

January 1995

ABSTRACT

On the Persistence of Leadership or Leapfrogging in International Trade*

When two countries, starting from different quality levels reflecting different conditions of domestic market demand, open to trade, two possible equilibria arise. In the first, the quality leader maintains its position. In the second, leapfrogging occurs. The latter is possible only if the initial quality gap is not too wide, however. Further, when the risk dominance criterion is used, only the former equilibrium is selected. This result holds for both segmented and integrated markets. Qualities, profits and world welfare are higher when firms can price discriminate (i.e. under segmented markets).

JEL Classification: F12, F15, L13

Keywords: international trade, product differentiation, country asymmetries, integrated markets, segmented markets, equilibrium selection

Massimo Motta
and Antonio Cabrales
Department of Economics
Universitat Pompeu Fabra
Balmes 132
E-08008 Barcelona
SPAIN
Tel: (34 3) 542 1669/2684

Jacques-François Thisse
CERAS
28 rue des Saints-Pères
F-75007 Paris
FRANCE
Tel: (33 1) 4260 3413

*This paper is produced as part of a CEPR research programme on *Market Integration, Regionalism, and the Global Economy*, supported by a grant from the Ford Foundation (no. 920-1265). The authors acknowledge partial financial support from the European Commission Human Capital and Mobility project (no. ERB4050PL930320) (Motta), CEPR's MIRAGE programme (Motta), and the Spanish Ministry of Education through DGICYT grant (no. PB93-0398) (Cabrales). They also received helpful comments from T Cordella, F Delbono, V Denicolò, D Harhoff, L Rivera-Bátiz, C Scarpa and K Stahl. The usual disclaimer applies.

Submitted 4 January 1995

NON-TECHNICAL SUMMARY

The study of imperfect competition models has allowed an impressive advance in the theory of international trade. The analysis of trade between countries showing asymmetric conditions has not caught the attention of economists to the same extent, however. This is surprising because trade liberalization between countries with very different characteristics is the rule rather than the exception. This raises new specific questions about the impact of trade on the countries involved. In particular, one may wonder whether trade integration will bring about more benefit to a country than to the other and to which extent historical advantages tend to persist after trade. Such questions have been at the heart of many of the debates on the North American Free Trade Agreement or the completion of the Single Market within the European Union.

In this paper we investigate whether a country supplying low quality products can catch up with a rival country supplying high quality products when both have access to the same technology. Specifically, our main concern is to understand the role of domestic conditions in determining the international success of a firm. When countries open to trade, firms start from an initial level of quality of their product which depends on local characteristics of demand. The larger and/or more sophisticated the home demand, the higher the quality supplied to the domestic customers. In other words, the autarky equilibrium (i.e. the quality supplied to the national market when the economy is closed) determines the initial conditions of the trade game. This is because we want to emphasize the role of historical factors in determining the competitive advantages of the firms in the international stage.

Since firms face a larger (international) market and more competition, the autarky choices of quality and price are generally not optimal under trade. Firms are then given the possibility to update their quality-price decisions by paying adjustment costs which increase with the difference between the new desired quality and the initial one. In general, firms would like to be the quality leader on the international market since this would yield higher profits.

There exist two possible equilibrium outcomes of the trade game we have just described. In the first, 'persistence of dominance', the quality leader in the trade situation is the firm which provided the higher quality at autarky. This is the firm established in the larger (or richer) country. In the other, 'leapfrogging' equilibrium, the new leader comes from the smaller (or poorer) country. It starts with a lower quality than its rival when trade opens, but it manages to catch up and get the lead through a larger investment in quality than its rival.

In other words, we identify the possibility that a firm can make up for its initial quality gap despite the fact that no exogenous change in the available technology occurs.

The existence of the latter equilibrium is subject to two main qualifications, however. First when the countries (and hence the initial qualities produced by the national firms) are very different the only possible equilibrium is where there is persistence of leadership. Intuitively, this is because the additional effort that the lagging country should make to take the lead is so large, given the initial disadvantage, that the quality it would select would be easily overtaken by the leader.

Second, risk can explain why the 'leapfrogging' equilibrium may not be attained. To catch up with the initial gap, a higher investment should be made by the laggard than by the current leader. The higher the investment required by such a 'leapfrogging' strategy by the former firm, the higher the risk it would involve and the more likely that the firm has to rely on outside funds to finance the operation, thus increasing its cost. (This is an informal explanation of the risk dominance criterion used to select between the two equilibria described above.)

Putting these two results together suggests that historical conditions matter a lot in the international marketplace. Firms from countries with a larger market, or where potential consumers are more eager to get better products tend to develop higher quality products which puts them at an advantage in international competition.

Our results seem to fit quite closely with the evidence reported in the business literature. For example, in his recent book *'The Competitive Advantages of Nations'*, Michael Porter underlines the importance of home demand conditions as a determinant of national competitive advantages. In particular, demand conditions matter not only in terms of quantity but also of quality. The presence of sophisticated consumers putting pressure on national firms to raise the quality of their products and services turns out to be a crucial element in the international success of a firm. This is an outcome that our paper fully captures.

1. Introduction

In recent years, the study of imperfect competition models has allowed an impressive advance in the theory of international trade. However, the analysis of trade between countries showing asymmetric conditions has not caught much of the attention in the profession. Few exceptions can be recalled. Krugman (1980) shows that, in his now standard monopolistic competition model of trade, a country with large domestic demand ends up with higher wages at the equilibrium because of scale economies. Devereux and Lapham (1994) and Rivera-Bátiz and Xie (1993) analyze models with different endowments of knowledge and different sizes and show that trade integration may have an adverse effect on specialization and growth of a country. Motta (1992) applies an oligopoly model of vertical differentiation to the analysis of trade between two countries which differ in sizes and finds conditions under which losses from trade may arise for a small country. Finally, Flam and Helpman (1987) consider a model with two countries endowed with an efficient and inefficient technology, respectively. They show that the advanced country supplies the top quality products while the backward country produces and exports the bottom quality ones. However, a switch in the pattern of production and trade may occur when technical progress is faster in the South than in the North.

Yet, such a small attention to trade between asymmetric countries is surprising. Trade liberalization processes between countries with very different characteristics are the rule rather than the exception and they raise questions about their effects. In particular, one may wonder whether trade integration will bring about more benefit to a country than to the other and to which extent historical advantages tend to persist after trade. A similar question has been recently addressed by Brezis, Krugman and Tsiddon (1993). These authors question the idea supported by endogenous growth models that if a country acquires an advantage in technologically progressive sectors then this advantage will tend to grow over time. They show that a lagging nation may be able to "leapfrog" a rival country as a reaction to a major *exogenous* change in technology. The intuition is that a country experienced with an old and successful technology will be less ready to adopt the new one than a backward country. A similar argument has been proposed in a different context by Nelson and Winter (1981) who

underline that successful firms may be less eager to change, facilitating the task of the followers in the presence of exogenous changes in the economic environment. The same type of issues, but in a different perspective, can be found in the industrial organization literature which aims at understanding whether the leadership of a firm in a given sector tend to persist or to shrink over time (see, e.g. Reinganum (1985), Dasgupta and Stiglitz (1988), Gruber (1992), Budd, Harris and Vickers (1994)).

In this paper, we want to investigate whether a country supplying low quality products can catch up with a rival country supplying high quality products when both have access to the same technology. To this end, we consider an oligopolistic model with vertical product differentiation in a two-country setting. Our main concern is to understand the role of domestic conditions in determining the international success of a firm. When countries open to trade, firms start from an initial level of quality of their product which depends on local characteristics of demand. The larger and/or more sophisticated the home demand, the higher the quality supplied to the domestic customers. In other words, the autarky equilibrium determines the initial conditions of the trade game. Since firms face a larger (international) market and more competition, the autarky choices of quality and price are generally not the optimal ones under trade. Firms are then given the possibility to update their quality-price decisions by paying adjustment costs which follow an increasing function of the difference between the desired quality and the initial one (prices can be adjusted costlessly). In general, firms would like to be the quality leader at the equilibrium since this would yield higher profits.

It turns out there exist multiple strict Nash equilibria. In the first Nash equilibrium, the leader of the industry in the trade situation is the firm which provided the higher quality at autarky:¹ it belongs to the larger (or richer) country. We call it "persistence of dominance" equilibrium. In the other Nash equilibrium (we call it "change of leadership" equilibrium or "leapfrogging" equilibrium), the new leader comes from the smaller (or poorer) country. It

¹ An alternative way to express this result is to say that the leader when firms update their qualities is the same as the leader at the short-run trade equilibrium. Indeed, if firms were allowed to change their prices but not their qualities at the very moment trade is allowed (or if adjustment costs of quality are prohibitive) then the leader in the international market is the firm which supplies the higher quality at autarky. See Shaked and Sutton (1984) and Motta (1992) for an analysis of short-run trade effects in vertical differentiation models.

starts with a lower quality than its rival when trade opens, but it manages to catch up and get the lead through an additional investment in quality than its rival. In other words, we identify the possibility that "*leapfrogging*" arises despite the fact that no exogenous change in the available technology occurs.

The existence of multiple equilibria is subject to two main qualifications, however. Firstly, when the countries are very different the only possible equilibrium arising is the one where there is persistence of leadership. Intuitively, the additional effort that the laggard should make to take the lead is so large, given the initial disadvantage, that the quality it would select would be easily overtaken by the leader.

Secondly, if the risk dominance criterium of equilibrium selection (Harsanyi and Selten (1988)) is used, the only remaining Nash equilibrium will be the persistence of dominance equilibrium. Very loosely speaking, risk can then explain why the "leapfrogging" equilibrium may not be actually selected. To catch up with the initial gap, a higher investment should be made by the laggard than by the current leader. The higher the investment required by such a "leapfrogging" strategy by the laggard, the higher the risk it would involve (and the more likely that the firm has to rely on outside funds to finance the operation, thus increasing its cost). This may give some intuition about the selection of the **persistence of leadership equilibrium**.

