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TRADE POLICY AND LEAPFROGGING

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Abstract

The recent extensive study of vertical product differentiation models has allowed for the analysis of international trade issues in the presence of country asymmetries in terms of product qualities, technology, cost, market size and income. In the presence of such asymmetries, national industries will either be market leaders or lagging behind in the international market place in terms of their product qualities. The resulting asymmetry in profits creates powerful incentives for lagging industries as well as their national Governments to reverse this situation to their advantage, i.e., to induce "leapfrogging" in terms of product qualities. This paper presents an overview of existing research on leapfrogging as well as several new results and questions.

Keywords: Product Qualities, International Trade, Trade Policy.

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JEL classification: F12, F13, L13

Keywords: vertical product differentiation, oligopoly, trade, quality, Leapfrogging, country asymmetries

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Trade Policy and Leapfrogging

1. Introduction

The New Trade Theory is characterized by an extensive use of IO-models of imperfect competition due to the generally accepted notion that many international markets are imperfect.[1] Another property of international markets is the presence of vertical quality differences ("high" vs. "low" product quality) between substitutable products. Product differentiation of this type is an important dimension in international trade, since trade in differentiated but substitutable products (intra-industry trade) has grown most in the last decades. Explanations for intra-industry trade are based on the cross-hauling or reciprocal-dumping argument.[2] In this context, product quality is a strategic variable for the firm that can be influenced by trade policy.[3] The resulting product asymmetries are often attributable to historically grown regional differences in technology and production costs[4] (e.g. in the European car market), but they are also influenced by regional asymmetries with respect to market size, income, demand, technology and production costs.[5] Two further developments of the last decades have contributed to the increased importance of an analysis of international markets in the presence of regional asymmetries with respect to market conditions and trade policy. These developments could be labelled globalization and regionalization, respectively.[6] Globalization denotes the process of increasing international integration of markets due to the reduction of real and institutional costs of trade in goods, factors of production, technologies and information. However, at the same period, trade policy has become more and more regionally oriented. For example, trade policies of the EU and NAFTA affect about 60% of world trade.

In the presence of regional asymmetries, national industries will either be market leaders or be lagging behind in the international market place in terms of their product qualities. The

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[1] See e.g. Bresnahan (1989).
[2] See e.g. Brander/Krugman (1983).
[3] See Mintz (1973), Levinsohn (1988), Feenstra (1988, 1993), Menzler-Hokkanen (1994).
[4] Regional asymmetries with respect to production costs can also be the result of differences in factor endowments.
[5] See e.g. Cabrales/Motta (1995), Motta/Thisse/Cabrales (1995).
[6] Baldwin/Venables (1994).

resulting asymmetry in profits creates powerful incentives for lagging industries as well as their national governments to reverse this situation to their advantage, i.e. to induce "Leapfrogging" in terms of product qualities. This switch in competitive stance can, e.g., be induced by direct foreign investment into backward industries (East Germany, transformation economies) or by government measures such as subsidies, quotas or standards. Even trade liberalization has similar effects in certain circumstances. Examples of Leapfrogging-oriented trade policies are found in public programs that involve subsidizing research and development (R&D) in European value-added industries. The EU Commission has established a program that subsidizes R&D joint ventures in telecom and information technologies (SPRIT). More examples are found in the EU's environment, marine and biological programs, respectively.

The conceptual economic framework that explicitly includes quality aspects and regional asymmetries into the analysis is provided by models of vertical product differentiation. Product differentiation entails an additional strategic choice in form of an investment in quality (R&D, human and technological capital) prior to the final product market competition. These models are also particularly useful for the analysis of trade policies and Leapfrogging. This paper presents an overview of existing research on vertical product differentiation and Leapfrogging as well as several new results and questions.

The remainder of the paper is organized as follows. Sections 2 and 3 present the basic analytical framework and some main results about market behavior. Section 4 presents theoretical arguments for Leapfrogging induced by production subsidies, quality standards, quotas, tariffs, and trade liberalization. Section 5 discusses the significance of different cost specifications and market conditions. Section 6 surveys some empirical evidence on quality differentiation and market structure. Section 7 concludes.

2. The Theoretical Framework

Most of the theoretical results presented in this paper have been derived by utilizing some specific model out of the class of models of imperfect competition and vertical product quality differentiation. In this section, we introduce one benchmark model that has been extensively applied in the literature. The consequences of altering specific significant features,

such as form of competition or cost structures, are discussed later. Our benchmark analytical framework utilizes a two-country model of imperfect competition. This allows for the analysis of effects of various national and international economic policy measures on national welfare, industry profits and consumers' welfare in more than one country. The analysis captures some of the most important aspects of international markets.

The effects of trade policy on product quality have been investigated since the mid-70s but earlier studies are restricted to the cases of perfect competition or monopoly.[7] Other studies take oligopolistic competition into account but assume exogenously fixed product qualities.[8] The standard model of duopolistic competition with endogenous product qualities has been developed since the beginning of the 80s (Mussa/Rosen 1978, Gabszewicz/Thisse 1979, Shaked/Sutton 1982, Champsaur/Rochet 1989, Ronnen 1991)[9]. Consumers have identical preferences and different incomes. The income differences lead to differences in the willingness to pay for a particular product quality. Two firms offer products of different qualities in two (domestic and foreign) markets. The firms bear quality-dependent costs and compete in qualities and prices in a two-stage industry game. Since higher product differentiation reduces substitutability and price competition, even identical firms will offer distinct qualities in the resulting market equilibrium. Trade will take place since both firms operate in both markets (reciprocal-dumping argument). National governments can use trade policy to improve the strategic position of domestic industries (see e.g. Brander/Spencer 1984, Krishna 1989). There is also the possibility of strategic noncooperative interaction between two national governments.

The point of departure or benchmark case for the following discussion is a particular model labelled for this purpose as Type A. The Type-A model represents consumers by a uniform distribution of an income parameter in the interval [0, t]. In addition, production costs consist exclusively of quality-dependent convex fixed costs, i.e. marginal costs (with respect to quantity) are constant (equal to zero). Type A obtains market equilibria with incomplete market coverage (not all consumers buy). Without other entry costs, the number of firms in

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[7]See Spence (1975), Rodriguez (1979), Falvey (1979), Santoni/Van Cott (1980), Mayer (1982), Das/Donnenfeld (1987), Krishna (1987), Bond (1988).
[8]See e.g. Leland (1979), Shapiro (1983)
[9]For an overview, see Tirole (1988) or Waterson (1989).

the market is unlimited (no Finiteness Property). Furthermore, the profits of the firm providing the higher quality are higher than the profits of the other firm.

