2 - y)}{4 - xy}\right),$$

where X^M is the pure market power component of output behavior put forward previously in the monopoly case, equation (6), and S^X is the strategic component of firm *h*'s output behavior that is due solely to the presence of a rival offering a substitute good. The pure market power component is identical for the two firms as they possess identical technologies, and we henceforth denote this component as M, $M = X^M = Y^M$. The strategic component is always within a range with a lower bound of 2/3 and an upper bound of unity. A similar expression for the output of Y is

$$(11) \qquad Y = MS^Y = \frac{a - m}{2}\left(\frac{2(2 - x)}{4 - xy}\right)$$

Some interesting comparative statics arise out of this specification. Focussing our attentions on the strategic component as the market power component is invariant to quality levels, we differentiate S^X and S^Y with respect to the home firm's quality level and obtain

$$(12) \qquad S_x^X = \frac{2y(2 - y)}{(4 - xy)^2} \geq 0,$$

$$(13) \qquad S_x^Y = \frac{4(y - 2)}{(4 - xy)^2} < 0,$$

$$(14) \qquad S^X_x + S^Y_x = \frac{(8-2y)y-8}{(4-xy)^2} < 0.$$

We get the not-so-interesting result that a change in own quality level has a positive impact on own sales and a negative impact on the rival's sales, but we also get the interesting result that a change in own quality level has larger cross effects than own effects.

The intuition is as follows. When a firm increases its quality level this tilts up its demand curve thus raising marginal revenue which would tend to increase output, but increasing the own quality level also increases unit costs which dulls this incentive. For the monopoly case these tensions are in perfect balance (under our chosen functional forms) resulting in no net change in output, while under duopoly the existence of a differentiated substitute permits the firm to steal some sales from the rival such that marginal revenues increase more than marginal costs and the net output change is positive. When the rival increases quality, however, a firm suffers the deleterious effect of sales lost to the rival, but experiences no compensating decrease in cost given a constant own quality level. The incentive for the foreign firm to reduce output in response to the fall in marginal revenue is not ameliorated by falling marginal costs and hence Y falls more than X increases.[6]

Proposition 0: When goods are substitutes and that substitutability depends on quality levels, and when increases in own quality increases both marginal revenues and marginal costs at any given output level, then an increase in the own quality level has larger cross effects (reductions in rival's output) than own effects (increases in own output).[7]

It now remains to solve for the quality choices made in the first stage. We begin by expressing profits as a function of quality levels and parameters. Taking (10) and (11) and substituting into the profit expressions (4) and (5) we obtain

[6] A brief treatment of the substitutability between the goods is given in Appendix 1.

[7] Under a more general specification assuming monopoly output levels are unaffected by a rival's quality level, $X_x + Y_x = X^M{}_x S^X + X^M (S^X{}_x + S^Y{}_x)$. Assuming that $S^X{}_x$ and $S^Y{}_x$ have the signs shown in the main text, then a sufficient condition for Proposition 0 to hold true is that $X^M{}_x \leq 0$, i.e. that monopoly output be non-increasing in own quality level.

$$(15) \qquad \pi^h = xM^2S^X(2 - S^X - yS^Y) - F^h[x] = xM^2S^{X2} - F^h[x] = \frac{(a-m)^2 x(2-y)^2}{(4-xy)^2} - F^h[x]$$

and

$$(16) \qquad \pi^f = yY^{M2}S^{Y2} - F^f[y] = \frac{(a-m)^2 y(2-x)^2}{(4-xy)^2} - F^f[y].$$

Again focussing attention on the problem for firm h, and differentiating (15) with respect to x under the conjecture that y remains constant gives

$$(17) \qquad \pi_x^h = \frac{(a-m)^2(2-y)^2(4+xy)}{(4-xy)^3} - F_x^h = 0.$$

Solving equation (17) for x yields firm h's reaction function in quality space. However, this equation is highly non-linear in quality (for any non-linear $F[x]$, there will be four solutions) so an explicit algebraic solution for the reaction function (or Nash quality equilibrium) is exceedingly complicated. Still, it is possible to examine some properties of the reaction function in the region of quality space of interest to ensure that it is well-behaved and consistent with a stable equilibrium. The first term in the middle of (17) is the contribution of a quality improvement to revenues net of variable cost, and differentiation of this term shows it to be increasing in own quality level at a decreasing rate, thus allowing us to say that given a constant quality level on the part of the rival, increases in own quality level always increase revenues net of fixed costs.