These two results put together suggest that historical conditions matter a lot on the international marketplace. Firms which come from countries with a larger market, or where potential consumers are more eager to get better products, tend to develop higher quality products and this would put them at an advantage in the international competition. Note that the role played by the national market to determine firms' success has been already suggested by Linder (1961) and formalized successively by Krugman (1980) and Dinopoulos (1988) in the context of monopolistic competition and (spatial) horizontal product differentiation, respectively. In these models, however, the issue of persistence or change of leadership has not been addressed.

Our results also seem to fit quite closely the evidence reported in the business literature. For example, Porter (1990) underlines the importance of home demand conditions as a determinant of a national competitive advantage in an industry. In particular, demand conditions

should be understood not only in terms of quantity but also of quality (Porter says the latter is even more important, p.86). The presence of sophisticated consumers putting pressure on national firms to raise the quality of their products and services turns out to be a crucial element in the international success of a firm. Unusually stringent local needs and demand sophistication explain many stories of competitive advantage:

"Scandinavian firms, for example, did well in paper plants, dams, bridges, ports, and hydroelectric power generation facilities. Italian firms did well in road and infrastructure projects, drawing on experience in coping with difficult and varied Italian terrain. German firms did well in constructing chemical and metallurgically based process plants. Japanese firms were successful in the construction of steel plants, shipyards, earthquake-proof buildings, railways, subways and other mass transit systems, dams (Japan generates a significant amount of electricity from hydropower), and aquaculture facilities." (Porter, 1990, p.269).

This is an outcome that our model fully captures.

The remainder of the paper is organized as follows. Section 2 introduces the model to the reader and finds the autarky equilibrium. Section 3 analyzes the impact of international trade under the assumption that firms perceive markets as segmented. In section 4, similar results are obtained when markets are integrated, i.e. when firms are not able to price discriminate across countries (market integration hypothesis). The comparison between these two cases has also some interest in its own. In particular, it is worth mentioning that it may not be profitable for a firm coming from a large country to export to the small country under the integrated market hypothesis. Since to sell to the smaller/poorer country implies a decrease in the price charged in both markets, as long as the small country is "much smaller", it is more profitable to charge a high price and sell in the home market only. Furthermore, price discrimination increases the profitability of each firm in a way that generates an incentive to increase quality. This explains why equilibrium qualities sold by the firms are higher when markets are segmented. The positive effect played by higher qualities and higher profitability implies that total welfare is higher when markets are segmented than when they are integrated. Section 5 concludes the paper.

2. The model and the autarky case²

Consider two countries A and B with a single firm each. There are two goods, a differentiated product whose characteristics are to be chosen by the firms, and a numéraire which can be consumed or used to carry out research and development activities which determine the quality of the differentiated product. Each country has an initial endowment of the numéraire. In country j ($j = A, B$), there is a population uniformly distributed over the interval $[0, \bar{\theta}^j]$ with density S^j . If a product of quality q is available in country j , the utility of a consumer of type $\theta = [0, \bar{\theta}^j]$ is given by

$$U_{\theta}(q, m) = \theta q + m \quad (1)$$

where m denotes the amount of the numéraire bought by this consumer, whose income is given and large enough for the consumer to be able to buy if she wants to. When the price of the differentiated product is p and its quality q , a consumer buys if and only if his net surplus

$$CS_{\theta} = \theta q - p \quad (2)$$

is positive, so that the marginal consumer is at

$$\hat{\theta}^j = p / q. \quad (3)$$

Producing a good of quality q involves constant marginal cost of producing the output (that we normalize to zero) and research and development expenditures given by $q^2 / 2$ units of the numéraire. Accordingly, the national surplus generated by a product of quality q in country j is given by

² For simplicity, we have chosen to develop our analysis in the context of a partial equilibrium model. However, it could be recast as a general equilibrium model.

$$W^j = \frac{S^j}{2} \left[(\bar{\theta}^j)^2 - (\hat{\theta}^j)^2 \right] q - \frac{q^2}{2}. \quad (4)$$

The firm located in country j chooses its quality and price in order to maximize its profit given by

$$\pi = S^j (\bar{\theta}^j - \hat{\theta}^j) p - \frac{q^2}{2}. \quad (5)$$

It is readily verified that the profit-maximizing choices in country j are such that

$$\bar{q}^j = \frac{S^j (\bar{\theta}^j)^2}{4} \quad (6)$$

$$\bar{p}^j = \frac{1}{8} S^j (\bar{\theta}^j)^3. \quad (7)$$

Introducing (6) and (7) into (3) shows that the firm always supplies half of the market. Since $\bar{\theta}^j / 2$ is also the mean of the distribution, we see that both quality and price increase with the mean when the mass of consumers is constant. Intuitively, when the marginal willingness-to-pay of the average consumer is larger, the firm finds it optimal to improve its quality and to charge a higher price. Similarly, *ceteris paribus* an increase in the consumer density leads the firm to raise both its quality and price because the burden of quality improvement falls on fixed costs. Evaluating the national surplus (4) at (6) and (7) yields

$$\bar{W}^j = \frac{1}{16} (S^j)^2 (\bar{\theta}^j)^4. \quad (8)$$

3. The impact of international trade: segmented markets

Assume now that the two countries have the same population ($S^A \bar{\theta}^A = S^B \bar{\theta}^B$). This assumption allows us to neutralize our analysis from market size effects. Without loss of generality, let $S^A = 1$ and $\bar{\theta}^A \geq \bar{\theta}^B$. Hence, it must be that $S^B = \bar{\theta}^A / \bar{\theta}^B$ and that $\bar{q}_A \geq \bar{q}_B$. Furthermore, we suppose that the two countries have access to the same technology in producing the differentiated product. In other words, countries are identical except for the average marginal willingness-to-pay (or, in more business-like terms, except for the sophistication of demand). Under these assumptions, it is readily verified that in autarky the quality produced by the firm located in country A is higher than the quality produced in country B. The former firm can then be seen as the "quality leader" when the economies are open to international trade.³

In this formalization, the only difference between the two countries is that the average propensity to pay for quality is higher in country A. However, interpreting country A as being the richer or the larger country is equally possible within this model. As for the interpretation in terms of citizens' wealth, we should: (i) notice that one would expect preference for quality - expressed here by the parameter θ - to be positively correlated with incomes; (ii) observe that in the type of models studied here higher taste for quality can be associated to lower marginal utility of income and therefore higher income [Tirole (1988), p.86]. As for the interpretation in terms of size differences, one can observe that if the density of consumers in country A were equal to the density of consumers in country B ($S^A = S^B$) then the market size of A would be bigger and in turn the quality advantage enjoyed by country A's firm over its rival would be even higher. Hence, all the results obtained below would be strengthened. The same is true for

³ We are fully aware that our formulation obviously implies lack of perfect foresight by the agents. When they decide on their autarky choice of quality, firms do not anticipate that trade will open at a later stage. In other words, firms attach a zero probability to the event that trade opens and when it does, they are taken completely by surprise. Although not always unrealistic (firms certainly did not expect that Germany would be reunified when the Berlin Wall fell) our assumption may be thought as not completely satisfactory. However, the reader should consider that our purpose is to analyze the role historical conditions play when trade liberalization occurs. Among the many possible assumptions that we may have used to describe the initial condition of the trade game, we think that the autarky equilibrium gives a reasonably acceptable one.

the case where $S^A > S^B$, with $\bar{\theta}^A$ equal or larger than $\bar{\theta}^B$. This means that we could interpret country A as being the "large" country and country B as being the "small" country.

We suppose that only one firm operates in each country. In Appendix 1 we show conditions under which a monopoly arises endogenously in each market at the autarky equilibrium. In particular, it is shown there that if $\bar{\theta}_B > .21926\bar{\theta}_A$ then the assumption on market demand in the two countries is compatible with the assumption of monopoly in each country under autarky.

We assume that the numéraire is the same for both countries and that the differentiated product can be shipped from one country to the other at no cost. When trade is open, we also assume that firms perceive the two markets are segmented (for instance, institutional constraints prevent arbitrage between different countries). We shall deal with the case of integrated markets in the next section. Because they now face an enlarged market, firms have an incentive to modify their quality choices before competing in prices. In so doing, firms incur adjustment costs that depend only upon the quality change and are given by $(q_i - \bar{q}_i)^2 / 2$. Consequently, the incremental cost increases with the quality change, but its variation is independent of the initial quality level. The latter assumption means that the technology involves no a priori bias in favor of the top or bottom quality firm.

Suppose without loss of generality that $q_1 > q_2$. The consumer in country j indifferent between buying from either firm is denoted $\hat{\theta}_{12}^j$ while the consumer indifferent between buying or not the differentiated product is $\hat{\theta}_2^j = p_2^j / q_2^j$. It is immediate that

$$\hat{\theta}_{12}^j = \frac{p_1^j - p_2^j}{q_1 - q_2}, \quad \text{for } j = A, B. \quad (9)$$

The national surplus of country $j = A, B$ after the opening to international trade is given by:

$$W^j = \frac{S^j}{2} \left[\left((\bar{\theta}^j)^2 - (\hat{\theta}_{12}^j)^2 \right) q_1 + \left((\hat{\theta}_{12}^j)^2 - (\hat{\theta}_2^j)^2 \right) q_2 \right] + p_i^k X_i^k - p_h^j X_h^j - \frac{(q_i - \bar{q}_j)^2}{2} \quad (10)$$

when firm $i = 1, 2$ is located in country j , and firm $h \neq i$ is located in country $k \neq j$. In this expression, X_i^k (X_h^j) denotes exports, i.e. the quantity sold by firm i (h) on the foreign market k (j).