3. Some Basic Theoretical Results

In duopolistic models of vertical product differentiation, there generally exist two equilibria (in pure strategies) since a priori either firm can decide to offer either the higher or the lower quality. With identical firms, the two equilibria are essentially (up to the order of firms) identical. Therefore, most of the previous work is restricted to marginal analysis in the vicinity of one of these equilibria (e.g. Ronnen 1991, Motta 1992, 1993, Cremer/Thisse 1994, Boom 1995). Other studies apply marginal analysis also to the second equilibrium (e.g. Crampes/Hollander 1995, Motta/Thisse/Cabrales 1995).

The existence of regional asymmetries (especially with respect to cost of quality) can lead to the existence of only one equilibrium. This effect can also be attained by various trade policies(e.g. subsidies, tariffs, quality standards). This provides powerful incentives for the use of trade policy in the case where the domestic industry is initially in the position leading to lower profits. This is especially the case for the Type-A model. For the analysis of these cases, a complete description of firms profit-maximizing strategies (quality best responses) and the resulting multiple equilibria is crucial. This is the case, since the effects of various trade policy instruments are not always marginal (with respect to one initial equilibrium). On the contrary, trade policy can induce a switch from an initial equilibrium to another equilibrium. In the case of vertical product differentiation, this switch means that the firm initially offering the qualitatively inferior product ends up producing the qualitatively superior product (qualitative/technological Leapfrogging). This effect can be caused also, for example, by direct foreign investment in backward industries, industry-specific subsidies, or regional investment in infrastructure.

In describing firms' profit-maximizing strategic responses, the cases of quantity (Cournot) and price (Bertrand) competition need to be distinguished since they affect firms' profits differently.[10] Under Bertrand competition, a firm's profit functions consist of two

[10]This description of firm's quality best responses is based on Aoki (1995) and Lutz (1996c).

strictly concave segments connecting at the quality level of the competitor (see Figure 1). Each of these segments contains a local profit maximum, leaving the firm to decide whether to choose the low-quality or the high-quality maximum. If the competitor's quality rises, then the low-quality segment of the profit function rises and the high-quality segment falls making the low-quality choice more attractive. This gives rise to a quality best response where both firms set their qualities as strategic complements (see Figure 2). Profits along this quality best response are as follows: With a competitor's quality close to zero, a firm will set a high quality making close to monopoly profits. As the competitor's quality rises, the firm's profits decrease as long as it provides the higher quality. Eventually it will be more profitable to provide lower quality. From then on, profits increase with an increase in the competitor's quality. With two identical firms i and j that set qualities s_i and s_j, this gives rise to a situation as depicted in Figure 3, where the intersections of the best responses indicate two asymmetric equilibria. Generally, there will be two pure-strategy equilibria as long as firms are not too different with respect to cost of providing quality. The ratio of high quality to low quality is constant with respect to market size but increases monotonically in the ratio of cost parameters of the two firms. The existence of a unique quality equilibrium due to cost differences can be illustrated using Figure 3. In Figure 3, an increase in the fix cost of firm j would lead to a leftward shift in qbr_j. If this increase gets sufficiently large, the intersection of qbr_i and qbr_j in the lower right corner of Figure 3 vanishes. Only one equilibrium with firm i providing high quality remains. This is illustrated in Figure 4.

While the existence of Cournot versus Bertrand competition does not affect the qualitative market outcome much without regulation or trade policy, there is a variety of evidence for some significance of market conduct in the presence of such policies.[11] Cournot-conduct entails a lower degree of price competition than Bertrand-conduct. Generally, this leads to higher quality differentiation and profits in the former case. Profits, however, are a key variable for the analysis of entry, exit and Leapfrogging. Furthermore, with Cournot-conduct, qualities are not generally strategic complements any more. In the case of the duopoly,

[11] Direct comparisons have been forwarded, for example, by Motta (1993), Aoki (1995) and Herguera/Kujal/Petrakis (1996, 1994). The case of trade policy in the presence of price competition has been treated, for example, by Krishna (1987, 1989), Cremer/Thisse (1994) and Boom (1995), while the case of quantity competition was analyzed, for example, by Das/Donnenfeld (1989).

the higher quality will be set as a strategic complement whereas the lower quality will be set as a strategic substitute. This is potentially significant with respect to any policy that directly changes the shape of quality best responses (e.g. quality standards). However, in many cases market results will be very similar. In the following sections, we will discuss differences where appropriate.

Furthermore, policies such as quality standards enable one firm to prevent exit of the competitor although the firm lacks this ability in the unregulated market equilibrium (without additional fixed entry costs) (Lutz 1996b). This effect can also be present for various other trade policies. Section 4.2. below contains a case (Herguera/Lutz 1996a) where a quality standards leads to Leapfrogging and exit of one firm.[12]

4. Policies that Facilitate Leapfrogging

The possibility of Leapfrogging arises generally when a policy changes an industry's potential profits as the high-quality provider relative to its profits as the low-quality provider. It follows that a general analysis of Leapfrogging necessitates the analysis of firms' strategic best responses and profits. The intersection of two firm's quality best responses constitutes a (pure-strategy) Nash equilibrium in qualities. As already outlined in Section 3, the number as well as the locations of the equilibria are determined by the relative locations of the best responses, which in turn are determined by market factors, cost factors, and (trade) policies applied. In particular, any policy that shifts the quality best response of a firm may lead to a switch from one equilibrium to another. One particular policy of this kind is a production or R&D subsidy, another one is an ad-valorem tariff. Both policies directly change the cost of providing a certain level of quality. Other policies such as quality standards, quantity constraints or specific tariffs affect firms' quality best responses in a much less straight-forward way. They may lead to Leapfrogging in certain circumstances, but their analysis is more complicated. Since the literature on Leapfrogging is rather fragmentary at this time, we will often restrict the discussion to presentations of certain benchmark cases or examples. In what

[12] Earlier work on entry (e.g. Donnenfeld/Weber 1992, Hung/Schmitt 1992) concentrates on cases where fixed entry costs are present.

follows, we will discuss R&D or production subsidies, minimum quality standards, trade liberalization, tariffs, and quantitative trade restrictions.