By way of an example, assume $F^h[x] = bx^2$ and $F^f[y] = by^2$ where $b \geq 0$. These forms are not sufficiently convex at high quality levels, but a prudent selection of parameter values ensures any equilibria do not end up as corner solutions. Evaluating (17) at $x = 0$ and solving for y gives the y-intercept $y|_{x=0} = 2$ regardless of the function form of F^h, which is assumed to be an impossible value for y. Locating the x-intercept yields

$$(18) \qquad x|_{y=0} = \frac{(a-m)^2}{8b}$$

which is the monopoly value and is constrained to be less than unity, hence requiring that $8b > (a\text{-}m)^2$. The quality reaction function for firm f is symmetric. For a stable, permissible equilibrium to exist, it must also be the case that the reaction functions slope downward. Numerical simulations confirm that, for the above assumptions on the form of F this is indeed the case (though the reaction functions are not of consistent curvature), providing for an interior solution for the quality levels. An example is provided in Figure 2, which is a plot of iso-profit lines for the home firm.[8] Profits are decreasing in y for any given x, and are equal to zero along the vertical axis. The quality reaction function is picked out by taking those values of x which maximize profits for every value of y, and is readily seen to be downward sloping.

Differentiating firm h's first-order condition for optimal quality choice (17) with respect to its rival's quality level gives us

$$(19) \qquad \pi^h_{xy} = -\frac{4(a-m)^2(2-y)\{xy(x-4)+8(x-1)\}}{(4-xy)^4} < 0.$$

Thus the quality levels are strategic substitutes as first described by Bulow, Geanakoplos and Klemperer (1985). An increase in the rival's quality level reduces the marginal value of a quality improvement.

3. Asymmetric Market Access and Strategic Quality Advantage

We now permit firms to have asymmetric access to multiple markets, for the moment neglecting justification for the differential access. We assume there to be two markets, denoted home (H) and abroad (A). Markets are assumed to be segmented, and each is identical in terms of preferences (1). Both firms continue to sell in the home market as in Section 1. Now suppose that firm h also sells in the abroad market, A. Second-stage output decisions are independent across markets because of the segmentation.[9] The output level of each firm in the home market will be as in the duopoly case given by

[8] This plot was generated in Mathematica 3.0. A complete copy of the generating program is available from the author upon request.

[9] Despite the fact that marginal cost is jointly determined across markets as is quality, quality is given when output decisions are made so output decisions are separable across segmented markets.

(10) and (11). The output level of firm h in the abroad market will then be as described in the monopoly benchmark given by (6).

The results of R&D, however, are joint across markets so the firms will maintain a single R&D effort that implies a uniform quality of all goods the firm produces regardless of location of sale. Firm f sells only in a single market (H) and its problem is as described in the previous section. Firm h's profit function differs from that case, becoming

$$(20) \qquad \pi^h = x(a - X^H - yY^H)X^H + x(a - X^A)X^A - mx(X^H + X^A) - F^h[x],$$

where superscripts on output levels denote the market of sale. Substituting into (20) the duopoly output levels for X^H and Y^H and the monopoly output level for X^A, we obtain

$$(21) \qquad \pi^h = \frac{(a-m)^2 x(2-y)^2}{(4-xy)^2} + \frac{x(a-m)^2}{4} - F^h[x].$$

Differentiating (21) with respect to x yields an expression for firm h's quality reaction function,

$$(22) \qquad \frac{(a-m)^2(2-y)^2(4+xy)}{(4-xy)^3} + \frac{(a-m)^2}{4} - F_x^h = 0.$$

Comparison of (22) to (17) shows that the marginal contribution of a quality improvement to revenues net of variable costs (the first two terms on the LHS of (22)) is higher for all quality levels. Thus, at the pre-expansion quality equilibrium profits must increase, and so any profit-maximizing quality movement away from that equilibrium must increase profits for the home firm relative to the pre-expansion equilibrium. As well, the new marginal condition makes the profit-maximizing level of R&D and quality higher, thus the home firm will do more R&D and sell a higher quality product when it services the additional market. The foreign firm suffers adversely from the increased R&D effort of the home firm. Increases in x lower the revenues net of variable costs for the foreign firm, such that the marginal contribution of the foreign firm's R&D effort to revenues net of variable costs decreases relative to the pre-expansion equilibrium giving the foreign firm the incentive to lower its quality level and R&D effort. Together with the increase in x, this means the profits of the foreign firm must fall. The above discussion constitutes proof of the following proposition:

Proposition 1: when quality is joint in production across markets and a single firm of two enters a new market from an initial situation of symmetry, the quality, R&D and profit level of the penetrating firm increases while the quality, R&D and profit level of the rival firm falls.