The profits of a firm under international trade are defined as follows:

$$\pi_1 = (\bar{\theta}^A - \hat{\theta}_{12}^A) p_1^A + S^B (\bar{\theta}^B - \hat{\theta}_{12}^B) p_1^B - \frac{(q_1 - \bar{q})^2}{2} \quad (11)$$

$$\pi_2 = (\hat{\theta}_{12}^A - \hat{\theta}_2^A) p_2^A + S^B (\hat{\theta}_{12}^B - \hat{\theta}_2^B) p_2^B - \frac{(q_2 - \bar{q})^2}{2} \quad (11')$$

where \bar{q} is \bar{q}_A if the firm was the quality leader at autarky and \bar{q}_B otherwise. This corresponds to the two different scenarios discussed in the introduction, that is, the one of persistent leadership and the case of leapfrogging.

Consider a pair of given qualities. The equilibrium prices of the corresponding subgame are (note they do not depend on S^j):

$$p_1^{j*} = \frac{2\bar{\theta}^j q_1 (q_1 - q_2)}{4q_1 - q_2} \quad (12)$$

$$p_2^{j*} = \frac{\bar{\theta}^j q_2 (q_1 - q_2)}{4q_1 - q_2}, \quad j = A, B \quad (12')$$

Though the national markets are segmented in prices, they are integrated in terms of qualities since each firm offers the same quality on each market.⁴ Put in another way, each firm chooses its quality in order to maximize the sum of its profits on each market net of the adjustment costs, given the prices (12) and (12'):

$$\pi_i(q_1, q_2) = \frac{4\bar{\theta}_A q_1^2 (q_1 - q_2) (\bar{\theta}_A + \bar{\theta}_B)}{(4q_1 - q_2)^2} - \frac{(q_1 - \bar{q}_i)^2}{2} \quad (13)$$

⁴ A similar approach is adopted by Venables (1990) where firms choose a single capacity for the whole production but choose different prices in each market.

$$\pi_2(q_1, q_2) = \frac{\bar{\theta}_A q_1 q_2 (q_1 - q_2) (\bar{\theta}_A + \bar{\theta}_B)}{(4q_1 - q_2)^2} - \frac{(q_2 - \bar{q}_k)^2}{2}. \quad (13')$$

j,k=A,B and j≠k.

Since the equilibrium qualities depend on the qualities produced under autarky as well as on the taste preferences of consumers in the two countries, the determination of the equilibrium is especially complex, though we use a simple model.

Because no analytical expression can be found for the equilibrium of the quality game, we have solved it for different values of $\bar{\theta}^A$, using the computer program Mathematica. All the results are qualitatively the same for different values of this parameter. Hence, we characterize here the equilibrium for $\bar{\theta}^A = 10$, for the sake of simplicity. Thus $\bar{\theta}^B$ may vary between 0 and 10. There are two candidate equilibria, which are given by the two quality pairs which satisfy the first order conditions corresponding to the system of the derivatives of (14) and (15) (see Appendix 2).

In one candidate equilibrium, the leader is the firm from country A, which had the higher quality under autarky: $q_1 = q_A$ and $q_2 = q_B$. In the other, the leader is the firm from country B: $q_1 = q_B'$ and $q_2 = q_A'$. These candidate equilibria are obtained subject to the condition that firm i provides the higher quality and firm j the lower quality. However, for the candidate equilibria to be equilibria we must check that firm i (resp. firm j) does not find it profitable to deviate and produce a lower (resp. higher) quality than its rival. In other words, the firm supposed to be the quality leader should not have an incentive to provide a quality lower than its competitor; and vice versa. We now show under which conditions these candidate equilibria are the Nash equilibria of the quality game as depicted in Figure 1.

Figure 2 shows that *the persistence of leadership* ($q_1 = q_A, q_2 = q_B$) *is always an equilibrium*. Indeed, at this quality pair, the firms earn profits π_A and π_B . If the firm from country A decided to deviate and to produce the best possible quality subject to this quality being lower than q_B , it would obtain lower profits $\pi_A(l)$. Likewise, the firm from country B does not find it profitable to deviate and to produce the higher quality. The leader produces a quality q_A which is much higher than the quality produced in autarky by the firm from country

B. If the latter tried to catch up with the rival firm's quality, it would have to incur a big adjustment cost. But to catch up would not be enough, since price competition would reduce to zero gross profits despite the major investment in quality. The firm from country B should then significantly increase its quality beyond the candidate equilibrium quality q_A . However, this would increase so much its adjustment costs that the highest profits $\pi_B(l)$ it can obtain by deviating would be negative.

Figure 3 analyzes the case of "change of leadership" along the same lines. In this case, though, the firm from country A may have an incentive to deviate from the candidate equilibrium quality. Indeed, when country B's demand shows much less preference for quality than country A's, the firm located in country B starts the international trade game with a quality disadvantage. Given the adjustment costs it has to incur to reach the desired quality level, the latter cannot be very large (notice from Figure 1 that the lower $\bar{\theta}_B$ the lower q_B'). Therefore, the additional investment cost made by the firm from country A to select a quality sufficiently higher than q_B' is the more affordable the lower $\bar{\theta}_B$. Figure 1 also shows that the best quality choice that the firm from country A can do conditional on its rival choosing the candidate equilibrium quality gives it a profit $\pi_A'(l) > \pi_A'$ for $\bar{\theta}_B < 3.2$. The former has then an incentive to deviate by providing the higher quality. In other words, whereas the persistent leader equilibrium exists for the whole set of parameter values, *the "change of leadership" equilibrium exists only when $\bar{\theta}_B$ exceeds some critical value*, i.e. $\bar{\theta}_B \geq 3.2$. This explains why in Figure 1 the equilibrium qualities corresponding to the "leapfrogging" equilibrium are drawn only for these values of the parameter.

Figure 4 shows welfare in each country under the two types of equilibria, where they exist. First of all, one notices that *the welfare of a country is always higher when the domestic firm is the quality leader at the trade equilibrium*: $W_A > W_A'$ and $W_B' > W_B$. This is mainly because the equilibrium profit earned by the top quality firm is always higher than the profit earned if it were the bottom quality firm. Secondly, welfare levels are increasing with $\bar{\theta}_B$. This is because the qualities also increase with $\bar{\theta}_B$, which has a positive effect on consumer surplus. The closer the market demands of the two countries are, the higher the quality of country B's firm at autarky. In turn, this means that this firm can afford a higher level of quality (it has to

pay lower adjustment costs for any given level of desired quality) and that the rival firm has to push upward its desired quality level. Thirdly, the comparison of world welfare levels shows that the more efficient equilibrium is the one where there is persistence of leadership. This market configuration allows to save on adjustment costs and to reach higher levels of quality than in the case of change of leadership.

4. The impact of international trade: integrated markets

In the previous section, we have analyzed international trade under the assumption that firms can charge different prices in the two markets they face. In some cases, firms cannot price discriminate because of legal constraints or because of arbitrage by consumers. This is the case dealt with in the present section.

Before starting the computations of the equilibria, we should notice that the constraint of charging the same price in both countries might not render profitable the exports in some cases. Suppose that the consumers located in country B have a very low average taste for quality $\bar{\theta}_B$. These consumers have a low willingness to pay and to capture them a low price should be set. However, this implies reducing the price in the more profitable market A, where consumers have a high willingness to pay for the good. The reduction in profit in the more sophisticated market A may therefore outweigh the additional profit brought by sales in country B.

There are two possible sub-cases which should be studied: (i) both firms sell in both countries; (ii) firm A sells only in its own market (it turns out that it is never profitable for the firm from country B not to serve its local market).

When demand in both markets is supplied, we have:

$$\pi_1 = p_1(\bar{\theta}^B - \hat{\theta}_{12})(1 + S_B) + p_1(\bar{\theta}^A - \bar{\theta}^B) - \frac{(q_1 - \bar{q})^2}{2} \quad (14)$$

$$\pi_2 = p_2(\hat{\theta}_{12} - \hat{\theta}_2)(1 + S_B) - \frac{(q_2 - \bar{q})^2}{2} \quad (14')$$

where \bar{q} is \bar{q}_A if the firm was the quality leader at autarky and \bar{q}_B otherwise. Indeed, like in the case of segmented markets, the two cases of persistence and change of leadership may arise. Equilibrium prices at the price subgame are:

$$p_1 = \frac{4q_1(q_1 - q_2)\bar{\theta}^A\bar{\theta}^B}{(4q_1 - q_2)(\bar{\theta}^A + \bar{\theta}^B)} \quad (15)$$

$$p_2 = \frac{2q_2(q_1 - q_2)\bar{\theta}^A\bar{\theta}^B}{(4q_1 - q_2)(\bar{\theta}^A + \bar{\theta}^B)}. \quad (15')$$

After substitution we find the expression of profits as a function of qualities:

$$\pi_1(q_1, q_2) = \frac{16q_1^2(q_1 - q_2)(\bar{\theta}^A)^2\bar{\theta}^B}{(4q_1 - q_2)^2(\bar{\theta}^A + \bar{\theta}^B)} - \frac{(q_1 - \bar{q})^2}{2} \quad (16)$$

$$\pi_2(q_1, q_2) = \frac{4q_1q_2(q_1 - q_2)(\bar{\theta}^A)^2\bar{\theta}^B}{(4q_1 - q_2)^2(\bar{\theta}^A + \bar{\theta}^B)} - \frac{(q_2 - \bar{q})^2}{2}. \quad (16')$$

Like in section 3, we take $\bar{\theta}^A = 10$ and we are able to find an analytical solution to the first order conditions of the system above with the help of a computer programme (see Appendix 3). In the first pair of solutions the leader is the firm from country A: $q_1 = q_A$ and $q_2 = q_B$. In the second, the leader is the firm from country B: $q_1 = q_B'$ and $q_2 = q_A'$. Before concluding that these two pairs represent the equilibria, though, we have to check two points.