4.1. R&D or Production Subsidies

This case is discussed concentrating on Bertrand competition in the second stage of the industry game, since the qualitative results will be the same for the case of Cournot competition. Even though the analysis of Leapfrogging in a vertical product differentiation framework has recently been addressed by authors such as Herguera/Kujal/Petrakis (1994), Lutz (1996b), and Motta/Thisse/Cabrales (1995), there is hardly any literature covering the usage of R&D subsidies to induce Leapfrogging.[13] The analysis presented here is from Herguera/Lutz (1996b).

As outlined in Section 3, Bertrand competition will lead to a quality best responses where both firms set their qualities as strategic complements (as in Figure 2). With two identical firms i and j that set qualities s_i and s_j, this gives rise to a situation as depicted in Figure 3 and there will be two pure-strategy equilibria as long as firms are not too different with respect to cost of providing quality. The ratio of high quality to low quality is constant with respect to market size but increases monotonically in the ratio of cost parameters of the two firms. The existence of a unique quality equilibrium due to cost differences can be illustrated using Figures 3 and 4. In Figure 3, an increase in the fix cost of firm j would lead to a leftward shift in qbr_j. If this increase gets sufficiently large, the intersection of qbr_i and qbr_j in the lower right corner of Figure 3 vanishes. Only one equilibrium with firm i providing high quality remains. This is shown in Figure 4.

This case starts from an initial situation with identical firms, where one is domestic (firm i) and the other is foreign and both are acting in the domestic market. It is assumed that the domestic firm is initially offering the lower quality, providing the motive for a Leapfrogging-inducing policy by the domestic government. This initial situation could be the outcome of the foreign firm being longer in the market than the domestic firm, so that the foreign firm operated as a Stackelberg-leader towards the domestic firm in the past. The

[13] Other issues related to R&D are treated,e.g., by Motta (1991), Leahy/Neary (1995a, 1995b).

analysis shows that an R&D subsidy can be found that leads to a reversal of the quality ordering in equilibrium and increases domestic profits as well as domestic welfare (measured as the sum of consumer surplus and profits minus subsidy cost).

However, it cannot be generally argued for the application of such policies, even though this case entails welfare increases for the domestic country. Since strategic interaction between governments will likely take the form of a subsidy race leading to a prisoner's dilemma, this analysis merely suggests that policy makers should be aware of the possibility of rather radical effects of R&D subsidies.

4.2. Minimum Quality Standards

Ronnen (1991) uses Shaked and Sutton's framework to demonstrate cases where quality standards improve welfare. He concludes that there exists a binding minimum quality standard such that all consumers are weakly better off, both firms have positive profits, and total welfare is increased. As a result of such a standard, profits of the high-quality provider must fall, whereas profits of the low-quality provider may even rise if the standard is set close to the equilibrium level of low quality without regulation.[14] Crampes/Hollander (1995) present a study where quality improvements fall on variable costs. They present results where all consumers lose through the imposition of a standard. Boom (1995) introduces National Treatment of standards into a two-country model. Here, a relatively high standard imposed in one country can lead to market exit and a reduction of product variety in one country reducing consumers' welfare. Lutz (1996a, 1996b, 1996c) analyzes standards under Mutual Recognition. Here, each government maximizes regional welfare subject to its own standard. Now both firms face binding standards and are forced to increase quality. This leads to a

[14]Ronnen starts from the assumption that the chosen order of qualities is already determined, i.e. it is a priori clear which of the firms offers the higher quality. Consequently, Ronnen analyzed firms quality best responses only in the vicinity of one existing equilibrium. However, with completely endogenous choice of quality, there exist up to two equilibria and each firm's quality best response is discontinuous and contains a high- and a low-quality branch, respectively. In our paper, we demonstrate the derivation of complete quality best responses and the resulting equilibria. These equilibria are in pure strategies. If there are two pure-strategy equilibria, there also exists at least one mixed-strategy equilibrium. However, the analysis of mixed-strategy equilibria is beyond the scope of this work. The emergence of multiple equilibria has also been acknowledged by, *e.g.*, Boom (1995) or Crampes/ Hollander (1995). The question of selection between two asymmetric equilibria was recently addressed by Motta/Thisse/Cabrales (1995) who demonstrate how the risk dominance criterion can be utilized for this purpose in models of the type employed here.

higher degree of product differentiation than with a single standard. However, since costs are convex in quality, the government regulating the low-quality provider prefers to increase its industry's quality more than the other government. Therefore, quality differentiation is lower than without regulation. In addition, each region benefits from an increase in quality of the other region's product. Introducing quality standards will increase both qualities, reduce the ratio of qualities, reduce both national industries' profits, increase national welfare in both regions, and reduce the ratio of national welfares.

The effects of quality standards on industry competition are primarily driven by their influence on price competition and the qualities produced. Due to the duopoly situation and the nature of price and quality competition, an unregulated equilibrium results in qualities being too low, prices being too high and quality differentiation being too low when compared to a welfare-maximizing solution. When qualities produced become more similar, price competition intensifies. In response to quality standards, qualities rise, quality differentiation is reduced, and prices adjusted for quality fall. In the case of a single standard, only the low-quality provider is constrained. High quality rises also because qualities are strategic complements due to the effect of quality differentiation on price competition. Reduced quality differentiation results because increasing quality is increasingly costly.

Even though the analysis of Leapfrogging in a vertical product differentiation framework has recently been addressed in the literature (see Section 4.2.), there is hardly any literature covering the usage of standards to induce Leapfrogging. The example presented here is from Herguera/Lutz (1996a). A more efficient domestic firm and a less efficient foreign firm operate in a single domestic market. The foreign firm initially produces and sells a product of higher quality. (This initial situation could be the outcome of the foreign firm being longer in the market than the domestic firm, so that the foreign firm operated as a Stackelberg-leader towards the domestic firm in the past.) Since the domestic firm could make higher profits by offering the higher quality, there is an incentive for the domestic government to facilitate this outcome by some policy. In the absence of a facilitating policy, however, the domestic firm cannot credibly leapfrog, since the current outcome represents a Nash-equilibrium. It is shown that the domestic government can choose a standard such that the domestic firm: (1) cannot

have nonnegative profits as the low-quality firm; and (2) can set a quality such that the foreign firm cannot have nonnegative profits as either the low-quality or the high-quality firm; and (3) domestic welfare is increased. Hence, the standard facilitates Leapfrogging as well as exit of the foreign competitor. This result depends crucially on the cost asymmetry between domestic and foreign producers. Hence, the purpose of this analysis is to illustrate that domestic standards can have strategic trade effects that are not marginal but entail a complete restructuring of the international market in question. Here, a standard that is nonbinding for the foreign firm ultimately leads to the exit (or non-entry) of the foreign firm. This standard also enables the domestic firm to act exactly like a monopolist without the threat of entry. In doing this, the domestic firm chooses a quality that is not bound by the standard, higher than the quality it would have chosen without a standard, and higher than the quality the foreign firm would have chosen without the standard (potential "Leapfrogging").