Graphically, the home firm's ability to service a new market shifts its quality reaction function outward. As the new equilibrium moves along the foreign firm's quality reaction function, the foreign firm's quality level and profits fall while the home firm's quality level and profits rise. The home firm's ability to apply its R&D to more markets gives it a strategic advantage in all markets that maintain rivals servicing fewer markets. Firms in a technologically competitive environment have an incentive to create a multimarket oligopoly.

This general principle holds as long as the home firm services even one more market than rivals. Making sales in an additional market beyond the two considered here would further shift out the home firm's quality reaction function, further increasing the home firm's R&D and quality levels and decreasing the foreign firm's R&D and quality levels. The principle also applies if the additional market, instead of having no indigenous firm, has an extant, strictly local producer of Y or some other good that enters into demand relative to X in an identical way. Upon the home firm penetrating the additional market, it would still increase its quality level while both rivals would decrease theirs. The qualitative effect of asymmetric market penetration would be the same if the home and foreign firms competed in several markets as long as one firm also has access to at least one other market. Note that the expanding firm would prefer to expand into a market without a competitor rather than one already serviced by a rival.

To this point we have assumed no transport costs, no barriers to trade, and no other cost of market access. However, this is rarely the case. The firm would at least need to negotiate contracts with local retailers or distributors, perhaps at most build a local production facility. The literature on multinationals discusses a wide variety of ways to service a market, each with attendant costs. Real firms are often faced with several regional and international markets that they might wish to enter, and each could have a

different cost of entry; the cost of selling in another state within a single nation would likely be less than the cost of selling in another nation altogether, for example. This market penetration cost for a given market could just as easily vary across firms. The employees of a firm may have more past experience in penetrating new markets. A firm may have better local contacts or the ear of someone influential in local government. The firms may simply have different plant-specific costs due to different plant designs such that one would find it less costly to engage in, say, tariff-jumping investment.

Suppose that firm i has a market-specific penetration cost of G^j for the jth market. The firm would then have to weigh the additional profit from penetrating an additional market against the additional cost, G^j. If the penetration increases total profits, then of course the firm would proceed with the expansion. The issue of market penetration cost will become important when we discuss the possibility of FDI in the presence of trade barriers in the next section.

4. R&D, Trade Policy and Foreign Direct Investment

We now wish to evaluate the effects of tariffs and quotas on R&D and the incentive to invest in production abroad. We assume as in Section 3 that there are two countries, home (H) and abroad (A), and that the home firm is based in the former and the foreign firm in the latter. The countries are identical in all respects of production technology and preferences, being as specified in Section 2. Each firm is assumed to initially maintain a single plant in its base country and service the other country through exports. Transportation costs are assumed to be zero and we for now exclude the possibility of FDI. We assume that abroad maintains a policy of unilateral free trade throughout the analysis.

Assume an initial benchmark situation of free trade such that both firms access both markets. Noting a symmetric expression for the foreign firm, the profit function for the home firm is

$$(23) \qquad \pi^h = x(a - X^H - yY^H)X^H + x(a - X^A - yY^A)X^A - mx(X^H + X^A) - F^h[x].$$

As before, substituting for the duopoly output levels and optimizing with respect to the quality level yields an implicit solution for quality and R&D levels,

$$(24) \qquad \frac{(a-m)^2(2-y)^2(4+xy)}{(4-xy)^3}+\frac{(a-m)^2(2-y)^2(4+xy)}{(4-xy)^3}=F_x^h.$$

Consider the two terms on the LHS of (24). Each reflects the marginal contribution of sales in a country to profits gross of R&D expenses. Given that these terms are separable due to segmentation, and that the term corresponding to the abroad market will remain at the free-trade level, we will henceforth derive only the term corresponding to the home market as we only consider distortionary policies maintained by the home country.

Tariffs

Suppose home levies a specific tariff t in terms of the numeraire on imports of good Y. The home contribution to revenues net of variable costs for firm i, which we will denote by r^{Hi}, are specified as

$$(25) \qquad r^{Hh}=x(a-X^H-yY^H)X^H-mxX^H,$$

$$(26) \qquad r^{Hf}=y(a-Y^H-xX^H)Y^H-myY^H-tY^H.$$

Profit maximization yields an output reaction function for the home firm that is identical to that under free trade. The foreign firm's reaction function becomes

$$(27) \qquad R^Y[X^H,t]=\frac{a-m-xX^H-t/y}{2}.$$

Compared to free trade, a tariff shifts in the foreign firm's home output reaction function without a change in its slope, illustrated in Figure 1. It can already be seen that the output of the home firm will increase at the expense of the foreign firm, though this effect can be mitigated by increased foreign quality levels. A prohibitively high tariff will shift in the foreign firm's output reaction function such that it lies entirely within the home firm's reaction function and the foreign firm will maintain no sales in the home market. We assume throughout the analysis that the tariff is below the minimum prohibitive level t^p,