Firstly, as done in the case of segmented markets, we have to see whether at the candidate equilibrium the firm providing the low (high) quality does not have any incentive to switch to the high (low) quality given the quality chosen by the rival firm at the candidate equilibrium. It turns out that, like for the case of segmented markets, *the persistent leader*

equilibrium always exists, whereas the leapfrogging equilibrium exists only when $\bar{\theta}^B$ is large enough, i.e. $\bar{\theta}^B \geq 3.95$. This is done as in section 3.

More interesting is the new situation arising because of the constraint that the firms set the same price in the two different markets. As said above, we must check that the high quality firm finds it more profitable to sell in both countries.⁵ In fact, this is not always the case.

When the high quality is sold in country A only,⁶ profit earned by the high and the low quality firm are respectively:

$$\pi_1 = p_1(\bar{\theta}^A - \hat{\theta}_{12}) - \frac{(q_1 - \bar{q})^2}{2} \quad (17)$$

$$\pi_2 = p_2(\hat{\theta}_{12} - \hat{\theta}_2) + p_2 S^B(\bar{\theta}^B - \hat{\theta}_2) - \frac{(q_2 - \bar{q})^2}{2}. \quad (17')$$

It is standard to find the equilibrium prices for any subgame and, then, to use them so as to obtain the profit as a function of qualities:

$$\pi_1(q_1, q_2) = \frac{10\bar{\theta}^A(q_1 - q_2)(20q_1 - 20q_2 + 2q_1\bar{\theta}^B + q_2\bar{\theta}^B)^2 - (q_1 - \bar{q})^2}{(40q_1 + 40q_2 - 4q_1\bar{\theta}^B + q_2\bar{\theta}^B)^2} \quad (18)$$

$$\pi_2(q_1, q_2) = \frac{9\bar{\theta}^A\bar{\theta}^B(q_1 - q_2)q_2(10q_1 - 10q_2 + q_1\bar{\theta}^B) - (q_2 - \bar{q})^2}{(40q_1 + 40q_2 - 4q_1\bar{\theta}^B + q_2\bar{\theta}^B)^2} \quad (18')$$

As above, we set $\bar{\theta}^A = 10$ and find an analytical solution to the first order conditions corresponding to this system by making use of a computer program. We have then proceeded to compare the profits associated to the strategy of selling in country A only with the profits corresponding to sales in both markets. It turns out that when the leader is the firm which

started with the high quality at autarky, then this firm prefers to sell in the local market A only rather than selling in both markets as long as $\bar{\theta}^B < 2.75$.⁷ For higher values of the willingness to pay of the residents of country B, the firm prefers to serve both countries. As for the change of leadership equilibrium, we know that this exists only where $\bar{\theta}^B \geq 3.95$. In this interval the average willingness to pay of the consumers in country B is high enough for the firm to find it more profitable to supply both markets.

Figure 5 and 6 illustrate qualities and profits at the two equilibria. Note that at the persistence of leadership equilibrium, qualities exhibit a discontinuity when $\bar{\theta}^B \equiv 2.75$. Indeed, this is the point where the firm from country A switches from serving only the domestic market to serving both markets. As the monopoly in the local market vanishes, this creates a discontinuity in both the low quality firm's profit, which shift downward, and in the welfare functions, which shift upward (see Figure 7). The latter is due to the increase in consumer surplus in both countries when the leader supplies both markets. The consumers located in country B gain because, with the flow of exports from country A, they have access to higher quality. Those located in country A gain because of a decrease in prices. Indeed, in order to supply the foreign market, the price set internationally by the leader decreases to the benefit of the consumers in country A who would have consumed the good at a higher price otherwise.

On the whole, therefore, *the results obtained under segmented and integrated markets are very similar*. The two equilibria which arise share similar features and the leapfrogging equilibrium exists only when the two markets are not too different, in the sense that $\bar{\theta}^B$ must be higher than a certain threshold. It is also worth comparing the equilibrium values under the two alternative market pricing systems. *Qualities and profits are lower under integrated markets than under segmented markets* for either equilibrium and each firm, provided that the quality leader supplies both markets, as shown in Figures 8 and 9 in the case of persistence of leadership. When firms cannot discriminate with respect to the price they can charge in the different markets, their profitability decreases. In turn, this reduces the incentive to invest to enhance the quality offered. This gives also an intuition as to why the threshold level of $\bar{\theta}^B$ above which

⁵ Since the low quality product is mainly addressed to consumers having a lower willingness to pay, the firm producing the low quality always finds it more profitable to sell in both markets.

⁶ For simplicity, we assume that country B's consumers cannot buy the high quality products from country A directly.

⁷ Barros and Martinez-Giralt (1994) analyze a horizontal product differentiation model with asymmetric countries and also find conditions under which a firm prefers not to export when markets are integrated.

the change of leadership equilibrium exists is higher in the case of integrated markets than under segmented markets. Since qualities tend to be lower when firms cannot price discriminate, firm A needs a lower investment to deviate from the candidate equilibrium and select a quality higher than the quality that the leader from country B would offer. This calls for a stronger condition for the leapfrogging equilibrium to exist.

As for the welfare comparison, the results are clearcut but less straightforward. In particular, it can be seen from Figures 10 and 11 that both in the persistence of leadership and in the change of leadership equilibria, the following rankings hold under the proviso that both markets are served by the top quality firm:

$$W_A^S \leq W_A^I; \quad W_B^S \geq W_B^I; \quad W_{TOT}^S \geq W_{TOT}^I; \quad (19)$$

where the indices S and I refer to segmented and integrated markets respectively, while the index TOT refers to world welfare. The intuition for the above inequalities is as follows. When markets are integrated, the prices of each product can be seen as some kind of weighted average between the prices that each firm would charge in each single market if it were allowed to do it. Given that market A's consumers have a higher willingness to pay than those in country B, it can be shown that:

$$p_{i,A}^S \geq p_{i,A}^I = p_{i,B}^I \geq p_{i,B}^S \quad (i=1,2). \quad (20)$$

Therefore, for any given pair of qualities on offer, the consumers in country B tend to be better off under segmented markets than under integrated markets,⁸ while the opposite is true for the consumers located in country A. This should help explain the ranking of welfare indicators given above. Of course, this reasoning holds for identical qualities in segmented and integrated markets, which is not what happens in equilibrium. Under segmented markets, qualities are higher than when firms cannot price discriminate. However, this effect tends to increase

⁸ This conclusion is strengthened by the fact that when firms cannot price discriminate the high quality firm may wish not to serve country B's market.

consumers' welfare (and firms' profits) in the same direction in both countries. Put together, these two effects explain why *world welfare is higher under segmented markets whereas country A (resp. B) is better off under integrated markets (resp. segmented markets)*. This result invites us to reconsider the claim made in the international trade literature that market integration is socially better than market segmentation (see, e.g. Smith and Venables (1988) and more recently, Anderson, Schmitt and Thisse (1994) and Barros and Martinez-Giralt (1994)). This is because our model can account for endogenous product choice, whereas the aforementioned papers deal with products whose specification is exogenously given.

5. Equilibrium selection

The game we have described has two strict Nash equilibria for a whole range of values of $\bar{\theta}^B$. Standard refinements such as perfectness, properness, or strategic stability do not select among strict Nash equilibria. There is a notable exception, though, which is the concept of risk-dominance introduced by Harsanyi and Selten (1988). Let a 2x2 game with the following payoff matrix:

| | | |
|----------------|----------------------------------|----------------------------------|
| | B ₁ | B ₂ |
| A ₁ | a ₁₁ ,b ₁₁ | a ₁₂ ,b ₁₂ |
| A ₂ | a ₂₁ ,b ₂₁ | a ₂₂ ,b ₂₂ |

where the payoffs are such that E₁=(A₁,B₁) and E₂=(A₂,B₂) are strict Nash equilibria. Let LA₁=a₁₁-a₂₁, that is LA₁ is the gain made by player A by predicting rightly that the other player will play E₁ (and best responding to the prediction) instead of predicting wrongly that the other player will play E₂ (and best responding to the prediction). Similarly, let LB₁=b₁₁-b₁₂, LA₂=a₂₂-a₁₂, LB₂=b₂₂-b₂₁. We say that equilibrium E₁ risk dominates equilibrium E₂ when LA₁LB₁ > LA₂LB₂. Therefore, the risk dominance concept selects the equilibrium to which corresponds the highest gains to the players for a correct forecast of the equilibrium.

Besides the intuition and the axiomatization provided by Harsanyi and Selten, there are more reasons why risk dominance could be considered a good equilibrium selection criterion (see Kandori, Mailath and Rob (1993) and Carlsson and van Damme (1993)). Perhaps the most appealing argument for risk dominance is that in experiments performed by Van Huyck, Battalio and Beil (1990) for a pure coordination game, the risk dominant equilibrium is the one selected by actual players.

For the game under consideration, the risk dominance criterion selects the equilibrium with persistence of leadership.⁹ Let E_1 be the persistence of leadership equilibrium and E_2 the leapfrogging equilibrium. Recall that A is the country with higher preference for quality and B the country with lower preference for quality.

In our case $a_{11}=\pi_1(q_A, q_B)$, $a_{21}=\pi_1(q_A', q_B)$, $a_{12}=\pi_1(q_A, q_B')$ and $a_{22}=\pi_2(q_B', q_A')$. Also $b_{11}=\pi_2(q_A, q_B)$, $b_{21}=\pi_2(q_A', q_B)$, $b_{12}=\pi_2(q_A, q_B')$ and $b_{22}=\pi_1(q_B', q_A')$. With segmented markets π_1 , π_2 are given by equations (13), (13'), while they are given by equations (16), (16') with integrated markets.