However, it cannot be generally argued for the application of such policies, even though this case entails welfare increases for the domestic country. Since several examples can be constructed where the outcomes are quite different, this suggests that policy makers should be aware of the possibility of rather radical and detrimental effects of domestic standards.

4.3. Trade Liberalization

Motta/Thisse/Cabrales (1995) investigate whether the opening of trade will lead to persistence of an initial quality leadership caused by national differences in demand. Countries operate under autarchy in the first period, whereas trade occurs in the second. They conclude that persistence of leadership is most likely to result. This is the only possible outcome if differences in national demand are very large. In all other cases, *i.e.* when multiple equilibria exist, using the risk dominance criterion[15] leads to the selection of the persistence-of-leadership outcome. Initial leadership without trade, i.e. under autarky, is the result of one country having a bigger market than the other. This leads to quality choices where the firm in the bigger country offers a higher quality even though firms are identical. When trade is opened between both countries and firms can adjust their qualities accordingly (bearing adjustment

[15]Loosely speaking, the risk dominance criterion means that firms evaluate the risk of ending up in the "wrong equilibrium" when choosing their strategies.

costs), the possibility arises for the firm offering the lower quality in autarky to now offer the higher quality in the joint market. This constitutes a case of Leapfrogging induced by trade liberalization. This is, however, only possible if country sizes are not to different. Furthermore, if both firms use the risk dominance criterion to select their strategies, Leapfrogging will generally not arise.

This indicates that trade liberalization by itself is typically unlikely to lead to Leapfrogging. However, since the possibility of Leapfrogging is introduced by trade liberalization, this might influence the timing of other Leapfrogging-inducing policies.

4.4. Tariffs

Tariffs and quotas have been widely analyzed as protection instruments in international trade. The main argument for tariff protection in imperfectly competitive markets was put forward by Brander/Spencer (1984). In a duopoly, they argued, with one foreign and one domestic firm, the domestic government has incentives to impose a tariff on the foreign imports since it gains via three channels: it improves the terms of trade, it gains tariff revenues and it provides a strategic advantage to the domestic firm via an increase in its market share at the expense of the foreign competitor. When firms compete also in the long run in R&D investments that may lead to higher quality of the products on the market, tariffs may have important effects not only on the product market but also on the previous R&D optimal choice by each firm.

If there is a monopoly Krishna (1987) showed that a specific tariff increases the price-quality ratio of the high quality good less than the ratio of the low quality good. Since demand for each variety is inversely related to its price the total demand for the high quality good increases. The observed effect of the trade policy is an upgrading of the average quality. The ad valorem tariff has ambiguous effects on the quality offered in monopoly or leaves the qualities unaffected in perfect competition, as in Rodriguez (1979) or Santoni/Van Cott (1980).

In oligopoly the effect of a specific tariff on the imported high quality good depends on the credibility of the government announcement[16] and on the existence of set up costs of quality. Reitzes (1992) points out that if significant set up costs exist, then the tariff induces a suboptimal choice of quality on the part of the foreign firm. Furthermore, a high enough tariff protection may induce the domestic firm to achieve the first best quality choice. This is best explained as a coordination problem: when high fixed costs, no firm has incentives to commit to large investments unless a protection instrument guarantees that a sufficiently large market share will be enjoyed in the final products market. This can be achieved for the domestic firm if protected by a tariff.

If the tariff announced is credible, there is an interval of tariffs (i.e., the non-prohibitive tariffs) that lead to quality downgrading on the part of the high quality foreign firm and to upgrading for the low-quality domestic firm. The tariff will reduce the market share of the foreign firm and increase the market share of the domestic firm.[17] This leads to quality downgrading (upgrading) by the foreign (domestic) firm, since fixed costs of quality are distributed across less (more) output. More importantly, if firms do not believe the government announced tariff, the foreign firm will expect a high enough tariff that will provoke Leapfrogging and this induces the foreign firm to produce a lower quality than the rival[18]. Since the government gains by placing the domestic firm in the upper segment of the quality ladder, the home firm will produce the high quality good. It is interesting to note that in a partial one country equilibrium setting, the domestic government is better off by not committing to a specific tariff, since it can provoke Leapfrogging with a low ex-post tariff rate.

4.5. Quantitative Trade Restrictions

In perfect competition, first Falvey (1979) and Swan (1970) showed that a quantitative restriction on trade would lead to quality upgrading on the part of a multi-product monopolists. The quota places a shadow price on any unit of the high- or the low quality goods. Any increase in the quality of any of the goods reduces the shadow price of the

[16]To the problem of credibility, compare also Leahy/Neary (1994).
[17]This is essentially the same effect as in Brander/Spencer (1984).
[18]See Herguera/Kujal/Petrakis (1996).

restriction. Hence, raising quality as a response to the quantitative restriction is profitable for the monopolist assuming that the marginal consumer values quality increments less than the average consumer does. For the case of a monopolist serving a destination market, in a model of endogenous quality choice the effects of quotas in the product line of a monopolists have been studied[19]. In this vertical product differentiation model, quality is a factor that raises the willingness to pay for any given output. Depending on the rationing rule implied by the quota the marginal consumers left out after the quota may be the high valuation or the low valuation consumers. If only the low valuation marginal consumer is expelled of the market after the quantitative restriction then the monopolist raises the average quality of the products as a response. In what follows, we discuss to what extent the result of quality-upgrading holds when there is strategic interaction among several firms.

For the case of oligopoly the theoretical and empirical results are more complex. A very important distinction comes regarding the timing and credibility of the trade policy announcement. When the announcement of the quantitative restriction is credible and firms simultaneously choose the quality and the quantity of the good, the quotas may lead to quality upgrading depending on the initial location of the firms in the quality ladder. If the foreign (restricted) firm is the high quality producer, after the quota is imposed it will increase the quality attached to its good since total sales in the market decrease and marginal revenue is increasing in the quality. The high valuation consumers are willing to pay an increasing price if the quality offered is higher. The foreign firm quality response will be opposite if it starts producing the low quality good, whereas the domestic firm responds to a quota by increasing its quality if it produces the low quality initially or by downgrading if it produces the high quality initially[20]. The driving force of these results lies in what Krishna points out as the quota as a "facilitating device" tending to reduce the amount of competition. In fact the facilitating practice result is very important since, depending on the timing of moves by the firms, it may lead to the opposite result, i.e., quality downgrading, by both firms in the market. We can think of the quality, or R&D investment, as a choice made for the long run, while the quantity

[19] See Krishna (1987), Spence (1976).
[20] See Das/Donnenfeld (1987), Krishna (1983), Harris (1986) and Ries (1993).