$$(28) \qquad t<t^p=\frac{y(a-m)(2-x)}{2}$$

Solving the system of reaction functions for outputs yields expressions for those outputs,

$$(29) \qquad X^h = \frac{(a-m)(2-y)+t}{(4-xy)}$$

and

$$(30) \qquad Y^h = \frac{(a-m)(2-x)-2t/y}{(4-xy)}.$$

The comparative statics effect of the tariff are as in the basic Cournot model: home output increases but by less than foreign output falls. The comparative statics effects of quality changes hold unambiguously for the home firm, and are as stated in Proposition 0. These effects are ambiguous for the foreign firm. If we only permit non-prohibitive tariffs, then an increase in the foreign firm's quality will increase its home sales and decrease those of the home firm. The effect on total output depends on the value of t. If t is lower than the critical value t^l, $t^l = \frac{(a-m)y^2(2-x)^2}{8-xy(4-y)}$, then cross effects outweigh own effects. If $t^l < t < t^p$, then the contrary is true.

Substituting (29) and (30) into (25) and (26) gives

$$(31) \qquad r^{Hh} = \frac{x((a-m)(2-y)+t)^2}{(4-xy)^2}, \text{ and}$$

$$(32) \qquad r^{Hf} = \frac{y((a-m)(2-x)-2t/y)^2}{(4-xy)^2}.$$

Optimizing with respect to quality levels yields (for the entire, multimarket profit functions)

$$(33) \qquad F_x^h = D^h + \frac{((a-m)(2-y)+t)^2(4+xy)}{(4-xy)^3}, \text{ and}$$

$$(34) \qquad F_y^f = D^f + \frac{y^2(a-m)^2(2-x)^2(4+xy)+8txy^2(a-m)(x-2)+4t^2(3xy-4)}{y^2(4-xy)^3}.$$

The first term on the RHS, D^i, reflects activity in the undistorted foreign market and is as in the free trade case [see equation (24) and ensuing discussion]. The second term reflects the home country tariff distortion. Given y, this term in (33) is greater than the commensurate term in (24), so the home firm will

increase its quality level. An increase in the tariff will cause the home firm's quality reaction function to shift to the right relative to free trade.

The situation for the foreign firm is not straightforward, as the tariff-distorted multimarket reaction function does not exist for all quality combinations. Specifically, the second-order conditions break down within the region of interest. Numerical simulations (not reported) suggest that the foreign firm's quality reaction function is well defined up to some $\underline{x}$, where $\underline{x}$ is defined implicitly by the largest x that permits the necessary and sufficient conditions for profit maximization by the foreign firm to be satisfied in the region of interest in quality space.[10] For all $x > \underline{x}$, the foreign firm would not export to the home country and would switch to the quality reaction function corresponding to serving only its domestic market, which is everywhere below the quality reaction function under positive Y^h.

This is illustrated with linear representations of the quality reaction functions in Figure 3. $R^y(h+f)$ is the quality reaction function of the foreign firm when it has positive market share in the home market and $R^y(f)$ is the reaction function when it does not. As the home firm's quality level increases, the foreign firm would respond with a quality choice on $R^y(h+f)$ until $x > \underline{x}$, at which point the foreign firm switches to making its quality choice on $R^y(f)$. Note that this allows for the possibility of multiple equilibria. A quality reaction function for the home firm such as R^{x1} in Figure 3 would allow for two equilibria, one at point A where the foreign firm would export to the home market and maintain a relatively high quality level compared to point B, where the foreign firm would not export and would choose a relatively low quality level. Regardless, relative to free trade the home firm will have a greater R&D effort and higher quality level and the foreign firm will have a weaker R&D effort and lower quality level under a tariff.

Quota

[10] The conditions are given in Appendix 2 and do not permit an algebraic representation of $\underline{x}$ (numerically solving (34) for y yields no less than 6 solutions!). Essentially, the iso-profit curve going through $\underline{x}$ does not have a positively sloped portion whereas all higher iso-profit curves do. Numerical simulations confirm that $\underline{x}$ is decreasing in t.