In our case, LA_1 is what player A gains by forecasting rightly that the other player will play the persistence of leadership equilibrium, instead of forecasting wrongly that the other equilibrium arises. The interpretation of LB_1 , LA_2 and LB_2 is analogous. Figures 12 and 13 show that $LA_1 > LB_2$ and $LB_1 > LA_2$ (except when $\bar{\theta}_a=10$, the symmetric case).¹⁰

Equilibrium selection can be interpreted in a strong way or in a weak way. The strong interpretation is that we will never (or rarely) observe players choosing the strategies that lead to an equilibrium that is not selected. The weak interpretation is that the likelihood of observing players using the strategies that lead to each equilibrium is related to the difference $LA_1LB_1 - LA_2LB_2$. The larger this difference, the more likely it is that we will observe players using the E_1 strategies. We feel that the weak interpretation is more reasonable, not only because it is more difficult to reject, but also because most of the reasons in favor of risk dominance involve

uncertainty or a certain lack of rationality (Harsanyi and Selten (1988, p.89)). In such circumstances it would be hard to expect the strong interpretation to be satisfied.

6. Conclusions

The impact of international trade on asymmetric economies is an important issue as shown, for instance, by the debates which take place in North America (NAFTA) and the European Union. Similarly, it is still an open question whether less advanced countries can make up for their disadvantages in international competition. Our analysis reveals that lagging countries may be able to catch up with the more advanced countries if they are willing to make sufficiently large investments in R&D, at least when they have access to the same technology. However, this does not occur when the initial quality gap is too large.¹¹ Furthermore, our discussion of the equilibrium selection suggests that the leading countries are likely to keep their leadership, even when leapfrogging is also an equilibrium.

Since products are selected endogenously by the firms, total welfare is higher when markets are segmented. This is due to the fact that firms earn higher profits, other things being equal, when they can price discriminate, thus leading firms to choose higher quality products. This contrasts with conventional wisdom, in which product differentiation is exogenous, where integrated markets are considered as being preferable.

Our analysis is incomplete in several respects. First, it would be interesting to extend the analysis to the case of several firms in each country. Second, we do not deal with the impact of trade on the labor market. One may expect workers of the poorer country to be less productive, thus making our assumption that firms have access to the same technology somewhat problematic. The key question is then to determine where the technological innovations take place and where plants are located.

¹¹ In a completely different setting, Rodrik (1994) finds results which are reminiscent of ours. If an economy has sufficiently low (high) skill level of its workforce, it will specialize only in the low-technology (resp. high-tech) goods. However, for intermediate levels of the skill level, multiple equilibria are possible, and an economy may specialize in either low- or high-tech goods.

⁹ In the limiting case where the two countries have equal populations, risk dominance predicts that the mixed strategy equilibrium will be the one played.

¹⁰ Note that the Figures are drawn only for those parameter values where both equilibria exist.

References

- Anderson, S.P, Schmitt, N. and Thisse, J.-F. (1994) "Who Benefits from Antidumping Legislation ?", *Journal of International Economics*, forthcoming.
- Barros, P.P. and Martinez-Giralt, X. (1994) "Taste for Imports and Market Integration", Mimeo, Universitat Autònoma de Barcelona.
- Brezis, E.S., Krugman, P.R. and Tsiddon, D. (1993) "Leapfrogging in International Competition: A Theory of Cycles in National Technological Leadership", *American Economic Review*, 83, 1211-19.
- Budd, C., Harris, C. and Vickers J. (1993) "A Model of the Evolution of Duopoly: Does the Asymmetry between Firms Tend to Increase or Decrease ?" *Review of Economic Studies*, 60, 543-73.
- Carlsson, H. and van Damme, E. (1993) "Global Games and Equilibrium Selection", *Econometrica*, 61, 989-1018.
- Dasgupta, P. and Stiglitz, J. (1988) "Learning-by-Doing, Market Structure and Industrial and Trade Policy", *Oxford Economic Papers*, 40, 246-268.
- Devereux, M.B. and Lapham, B.J. (1994) "The Stability of Economic Integration and Endogenous Growth", *Quarterly Journal of Economics*, 109, 299-305.
- Dinopoulos, E. (1988) "A Formalization of the "Biological" Model of Trade in Similar Products", *Journal of International Economics*, 25, 95-110.
- Flam, H. and Helpman, E. (1987) "Vertical Product Differentiation and North - South Trade", *American Economic Review*, 77, 810-822.
- Gruber, H. (1992), "Persistence of Leadership in Product Innovation", *Journal of Industrial Economics*, 40, 359-375.
- Harsanyi, J.C. and Selten, R. (1988) *A General Theory of Equilibrium in Games*, Cambridge, MA: The MIT Press.
- Kandori, M. Mailath, G.J. and Rob, R. (1993) "Learning, Mutation and Long-Run Equilibria in Games", *Econometrica*, 61, 29-56.
- Krugman, P.R. (1980) "Scale Economies, Product Differentiation and the Pattern of Trade", *American Economic Review*, 70, 950-959.
- Linder, S. (1961) *An Essay on Trade and Transformation*, New York: John Wiley.
- Motta, M. (1992) "Sunk Costs and Trade Liberalisation", *Economic Journal*, 102, 578-587.
- Motta, M. (1993) "Endogenous Quality Choice: Price vs. Quantity Competition", *Journal of Industrial Economics*, 41, 113-131.
- Nelson, R. E. and Winter, S. G. (1982) *An Evolutionary Theory of Economic Change*, Cambridge, MA: Harvard University Press.
- Porter, M. E. (1990) *The Competitive Advantage of Nations*, London: Mac Millan.
- Reinganum, J. (1985) "Innovation and Industry Evolution", *Quarterly Journal of Economics*, 100, 81-99.
- Rivera-Bátiz, L. and Xie, D. (1993) "Integration among Inequals", *Regional Science and Urban Economics*, 23, 337-354.
- Rodrik, D. (1994) "Do Low-Income Countries Have a High-Wage Option?", CEPR D.P. No. 862.
- Shaked, A. and Sutton, J. (1984), "Natural Oligopolies and International Trade", in Kierzkowski, H. (ed.), *Monopolistic Competition and International Trade*, Oxford: Oxford University Press.
- Smith, A. and Venables, A. (1988) "Completing the Internal Market in the European Community: Some Industry Simulations", *European Economic Review*, 32, 1501-1525.
- Tirole, J. (1988) *The Theory of Industrial Organization*, Cambridge, MA: The MIT Press.
- Van Huyck, J. Battalio, R. and Beil, R. (1990) "Tacit Coordination Games, Strategic Uncertainty, and Coordination Failure", *American Economic Review*, 80, 234-249.
- Venables, A. (1990) "International Capacity Choice and National Market Games", *Journal of International Economics*, 29, 23-42.

Appendix 1. Monopoly in autarky as an endogenous market structure

In this appendix we determine the values of the parameters for which a natural monopoly would arise in each country when economies are closed. In other words, we show that a monopoly is the endogenous market structure in both countries under some assumptions on fixed costs and taste parameters.

A monopolist in country j ($j=A,B$) would choose the price and quality given by (6) and (7). It then earns a profit $\pi_j = .0312S_j^2\bar{\theta}_j^4 - F$, where F is a fixed cost that must be incurred to begin production (but that the firms do not have to pay when the trade game starts), regardless of the quality chosen.

If two firms were to enter the market under autarky, the equilibrium firms' profits would be given by $\pi_{1j} = .0244S_j^2\bar{\theta}_j^4 - F$ and $\pi_{2j} = .0015S_j^2\bar{\theta}_j^4 - F$ (see Motta (1993)). Hence, for only one firm to be in each market, we must have $.0015S_j^2\bar{\theta}_j^4 < F < .0312S_j^2\bar{\theta}_j^4$. Since this condition must hold for both countries, and given the assumption that $S_B = \frac{\bar{\theta}_A S_A}{\bar{\theta}_B}$ and $S_A = 1$, it must be that $.0015\theta_A^4 < .0312\bar{\theta}_B^2\bar{\theta}_A^2$, which amounts to $\bar{\theta}_B > .21926\bar{\theta}_A$.

Appendix 2. Determination of the equilibria of the international trade game: segmented markets

Equations (13) and (13') give the expression of profits in the quality stage of the game.

The first derivatives can be computed as:

$$\frac{\partial \pi_1}{\partial q_1} = \frac{4\bar{\theta}_A q_1 (4q_1^2 - 3q_1 q_2 + 2q_2^2) (\bar{\theta}_A + \bar{\theta}_B)}{(4q_1 - q_2)^3} - (q_1 - \bar{q}_j) \quad (\text{A2.1})$$

$j,k=A,B$ and $j \neq k$.

$$\frac{\partial \pi_2}{\partial q_2} = \frac{\bar{\theta}_A q_1^2 (4q_1 - 7q_2) (\bar{\theta}_A + \bar{\theta}_B)}{(4q_1 - q_2)^3} - (q_2 - \bar{q}_k). \quad (\text{A2.1}')$$

By equating (A2.1) and (A2.1') to zero, we then have two different systems of first order conditions: one for the case where the leader at the trade equilibrium is from country A and the other when the leader is from country B. Unfortunately, these systems cannot be solved such as they stand by Mathematica. Some additional work is needed to obtain the solutions.