(or price) competition takes place in the short run[21]. In this setting the quality choice is a sunk investment for the firms in the short run. The quantitative restriction may lead to quality downgrading by both firms. The reason is, that the domestic firm may choose not to compete aggressively in the quality stage since it knows the foreign firm is restricted. This facilitating practice that occurs in the last stage may also feed back into the R&D or quality stage. If firms believe in the government policy announcement they will not invest as much in the quality of the goods to be delivered as they would under free trade since both know that market sales will be restricted in the last period.

The quota may lead also to Leapfrogging. A quota set close to the free trade level of exchange will not induce any Leapfrogging, although it leads to small changes in the quality choices. There are, however, positive quota levels such that the initially high-quality foreign producer finds it no longer profitable to maintain its previous level of quality since the market share it will enjoy in the products market is expected to be too small. If the quota level announcement by the government is not credible the foreign firm expects precisely that level of quota to be implemented ex-post by the government and advancing it, it may decide to downgrade the quality of its products even below the quality offered by the domestic rival. It is important to note that in this idealized framework with only two competing firms, the domestic government achieves a Pareto improvement if it provokes the Leapfrogging. Profits for the firms are increasing in the quality segment and consumer surplus, even if total sales are reduced by the quota, increases due to the higher surplus derived from the high quality consumers[22]. Trade policy can cause a discontinuous change in the behavior of the firms in the quality as well as in the quantity (or price) dimension. It is also possible to combine a policy mix of R&D subsidies together with specific tariffs or quotas in order to achieve the Leapfrogging[23]. At this point it is very important to note that because of the presence of sunk or set-up costs of quality in the first stage, we can conclude that credibility is not an important asset for the domestic government. Clearly, if no sunk costs of quality exist, then no matter at what stage the government announces the policy, the quality choices will be optimal (first best). If the

[21] As in Herguera/Kujal/Petrakis (1994).
[22] As is shown in Herguera/Kujal/Petrakis (1996).
[23] As in Herguera/Kujal/Petrakis (1996).

government announces the tariff or quota level after the qualities have been chosen, then it can extract all the rents from the foreign firm because the foreign firm does not have the possibility to react. As noted by Reitzes (1992) and Herguera/Kujal/Petrakis (1996), it is the presence of sunk costs of quality in the sequential game that makes commitment on the part of the Government important for the competitors.

Credibility of the government is not desirable in this one-country equilibrium framework since the government gains by provoking Leapfrogging and it achieves this with a low ex-post tariff or quota level. In this setting, firms can also strategically manipulate their quality choices in order to influence the resulting level of protection. The domestic firm may locate in the low-quality segment in order to achieve a higher protection level from the domestic government because it wants to induce Leapfrogging.[24]

In a more general setting with several countries, of course, all countries would face the same incentives to use quantitative restrictions to induce Leapfrogging, leading once again to the danger of an inefficient outcome.

5. Differences in Cost Specifications and Market Structure

The cost structure in combination with assumptions about the distribution of consumers determines the structure of firms' profits in equilibrium. The Type-A model leads to identical rankings of qualities and firms' profits, respectively. Changes of product qualities induced by trade policy that lead to lower product differentiation will generally reduce profits of both firms but increase their market shares. This is possible since market coverage is increased by this policy (absolutely more consumers purchase products) (Ronnen 1991, Lutz 1993). The ranking of firms' profits, however, remains unchanged. However, if the market is covered already in unregulated equilibria (see Shaked/Sutton 1982 for the appropriate condition), the same policy will lead to an increase of the market share of the low-quality firm and a decrease of the market share of the high-quality firm (Boom 1995, Crampes/Hollander 1995). Furthermore, in the Type-A model, the high-quality firm can increase its market share by

[24] Another reason for quantitative restrictions is when there are informational externalities in the consumption of the goods. In this case the informational externality may lead to suboptimal levels of quality chosen by all the competitors. The Government may upgrade the average quality in the market and to achieve this it may set quantitative restrictions at the individual level. See Donnenfeld/Mayer (1987).

lowering price without increasing total cost. This possibility is greatly reduced in the presence of variable costs. As a result, the case of market coverage and variable costs quadratic in quality leads to identical profits and market shares for both firms (Crampes/Hollander 1995). This means that the choice of higher quality does not any more entail a strategic advantage for the respective firm. Moreover, trade policy will now lead to overproportional losses of the high-quality firm. In summary, it can be concluded that the effects of trade policy are highly dependent on assumptions about costs and demand structure. More comparative analysis in this area will be necessary to adequadely assess the robustness of any policy analysis presented.

6. Empirical Evidence

Empirical evidence on Leapfrogging or even on vertical quality differentiation is mostly anectodal or based on case studies. In many cases, it also takes the form of analyses of general conditions in developing countries. Some of these studies cover the computer industry in Eastern Europe (Bodea 1994), telecommunications in developing countries (Antonelli 1991), the Brazilian information technology industry (Bornstein 1995), the East-Asian semiconductor industry (Hong 1993), or technical cooperation with developing countries (Brinkerhoff (1990).

Direct empirical applications of models of vertical product differentiation are currently virtually non-existent (exceptions are, e.g., Messinger 1989 or Thomas 1988). This is probably due to two main reasons. The first is the (afore mentioned) lack of robustness of theoretical results. The second is the general problem of quality measurement. Studies about measurement of quality have been forwarded by Feenstra (1988, 1993), Greenaway (1984), Levinsohn (1988), Menzler-Hokkanen (1994). Provided that appropriate quality indices were available, empirical industry models of vertical quality differentiation using any particular quality measure might be constructed similarly to the way models of horizontal (or unspecified) quality differentiation have been constructed (compare, e.g., Dixit 1988, Gasiorek/Smith/Venables 1992, Smith/Venables 1988). However, this has not been done yet (to our knowledge).

In summary, the available empirical evidence suggests that Leapfrogging is an especially relevant phenomenon for developing and transformation economies.