Suppose the home country levies a binding quota on imports of Y. The quota will have markedly different results from the tariff for the simple reason that changes in quality levels will have no output effect on sales in the home market, and this will alter the incentives to do R&D as we will see. Suppose the quota is set at the level Y^q. The output reaction function of the home firm is as under free trade, and the output reaction function for the foreign firm is the same as under free trade up to the output level Y^q, where it becomes horizontal. Substituting into both profit functions the home firm's output reaction function for X, we obtain revenues net of variable costs as a function of parameters, quality levels and the quota,

$$(35) \qquad r^{Hh} = \frac{1}{4}x(a - m - yY^q)^2, \text{ and}$$

$$(36) \qquad r^{Hf} = \frac{1}{2}(y(a-m)(2-x)Y^q - y(2-xy)Y^{q2}).$$

Optimizing with respect to quality levels yields the conditions

$$(37) \qquad F_x^h = D^h + \frac{1}{4}(a - m - yY^q)^2 \text{ and}$$

$$(38) \qquad F_y^f = D^f + \frac{1}{2}Y^q((a-m)(2-x) - 2Y^q(1-xy)).$$

We first compare the quota to free trade. Substituting the duopoly output levels (10) and (11) into (37) and (38) gives

$$(37') \qquad F_x^h\Big|_{Y^q \to \textit{free trade}} = D^h + \frac{(a-m)^2(2-y)^2(4-xy)}{(4-xy)^3} \text{ and}$$

$$(38') \qquad F_y^f\Big|_{Y^q \to \textit{free trade}} = D^f + \frac{1/2(a-m)^2(2-x)^2(2+xy)(4-xy)}{(4-xy)^3}.$$

Comparison of (37′) to (24) shows that for a quota set at the free trade level, the home firm will do less R&D and have a lower quality than under free trade. This is because a firm's quality decision under free trade will take account of the rival's output changes, and a firm has an incentive to increase its quality level to steal sales from its rival (even though the home firm's R&D effort will be less than under a

monopoly because of competition from the foreign firm). With a binding quota, the foreign firm cannot increase sales so has a less credible R&D threat, which in turn weakens the strategic R&D incentive of the home firm. As the quota falls from the free trade level, (37) shows that the home firm's R&D reaction function shifts to the right until the quota falls to zero, at which point the home firm will maintain the quality level consistent with a monopoly in the home market. This implies that the home firm's R&D effort, as captured by its reaction function, will equal the free trade R&D effort at a quota that is set below the free trade level. The intuition behind this increase in the home firm's R&D effort with a falling quota is that as the home firm captures a larger market share, the marginal contribution of quality to revenues net of variable costs increases and the firm has a larger R&D effort, despite the mitigation of the strategic component to the firm's R&D effort.

Following the same procedure to evaluate (38′) confirms this. The foreign firm's quality reaction function shifts toward the origin under the quota relative to free trade. As the quota is increased, the foreign firm's reaction function continues to shift until, at an import-prohibiting quota, the foreign firm derives no marginal benefit from sales at home and the second term on the RHS of (38′) becomes zero. The prohibitive quota would correspond to the case presented in Section 3 where the home firm has access to a market that the foreign firm does not.

Substituting the tariff-distorted output levels into (37) and (38) yields

$$(37'') \quad F_x^h\big|_{Y^q \to tariff} = D^h + \frac{((a-m)(2-y)+t)^2(4-xy)}{(4-xy)^3}, \text{ and}$$

$$(38'') \quad F_y^f\big|_{Y^q \to tariff} = D^f + \frac{((a-m)(2-x)-2t/y)((a-m)(2-x)+(2-xy)t/y)(4-xy)}{(4-xy)^3}.$$

A procedure similar to that above for comparing free trade to a quota output equivalent can be employed here, and shows again that a quota set at the tariff output level yields a quality reaction function for firm 1 inside the quality reaction function under a tariff, with the intuition being as above; a tariff permits an output response which firms account for, whereas a quota does not. Evaluating the foreign firm's state in a repetitive fashion leads to the same conclusion. The foreign firm's R&D effort will always be more

under a tariff than under an output-equivalent quota.[11] The above results and discussion constitute proof of the following proposition:

Proposition 2: A quota will lead both the importing and domestic firms to reduce their R&D effort and quality level relative to an equivalent output under free trade or a tariff.

This result is largely due to the assumed structure of the game the firms play. As the firms are playing a quantity setting stage in a multi-stage game, quantity restrictions are bound to have a different impact than a relative price distortion such as a tariff. Where we posit that quality choice depends in large part on an output response, circumscribing that response will have a deleterious effect on quality choice.

Productive Foreign Investment

The above analysis of trade policy has assumed a static market structure. We now briefly consider the possibility of a firm establishing productive capacity in the other country. Assume that some plant-specific cost G must be incurred by either firm to produce in the other country, freeing that firm from the nuisance of trade barriers. The home firm, having undistorted access to the foreign market, will of course never establish a subsidiary abroad for any G. The foreign firm, however, suffers lost profits due to trade restrictions (even for a quota set at the free-trade level), not just in the home market but also in the foreign market, as an incentive to lower its quality level will jointly affect both markets. The foreign firm can overcome this by incurring the investment cost G, which would establish production of Y at home and free home sales of Y from distortion. The foreign firm will exercise this choice as long as the difference between the undistorted profit level and the distorted exporting profit level is greater than or equal to G.