Let us start with the case of persistence of leadership. Writing $q_1 = r q_2$ (with $r \geq 1$), replacing \bar{q}_A and \bar{q}_B with the values in expression (6), taking $\bar{\theta}^A = 10$ and dividing the first order conditions between them yields:

$$\frac{4r q_2 - 100}{4q_2 - 10\bar{\theta}^B} = \frac{4(4r^2 - 3r + 2)}{r(4r - 7)} \quad (\text{A2.2})$$

from which we can write:

$$q_2 = \frac{5(35r - 20r^2 + 4\bar{\theta}^B - 6r\bar{\theta}^B + 8r^2\bar{\theta}^B)}{8 - 12r + 23r^2 - 4r^3} \quad (\text{A2.3})$$

Substituting (A2.3) in either of the two first order conditions, we obtain an equation in r and $\bar{\theta}^B$ which is very cumbersome. Since we are interested in finding a solution for $r \geq 1$, the only root to consider is as follows:

$$r = a + \frac{\sqrt{e + b + 4a^2 - c}}{2} + \frac{\sqrt{-e + 2b + 8a^2 + c + \frac{d}{1280(2 + \bar{\theta}^B)^3} \sqrt{b + 4a^2 - c + e}}}{2} \quad (\text{A2.4})$$

where a, b, c, d, e are :

$$a = \frac{78 + 7\bar{\theta}^B}{16(2 + \bar{\theta}^B)}; \quad b = \frac{-(16 + \bar{\theta}^B)}{2(2 + \bar{\theta}^B)}; \quad c = \frac{18640 + 3574 + 171(\bar{\theta}^B)^2}{8(2 + \bar{\theta}^B)^3 \sqrt{15y}};$$

$$d = 1830040 + 308644\bar{\theta}^B + 26674(\bar{\theta}^B)^2 + 1091(\bar{\theta}^B)^3; \quad e = \frac{y}{8(2 + \bar{\theta}^B)^3 \sqrt{15^2}};$$

and where:

$$y = [-11575800 - 1735560\bar{\theta}^B - 45738\bar{\theta}^B + 1206(\bar{\theta}^B)^3 + \sqrt{3} \sqrt{(10 + \bar{\theta}^B)^2 770486846000 + 166106997680\bar{\theta}^B + 17270707788(\bar{\theta}^B)^2 + 1021119318(\bar{\theta}^B)^3 + 25485867(\bar{\theta}^B)^4}]^{1/3}$$

Once r is obtained (which turns out to be a decreasing and convex function of $\bar{\theta}^B$), substituting allows us to find out all the equilibrium values of the other variables in the case of persistence of leadership.

The same procedure can be followed to find the analytical solution for the case of change of leadership. In this case, the expression (A2.2) and (A2.3) become:

$$\frac{4rq_2 - 10\bar{\theta}^B}{4q_2 - 100} = \frac{4(4r^2 - 3r + 2)}{r(4r - 7)} \quad (\text{A2.5})$$

$$q_2 = \frac{5(80 - 120r + 160r^2 + 7r\bar{\theta}^B - 4r^2\bar{\theta}^B)}{2(8 - 12r + 23r^2 - 4r^3)}. \quad (\text{A2.6})$$

By replacing (A2.6) in one of the first order conditions we then obtain an equation in r and $\bar{\theta}^B$ which can be solved as in the case of persistence of leadership. It turns out that the r which solves our problem is an increasing and concave function of $\bar{\theta}^B$. It also has the same structure as in expression (A2.4), but that a,b,c,d,e are different functions of $\bar{\theta}^B$. We omit the expression of r in this case since we believe that very little can be gained by inspection of such a long and messy expression. In fact, the reader may wonder why we decided to put the exact expressions of the solution (at least for one case) in the first place. The main reason for that is that we wanted to illustrate the method we have used and to stress that the problem had an analytical solution, albeit one which can be obtained only by means of a specialized computer program. This means that everybody who has a program like Maple, Mathematica will be able to compute the equilibrium qualities of the game. This can be done with very few instructions and by making use of expressions (A2.1)-(A2.3). To check that qualities and other equilibrium values take the form given in the figures presented in the text is then just a matter of substitution.

To check that the solutions thus obtained represent an equilibrium is then straightforward. Suppose we consider the candidate equilibrium (q_A, q_B) as found above. First, we should see whether firm A does not have an incentive to produce a quality lower than $q_2 < q_B$. If it produced such a quality, its profit would be given by expression (15), where $\pi_2 = \pi_2(q_2|q_1 = q_B)$. One has then to compute the value of π_2 under the optimal value q_2 . The same should then be done for firm B, to check it is not profitable to deviate and produce $q_1 > q_A$. The deviation would give it the profit indicated by expression (14) for $\pi_1 = \pi_1(q_1|q_2 = q_A)$. The optimal quality of the deviation and the corresponding profit can then be computed (see Figure 2).

For the case of change of leadership, the procedure is exactly the same (see Figure 3).

Appendix 3. Determination of the equilibria of the international trade game: integrated markets.

Expressions (16) and (16') give profits of the firms under the hypothesis that both markets are served by both firms. The first order conditions are:

$$\frac{16q_1(4q_1^2 - 3q_1q_2 + 2q_2^2)(\bar{\theta}^A)^2\bar{\theta}^B}{(4q_1 - q_2)^3(\bar{\theta}^A + \bar{\theta}^B)} = (q_1 - \bar{q}) \quad (\text{A3.1})$$

$$\frac{4q_1^2(4q_1 - 7q_2)(\bar{\theta}^A)^2\bar{\theta}^B}{(4q_1 - q_2)^3(\bar{\theta}^A + \bar{\theta}^B)} = (q_2 - \bar{q}) \quad (\text{A3.1}')$$

We can then use the same procedure as in the previous appendix. By setting $q_1 = zq_2$ (with $z \geq 1$), dividing the first order conditions and rearranging terms, we obtain for the case of persistence of leadership:

$$q_2 = \frac{5(4\bar{\theta}^B + 35z - 20z^2 - 6z\bar{\theta}^B + 8z^2\bar{\theta}^B)}{(8 - 12z + 23z^2 - 4z^3)}. \quad (\text{A3.2})$$

For the case of change of leadership the above expression becomes:

$$q_2' = \frac{5(80 - 120z + 160z^2 + 7z\bar{\theta}^B - 4z^2\bar{\theta}^B)}{2(8 - 12z + 23z^2 - 4z^3)} \quad (\text{A3.3})$$

By replacing (A3.2) in the case of persistence of leadership and (A3.3) in the case of leapfrogging into either (A3.1) or (A3.1'), we then obtain an equation in z and $\bar{\theta}^B$. The analytical solutions $z(\bar{\theta}^B)$ which we do not give here are decreasing and convex in $\bar{\theta}^B$ for leader persistence and increasing and concave in $\bar{\theta}^B$ for leapfrogging. By substitution one can find the equilibrium qualities.

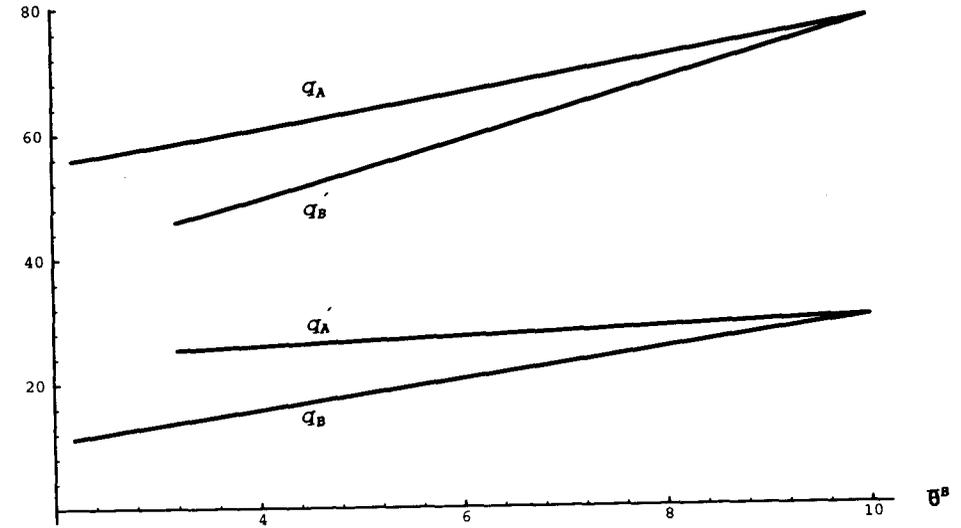


Figure 1 - Qualities, in the persistent leader equilibrium (q_j) and in the change of leadership equilibrium (q'_j), in the case of segmented markets ($j=A,B$).

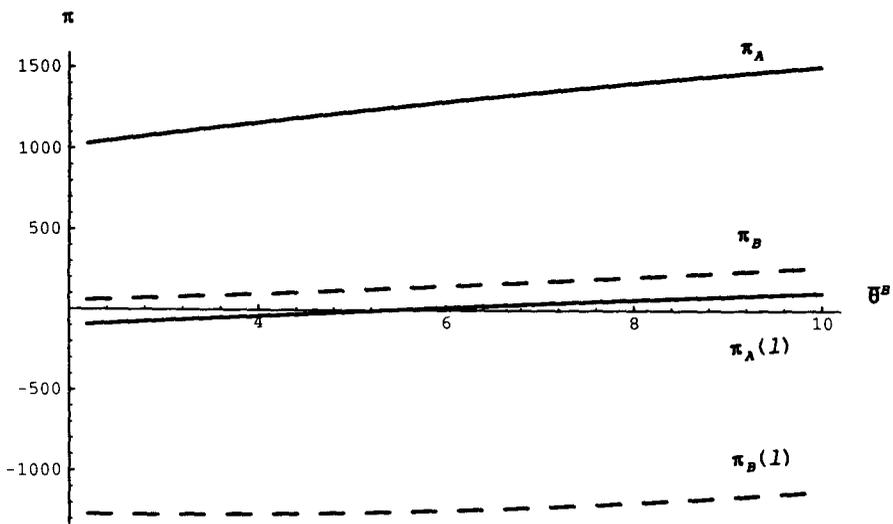


Figure 2 : Analysis of the existence of equilibrium for the case of persistence of leadership;
 π_J = profits of firm J=A,B at the candidate equilibrium and $\pi_J(l)$ = profits of firm J=A,B after deviation.