7. Conclusions

The purpose of this paper was to present an overview of existing literature on Leapfrogging. The research discussed suggest that several domestic policies might have strategic trade effects that are not marginal but entail a complete restructuring of the international market in question. These policies do not only include traditional trade policies such as tariffs and quantitative trade restrictions but also others such as R&D subsidies and quality standards. Furthermore, in addition to Leapfrogging, they might also induce exit or entry deterence.

However, we cannot generally conclude from the research discussed that these policies should be applied , even though most cases presented entail welfare increases for the domestic country. Since the results are mostly not robust with respect to country asymmetries and market conduct, this rather suggests that policy makers should be aware of the possibility of rather radical and detrimental effects of domestic policies. It also suggests that current theoretical research is still a long way from a general analysis of Leapfrogging-inducing policies. Hence, it is not too surprising that the state of empirical research is even more wanting.

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Appendix

A.1. The Model - Price (Bertrand) Competition

There are two firms, the domestic firm d and the foreign firm f, both competing in the domestic market. If both firms remain in the market, then they produce distinct goods, sold at prices p_d and p_f, respectively. The two products carry a single quality attribute denoted by s_d and s_f, respectively. Either firm faces production costs that are increasing, convex (quadratic) functions of quality, the exact level of which depending on quality chosen and a quality cost parameter b. Total costs of firm i are then:

$$c_i = b_i s_i^2 \tag{1}$$

In the domestic market, there is a continuum of consumers distributed uniformly over the interval [0, T] with unit density. Each consumer purchases at most one unit of either firm d's product or firm f's product. The higher a consumer's income parameter t, the higher is her (his) reservation price. Consumer t's utility is given by equation (2) if good i is purchased.[25] Consumers who do not purchase receive zero utility.

$$u_t = s_i t - p_i \tag{2}$$

Firms d and f play a two-stage game[26]. In the first stage, firms determine qualities to be produced and incur costs c_i (i = d, f). In the second stage, firms choose prices simultaneously.[27]

Price Competition

To solve the game, consider first the demand faced by the high-quality and low-quality firm, respectively. Let h and o stand for high and low quality, respectively. These demands are then given by:[28]

$$q_h = T - \left(\frac{p_h - p_o}{s_h - s_o}\right), \quad q_o = \frac{p_h - p_o}{s_h - s_o} - \frac{p_o}{s_o} \tag{3}$$

Let i = h, o; let $j \neq i$. The profit function for firm i is given by $\Pi_i = p_i q_i(p_i, p_j, s_i, s_j) - c_i(s_i)$. Taken both qualities as given, the price reaction functions in each market are given as the solutions to the first order conditions. Solving the resulting equations for both prices, equilibrium prices are then given as:

$$p_h = \frac{2Ts_h(s_h - s_o)}{4s_h - s_o}, \quad p_o = \frac{T(s_h - s_0)s_o}{4s_h - s_o} \tag{4}$$

Note that for all $s_h > s_o$, $T > t_h > t_o > 0$ will hold, *i.e.*, equation (4) is in fact an unconstrained price equilibrium.

Given the price equilibrium depicted above, demands and thus profits can be expressed in terms of qualities. For positive qualities s_i (i = h, o), these profit functions are:

$$\Pi_h = \frac{4T^2 s_h^2 (s_h - s_0)}{(4s_h - s_0)^2} - b_h s_h^2, \quad \Pi_o = \frac{T^2 s_h (s_h - s_o)s_o}{(4s_h - s_o)^2} - b_o s_o^2 \tag{5}$$

Similarly, consumer surplus[29] can be expressed in the following way:

$$CS = \frac{T^2 s_h^2 (4s_h + 5s_o)}{2(-4s_h + s_o)^2} \tag{6}$$

---

[25] Consumers who do not purchase receive zero utility.

[26] In this formulation, firm i not entering the market is equivalent to firm i choosing $s_i = 0$. The entry decision by firms is made simultaneously when choosing quality.

[27] To derive solutions, we will use the concept of subgame-perfect equilibrium, computing the solutions for each stage in reverse order. Both firms choose their respective product quality from the same interval $[0, \infty)$. The resulting market equilibria will include some consumers in the lower segment of the interval [0, T] not valuing quality enough to buy any product. This guarantees an interior solution of the price game.

[28] Let $t_h = (p_h - p_0)/(s_h - s_0)$ and $t_o = p_o/s_o$. Consumers with $t = p_o/s_o$ will be indifferent between buying the low-quality product and not buying at all. Consumers with $t = (p_h - p_0)/(s_h - s_0)$ will be indifferent between buying either the high-quality or the low-quality product. Consumers with $T \geq t > t_h$ will buy high quality, consumers with $t_h > t > t_o$ will buy low quality, and consumers with $t < p_o/s_o$ will not buy at all.

[29] Consumer surplus is defined as $\{\int(t^*s_h - p_h)dt + \int(t^*s_o - p_o)dt\}$ where the first integral goes from t_h to T and the second goes from t_o to t_h.

Properties of the Revenue and Consumer Surplus Functions

Let R_i denote firm i's revenue function. Let h and o denote high and low quality, respectively.

$$\frac{\partial R_h}{\partial s_h} \geq 0; \quad \frac{\partial R_0}{\partial s_o} \geq 0 \text{ for } s_o \leq \frac{4s_h}{7}; \quad \frac{\partial R_h}{\partial s_o} < 0, \quad \frac{\partial R_o}{\partial s_h} > 0;$$

$$\frac{\partial^2 R_h}{\partial s_h^2} \leq 0; \quad \frac{\partial^2 R_o}{\partial s_o^2} \leq 0; \quad \frac{\partial^2 R_h}{\partial s_h \partial s_o} > 0; \quad \frac{\partial^2 R_o}{\partial s_o \partial s_h} > 0.$$

Let CS_I (I = D, F) denote region I's consumer surplus function. Firms' qualities are denoted by s_h and s_0 for high and low quality, respectively.

$$\frac{\partial CS_I}{\partial s_h} > 0 \text{ for } s_o < \frac{4s_h}{5}; \quad \frac{\partial CS_I}{\partial s_o} > 0; \quad \frac{\partial^2 CS_I}{\partial s_h^2} > 0; \quad \frac{\partial^2 CS_I}{\partial s_o^2} > 0; \quad \frac{\partial^2 CS_I}{\partial s_o \partial s_h} < 0.$$