Now consider the above effects of trade policy on R&D behavior. A policy that reduces R&D effort does so because of a reduction in the marginal contribution of quality to revenues minus variable

[11] Of course, this holds only when the cum-tariff output level is positive. Were it zero, then the impact of the quota would be no different from that of the tariff.

costs. The firm would then choose to reduce fixed costs, but profits will regardless fall under a restrictive trade policy. An output-equivalent quota then will imply lower profits than under either a tariff or free trade. This suggests that for an arbitrary value of G, a quota is more likely to lead to FDI than a tariff.

Proposition 3: when quality is endogenous, tariffs and quotas are nonequivalent even in the presence of possible FDI. A quota set at an output-equivalent level is more likely to lead to FDI than a tariff.

As well, a quota could lead to FDI even when set at a free-trade level. This is consistent with other results in the literature that show a non-equivalence between tariffs and quotas when quality is a choice variable.[12] This leads to a general presumption away from Levinsohn's (1991) result that maintained an equivalence between tariffs and quotas when firms can engage in FDI in the absence of R&D choices. For a number of distinct models, the tariff-quota non-equivalence holds suggesting that this result is fairly robust, and to the extent that FDI decisions depend in part on quality choice and R&D effort it is reasonable to presume the non-equivalence persists regardless of the possibility of FDI.

Another interesting implication of Proposition 3 is that the process of tariffication, a centerpiece of multilateral trade liberalization efforts under the auspices of the GATT, will lead to marginally less cross-country direct investment all else being equal. The impact on R&D levels would be ambiguous. Those firms that do not choose to invest abroad under quotas will increase their R&D under tariffication, but some firms that would have invested abroad and choose not to under tariffication will do less R&D than would otherwise be the case.

5. Conclusion and Discussion

Within a framework featuring quality and endogenous R&D in a strategic environment, we are able to present a strong theoretical link between MNEs and the large firm-specific assets that often characterize them by highlighting multimarket economies of scale in R&D. We then showed how

different trade barriers have differing impacts on the ability of firms to exploit these scale economies and thus present different incentives to undertake FDI. In the process we illustrate how a quota might never lead to the quality-upgrading of imports. While we do impose a number of limiting assumptions, the broad results of this model should be robust to any combination of preferences and technology that accommodate Cournot conduct and provide downward-sloping quality reaction functions.

Of course, there are many other variables that determine a firm's ability to exploit multimarket economies of scale which we have not formally considered. Relevant to this model would be the similarity of demand across countries. While this may not be so important for process R&D that is cost-reducing, it would surely be critical for the product R&D we envision here. As non-OECD countries grow, firms will have more to gain by pandering to the tastes specific to any given nation or region. Differences in the regulatory environment can serve as a similar impediment, such as with differing product safety standards. The current efforts at regulatory harmonization would then have consequences similar to those for trade liberalization hinted at earlier.

Both regulatory and trade policy liberalization are issues that lie at the core of increasing economic integration, regional and otherwise, and our framework implies that this integration will then have significant consequences for R&D efforts and the pattern of FDI. Future research would usefully consider FDI and R&D decisions in a framework of economic integration.

[12] These results typically apply to quotas and ad valorem tariffs, while here we distinguish quotas and specific tariffs. Tentative investigations, not reported, suggest that ad valorem tariffs are non-equivalent to either specific tariffs or quotas in this model.

APPENDIX 1 – ON THE SUBSTITUTABILITY OF THE DIFFERENTIATED GOODS

Cross-price elasticities can give us a sense of the substitutability between X and Y. The Marshallian demand functions for X and Y can be obtained by solving the equation system (2) and (3) for output levels, yielding

$$\text{(A1.1)} \quad X = \frac{p^x + x[a(y-1) - p^y]}{x(xy-1)},$$

$$\text{(A1.2)} \quad X = \frac{p^y + y[a(x-1) - p^x]}{y(xy-1)}.$$

The cross-price elasticity of X with respect to p^y, denoted ε^{xy}, is calculated as $\varepsilon^{xy} = \frac{\partial X}{\partial p^y} \cdot \frac{p^y}{X}$.

Substituting (2) and (3) back into this term and then substituting the Cournot-Nash output solutions for X and Y yields the cross-price elasticity as a function of quality levels and parameters. It is important to remember that this term, and a term for the cross-price elasticity of demand for Y, are not quite true Marshallian elasticities but rather incorporate the response of the rival firm.