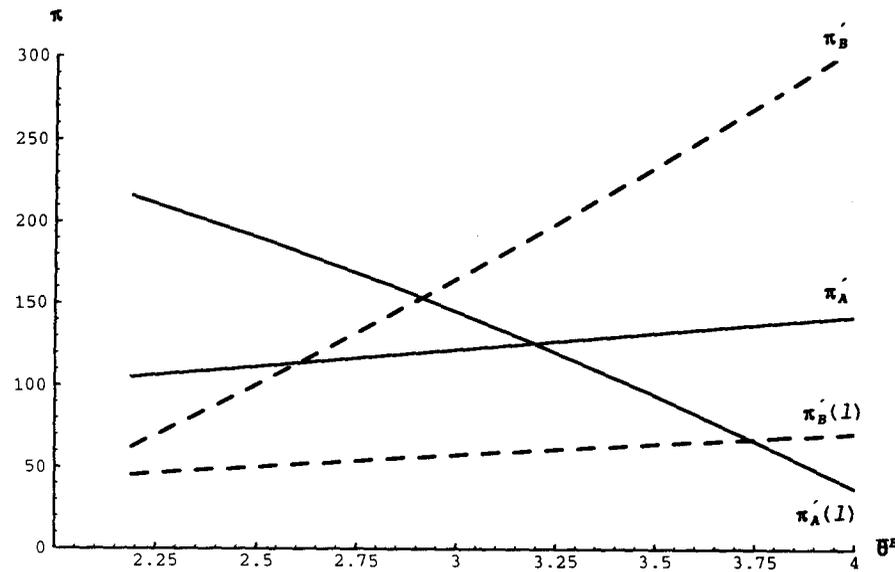


Figure 3 : Analysis of the existence of equilibrium for the case of change of leadership;
 π_J = profits of firm J=A,B at the candidate equilibrium and $\pi'_J(l)$ = profits of firm J=A,B after deviation.

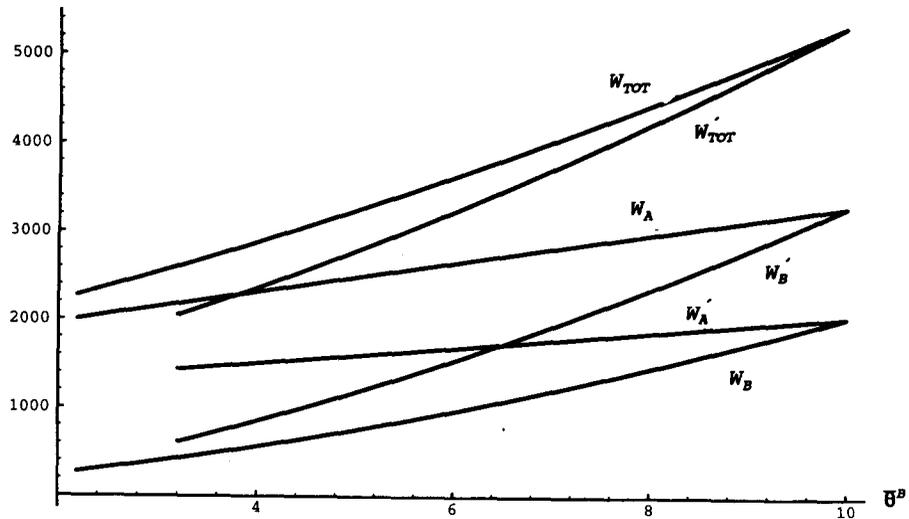


Figure 4 - Country and world welfare, in the persistent leader equilibrium (W_j, W_{TOT}) and in the change of leadership equilibrium (W'_j, W'_TOT) in the case of segmented markets ($j=A, B$).

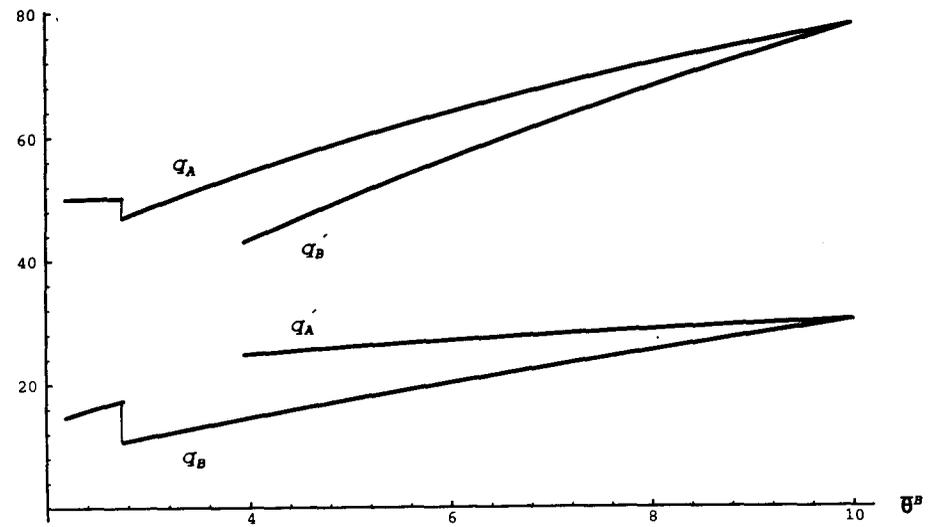


Figure 5 - Qualities, in the persistent leader equilibrium (q_j) and in the change of leadership equilibrium (q'_j), in the case of integrated markets ($j=A, B$).

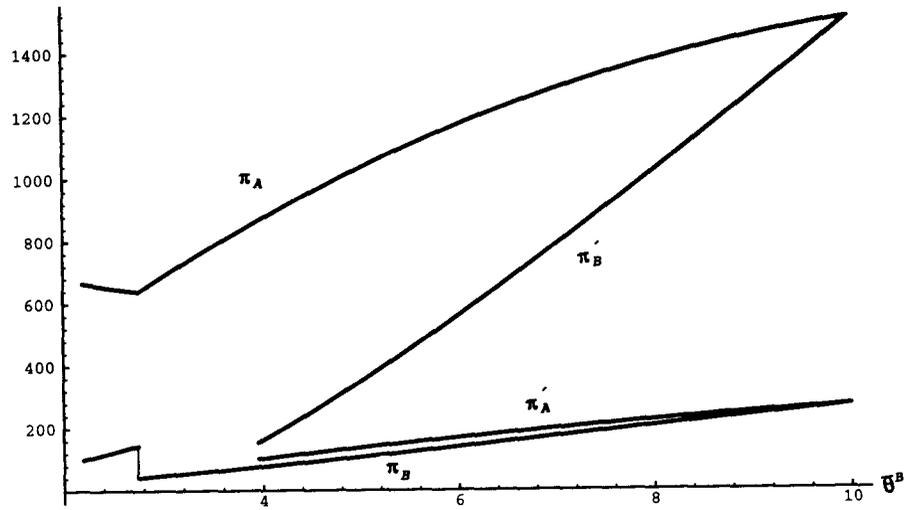


Figure 6 - Firms' profits, in the persistent leader equilibrium (π_j) and in the change of leadership equilibrium (π'_j), in the case of integrated markets ($j=A,B$).

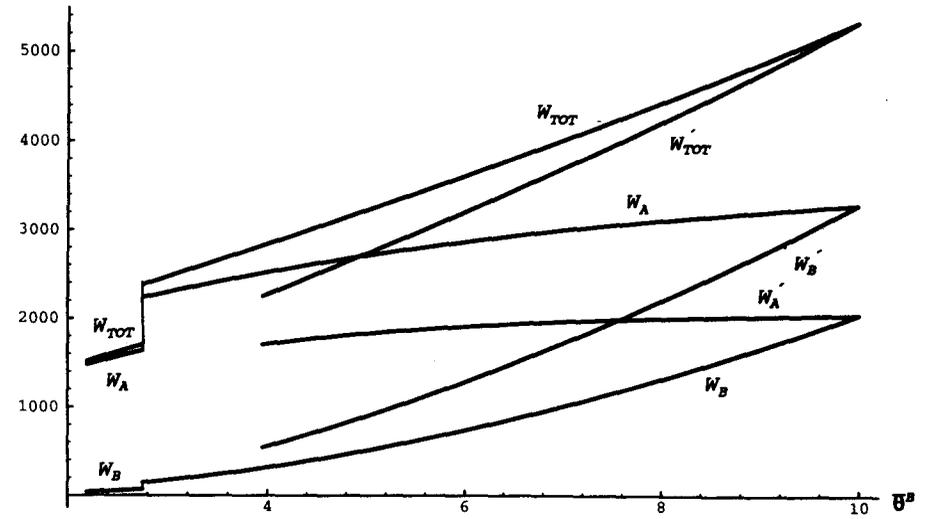


Figure 7 - Country and world welfare, in the persistent leader equilibrium (W_j, W_{TOT}) and in the change of leadership equilibrium (W'_j, W'_{TOT}) in the case of integrated markets ($j=A,B$).