Quality Competition

To derive the firms' quality best responses, we investigate each firm's profit function, given the other firm's quality choice, and taking into account the behavior in the price-setting subgame. Given the order of qualities, the profit functions in equations (5) are concave in the respective firm's own quality. The profit-maximizing choices form a Nash-equilibrium in qualities, where both marginal profit functions evaluate to zero. The first order conditions for the high and low quality firm, respectively, are then given as:

$$\begin{aligned} 4T^2 s_h (4s_h^2 - 3s_h s_o + 2s_o^2 -) / (4s_h - s_o)^3 &= 2b_h s_h \\ T^2 s_h^2 (4s_h - 7s_o) / (4s_h - s_o)^3 &= 2b_o s_o \end{aligned} \tag{7}$$

The slopes of the high and low quality firms' quality best responses can be calculated (using the implicit function theorem) as $ds_i/ds_j = -(\partial(\partial\Pi_i/\partial s_i)/\partial s_j)/(\partial(\partial\Pi_i/\partial s_i)/\partial s_i)$, where i is either high or low quality and j is the other quality. Both slopes are positive, but less than one.

From the properties of the revenue functions and the slopes of the quality best responses, it can be derived that the two qualities are strategic complements. Furthermore, a forced increase of the low quality will reduce product differentiation and increase price competition.

Divide the first order conditions given in (7), rearrange and write $s_h = r\, s_o$ and $b_0 = a\, b_h$ to obtain:

$$\frac{4(2 - 3r + 4r^2)}{4r^2 - 7r} = \frac{r}{a}$$

For a=1 (i.e. $b_0 = b_h = b$) r = 5.25123 while for a=2 (i.e. $b_0 = 2\, b_h = 2\, b$) r = 9.14152. Using r to express s_h in terms of s_0 and substituting for s_h in the first equation of (7) allows for calculating the equilibrium qualities for any given value of T and b. (However, the ratio of cost parameters a must be fixed.)

The resulting equilibrium qualities for identical firms (i.e. $b_h = b_0 \equiv b$) are then:[30]

$$s_h = 0.126655\, T^2 / b \text{ and } s_0 = 0.0241192\, T^2 / b$$

A.2. Quantity (Cournot) Competition

When firms use quantity as the strategic variable in the second stage of the industry game, the behavior of the model changes in some aspects. Most importantly, price competition will be reduced and the low-quality firm sets its quality as a strategic substitute to the high quality (rather than a complement).

Quantity Competition

To solve the game, consider first the inverse demand faced by the high-quality and low-quality firm, respectively. Let h and o stand for high and low quality, respectively. These demands are then given by:

$$p_h = T\, s_h - s_h\, q_h - s_o\, q_o, \quad p_o = (T - q_h - q_o)\, s_o \tag{3'}$$

Let i = h, o; let $j \neq i$. The profit function for firm i is given by $\Pi_i = p_i q_i(p_i, p_j, s_i, s_j) - c_i(s_i)$. Taken both qualities as given, the quantity reaction functions in each market are given as the solutions to the first order conditions. Solving the resulting equations for both quantities, equilibrium quantities are then given as:

$$q_h = T(2\, s_h - s_o)/(4\, s_h - s_o), \quad q_o = T\, s_h/(4\, s_h - s_o) \tag{4'}$$

---

[30] Note that T^2/b enters in a multiplicative way and therefore does not affect the calculations.

Given the quantity equilibrium depicted above, demands and thus profits can be expressed in terms of qualities. For positive qualities s_i (i = h, o), these profit functions are:

$$\Pi_h = \frac{T^2 s_h (2s_h - s_0)}{(4s_h - s_0)^2} - b_h s_h^2, \quad \Pi_o = \frac{T^2 s_h^2 s_o}{(4s_h - s_o)^2} - b_o s_o^2 \tag{5'}$$

Properties of the RevenueFunctions

Let R_i denote firm i's revenue function. Let h and o denote high and low quality, respectively.

$$\frac{\partial R_h}{\partial s_h} \geq 0; \quad \frac{\partial R_0}{\partial s_o} \geq 0 \text{ for } s_o \leq \frac{4s_h}{7}; \quad \frac{\partial R_h}{\partial s_o} < 0, \quad \frac{\partial R_o}{\partial s_h} < 0;$$

$$\frac{\partial^2 R_h}{\partial s_h^2} \leq 0; \quad \frac{\partial^2 R_o}{\partial s_o^2} \geq 0; \quad \frac{\partial^2 R_h}{\partial s_h \partial s_o} > 0; \quad \frac{\partial^2 R_o}{\partial s_o \partial s_h} < 0.$$

Quality Competition

The first order conditions for the high and low quality firm, respectively, are given as:

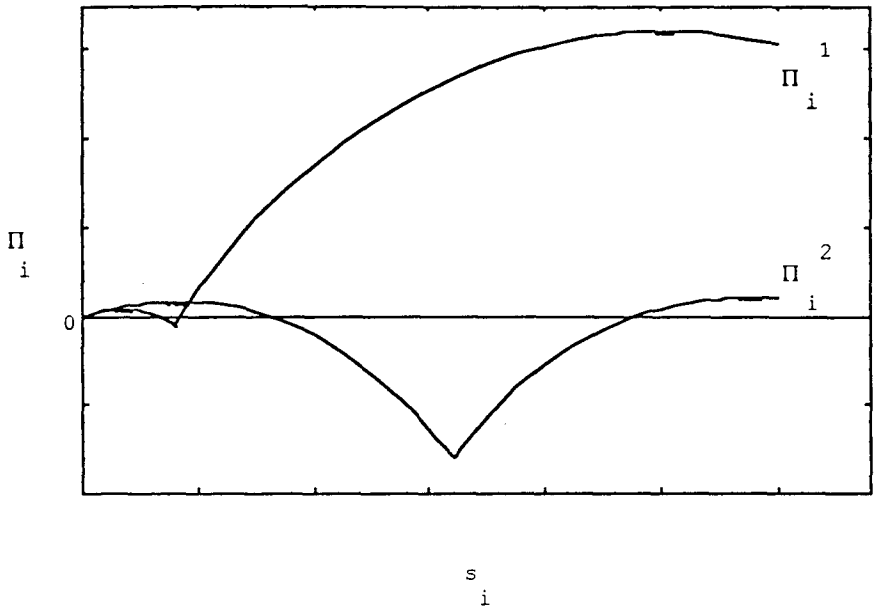
$$T^2(2s_h - s_o)(8s_h^2 - 2s_h s_o + s_o^2)/(4s_h - s_o)^3 = 2b_h s_h$$

$$T^2(4s_h + s_o)/(4s_h - s_o)^3 = 2b_o s_o \tag{7}$$

The slopes of the high and low quality firms' quality best responses can be calculated using the implicit function theorem. Both slopes are less than one in absolute value. The high- (low-) quality best response has a positive (negative) slope.