Using the above procedure, the cross-price elasticities ε^{xy} and ε^{yx} are given by

$$\text{(A1.5)} \quad \varepsilon^{xy} = -\frac{y\{a(x-2) + m[x(y-1) - 2]\}}{(a-m)(y-2)(xy-1)},$$

$$\text{(A1.6)} \quad \varepsilon^{yx} = -\frac{x\{a(y-2) + m[y(x-1) - 2]\}}{(a-m)(x-2)(xy-1)}.$$

Both cross-price elasticities are positive consistent with substitutability between X and Y. First, note that when both quality levels are equal to unity the goods become perfect substitutes – both are so good in the minds of consumers that they yield the same level of satisfaction. Let us discuss some properties of the elasticity of X with respect to p^y, ε^{xy}, noting symmetric behavior for ε^{yx}. Differentiating ε^{xy} with respect to each quality level gives us

$$\text{(A1.7)} \quad \frac{\partial \varepsilon^{xy}}{\partial x} = -\frac{y[y(2a+m) - (a-m)]}{(a-m)(y-2)(xy-1)^2},$$

(A1.8) $$\frac{\partial \varepsilon^{xy}}{\partial y} = -\frac{a[4+x^2y^2-2x(1+y^2)]+m[4+x^2y^2-x(-2+4y+y^2)]}{(a-m)(y-2)^2(xy-1)^2}.$$

The sign of (A1.7) depends on parameter values. Particularly, it is equal to zero at $y = 0$ and $y^* = (a\text{-}m)/(2a+m) \leq 1/2$. For $y < y^*$ it is negative, while for $y > y^*$ the converse is true. In any case, as the own-quality level x increases the absolute value of (A1.7) increases. The sign of (A1.8) is always positive. Thus, an improvement in the rival's quality always makes the goods closer substitutes and consumers will more readily switch to the rival's product. An improvement in one's own quality makes the differentiated goods less substitutable if the rival's quality is relatively low (depending on marginal costs relative to the size of the market, i.e. m vis-à-vis a) and consumers will be more hesitant to switch to the rivals product. However, if the rival's quality level is high then an increase in own quality will increase the substitutability of the goods. Consider this in relation to the home firm's quality reaction function. On the upper portion, own quality is low relative to the rival's quality and an increase in own quality increases the substitutability between the goods, enabling the home firm to take market share from the foreign firm an increasing the appeal of using strategic R&D for this purpose. On the lower portion, own quality is high relative to the rival's. Increasing own quality makes the goods less substituable, making it more difficult for the foreign firm to take market share and the appeal of strategic R&D on the part of the home firm lessens. Also, the larger the gap between the quality levels, the less substitutable the goods are.

APPENDIX 2 – NECESSARY AND SUFFICIENT CONDITIONS FOR PROFIT-MAXIMIZING QUALITY CHOICE WHEN SUBJECT TO TARIFF.

We present here the first- and second-order conditions for profit maximizing quality choice by the foreign firm when its exports are subject to a tariff. Define a new variable k, $k = (a\text{-}m)$. The first-order conditions are as in equation (34). The second-order conditions for a strict maximum require that $\pi^f_{yy} < 0$. Differentiating (34) with respect to y yields

$$\text{(A2.1)} \quad \pi^f_{yy} = \frac{k^2 xy^3(2-x)^2(8+xy) + 24ktx^2y^3(x-2) + 4t^2(8-xy(8-3xy))}{y^3(4-xy)^4} - F^f_{yy}.$$

As can readily be seen, this equation is highly non-linear so it is not possible to establish just when the conditions hold algebraically. However, it is still possible to show numerically that the quality reaction function for the foreign firm is well-defined up to some value $\underline{x}$, at which point the second order conditions become violated as described in the main text.