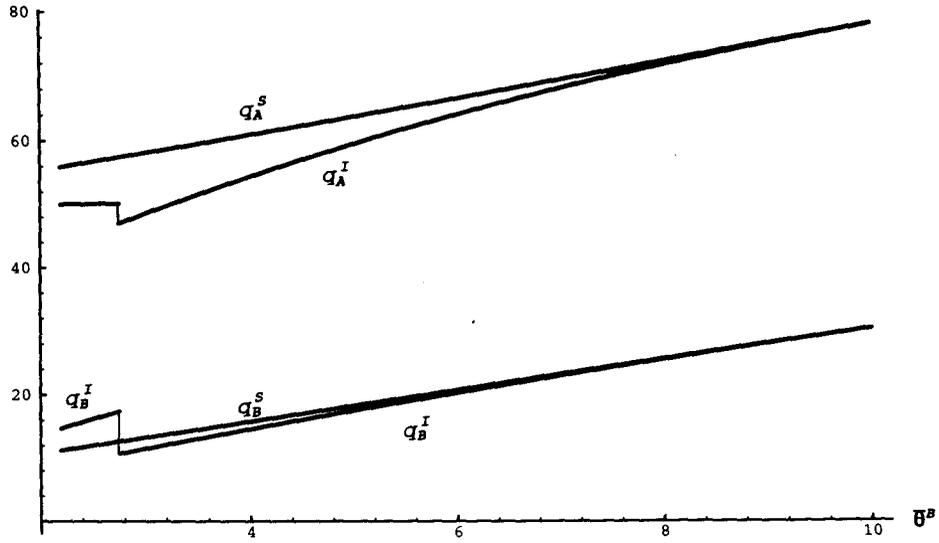


Figure 8 - Persistence of leadership: Equilibrium qualities under segmented (q_j^S) and integrated markets (q_j^I). ($j=A, B$)

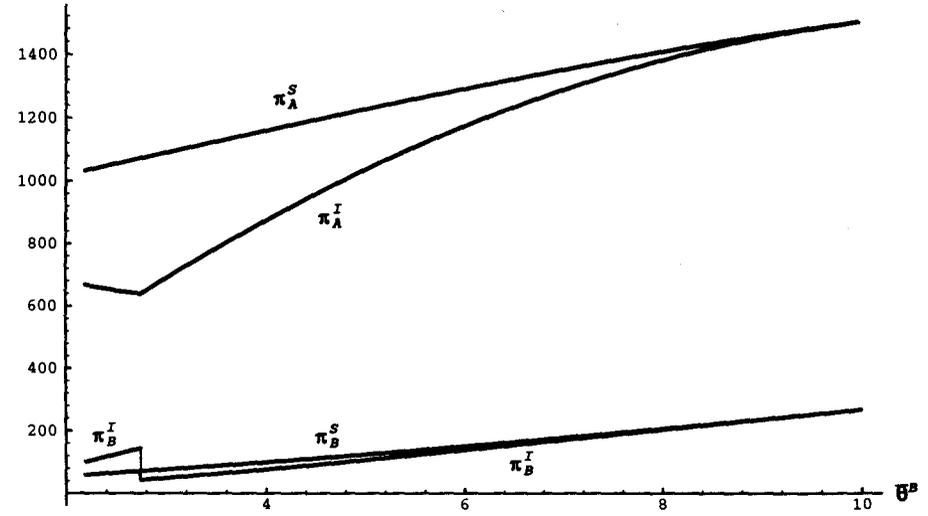


Figure 9 - Persistence of leadership: Equilibrium profits under segmented (π_j^S) and integrated markets (π_j^I). ($j=A, B$)

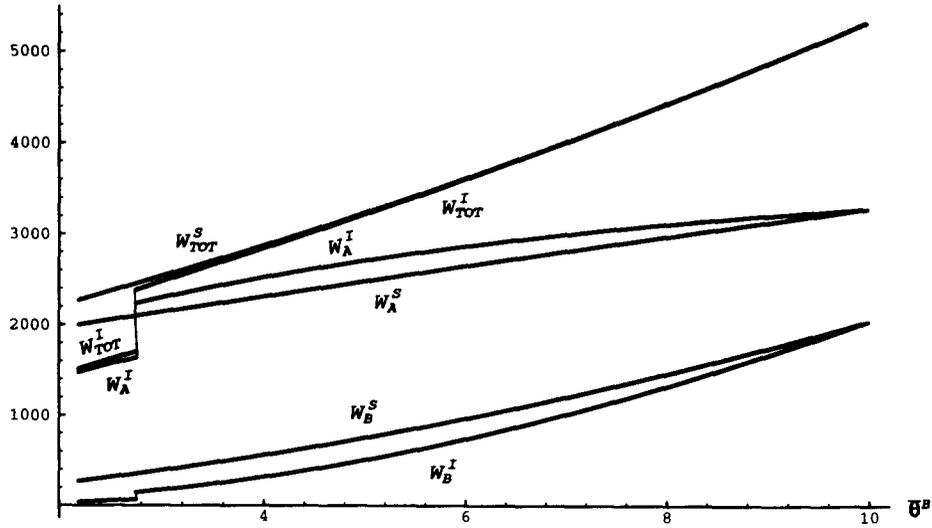


Figure 10- Persistence of leadership: Country j 's welfare ($j=A,B$) and world welfare under segmented (W_j^S, W_{TOT}^S) and integrated markets (W_j^I, W_{TOT}^I).

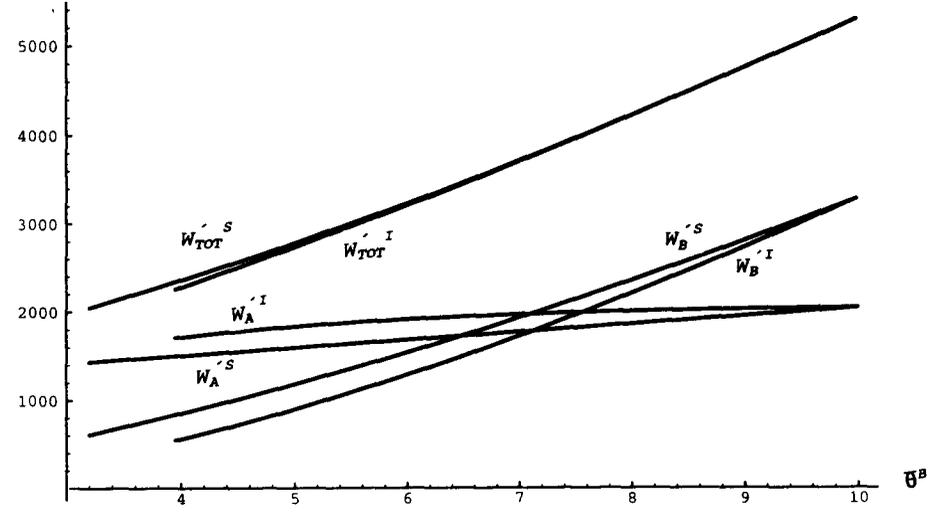


Figure 11- Change of leadership: Country j 's and world welfare under segmented (W_j^S, W_{TOT}^S) and integrated markets (W_j^I, W_{TOT}^I). ($j=A,B$)

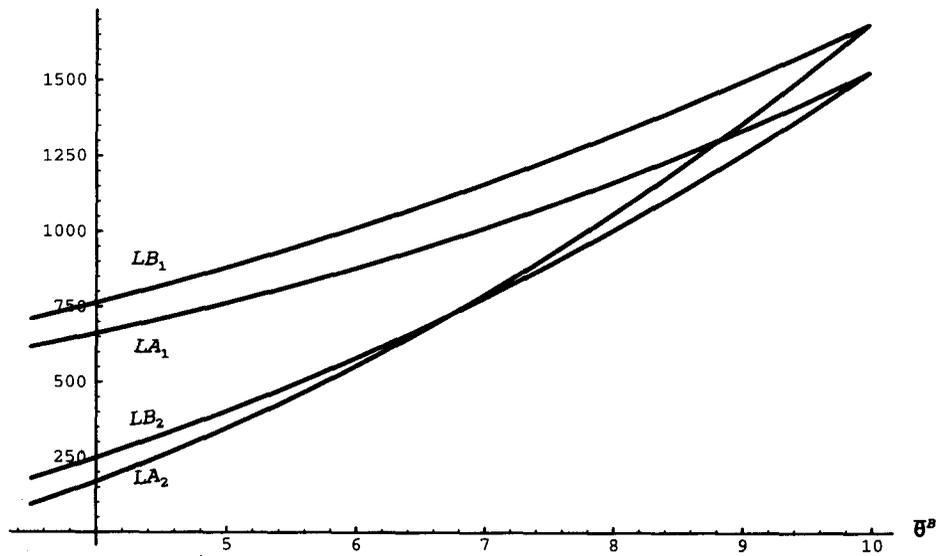


Figure 12 - Risk Dominance Comparisons - Segmented markets

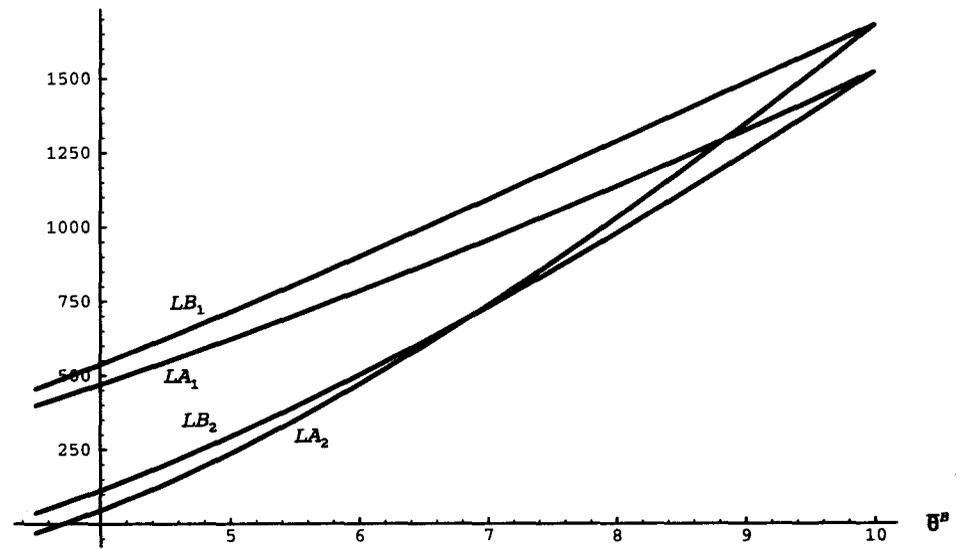


Figure 13 - Risk Dominance Comparisons - Integrated Markets