The resulting equilibrium qualities for identical firms (i.e. $b_h = b_o = b$) are then:

$$s_h = 0.125971\ T^2 / b \text{ and } s_o = 0.0451116\ T^2 / b$$



$s_j1 < s_j2$

Figure 1. Profit Functions

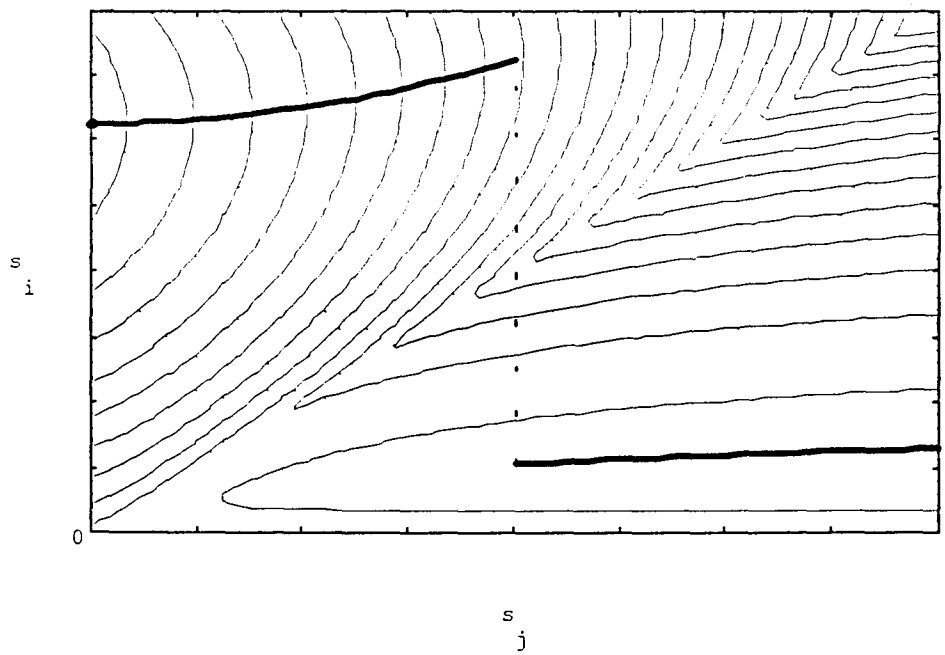
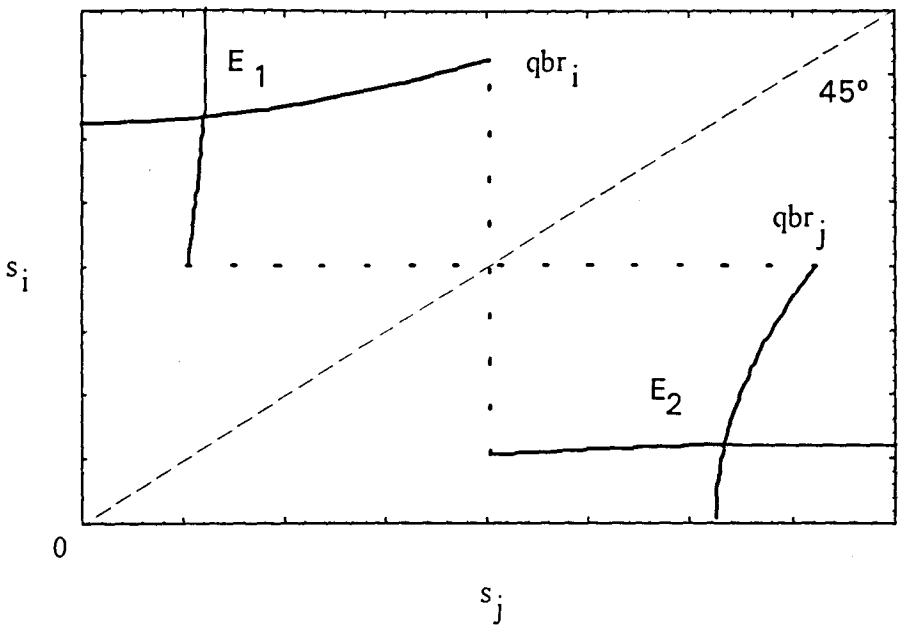
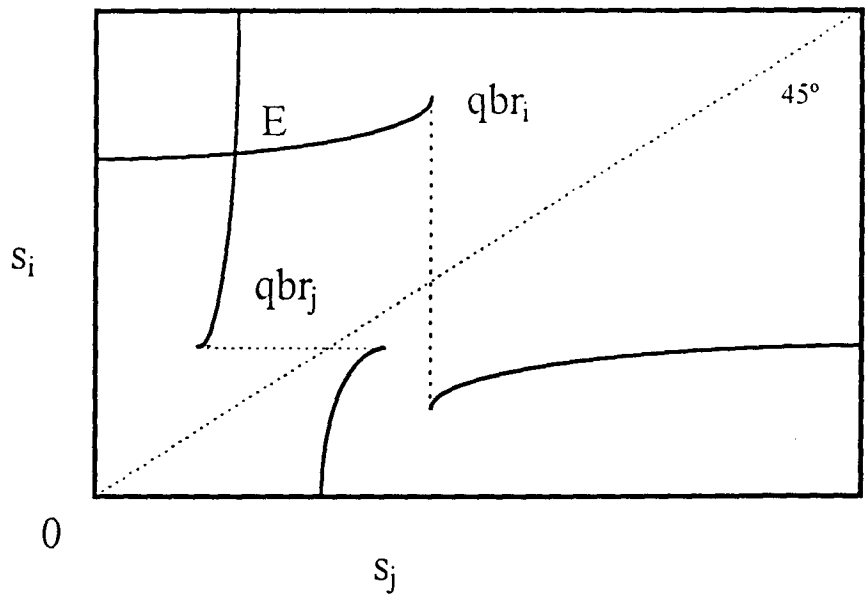


Figure 2. Isoprofit Curves and Quality Best Response



qbr = quality best response, $b_i = b_j$

Figure 3. Quality Equilibria - Identical Firms



qbr = quality best response, $b_i < b_j$

Figure 4. Quality Equilibria - Different Firms

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