FIGURE 1

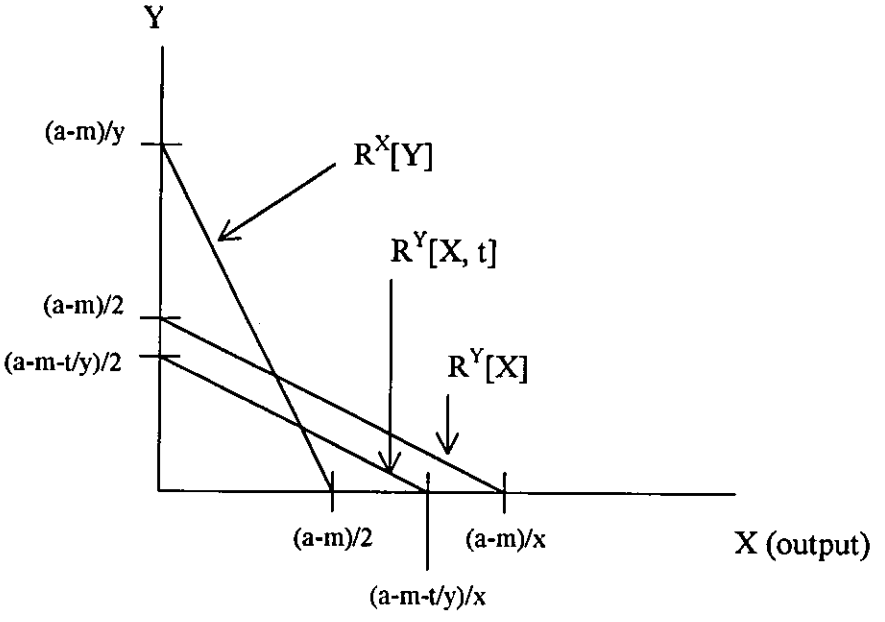
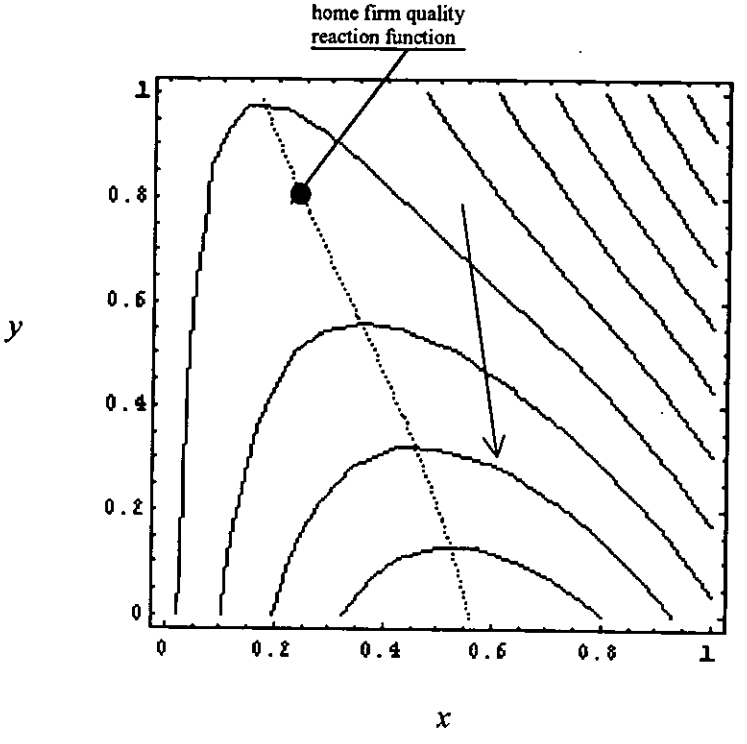
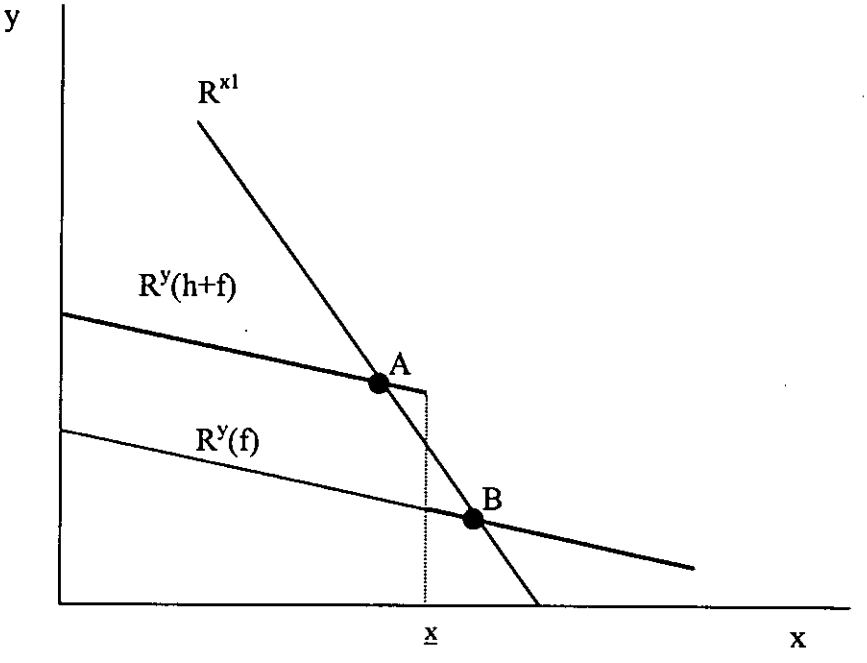


FIGURE 2



Parameter vales: $b = 50$, $(a\text{-}m) = 15$. Home firm profits increasing in direction of arrow.

FIGURE 3



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