

# Dumping and Injury Margins in a Reciprocal Dumping Model with Horizontal as Well as Vertical Product Differentiation

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## Abstract

*This paper examines the GATT/WTO rules for anti-dumping measures in a duopoly model with both horizontal and vertical product differentiation. The GATT/WTO rules allow for anti-dumping measures if the domestic producers are injured associated with price discrimination. However, it is argued in this paper that the calculations of injury margins are flawed because of negligence of quality differences. This gives countries with high quality producers an option to practice protectionism. This bias in the possibility to implement anti-dumping measures predominantly favours the developed countries which are specialized in producing high quality products. The paper also shows that qualities and prices converge when trade costs decrease. Moreover, it is shown that a decrease of trade costs harms the profit of the high quality producer and this might increase the high quality producer's pressure for anti-dumping measures. The paper suggests that prices should be corrected for quality differences in the assessment of injury. Such change will limit the number of anti-dumping cases, but also eliminate the advantage of the developed countries in the ability to introduce anti-dumping measures.*

**Keywords:** Formal and real injury margins; Reciprocal dumping; Horizontal product differentiation; Vertical product differentiation; Market integration.

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## 1. Introduction

It is indisputable that during the last half century GATT/WTO has been very successful in lowering the most favoured nation tariffs (MFN) in the world economy. However, to some extent international trade has not been liberalized as much as should be expected by the reduction of the MFN tariffs. The pressure for protectionism has not receded, but has found its way to other protectionists' measures. Increasingly anti-dumping policy (AD) has become the feasible instrument to shield the domestic market from foreign competition. The woolly WTO/GATT anti-dumping rules are to blame for this substitution of trade barriers<sup>1</sup>.

The WTO/GATT rules provide for use of anti-dumping measures in a given market when two conditions are fulfilled. First, dumping behaviour of a foreign producer should be proved. Secondly, the domestic producer(s) should experience 'injury' because of the foreign producer's behaviour. As argued in this paper the last concept, injury, is ill defined and opens the door for policy makers' discretion, when goods differ in quality.

According to the GATT/WTO rules dumping is defined as selling a product in a foreign market at a price lower than the normal value, with the normal value typically determined as the home market price or a cost based price. The *dumping margin* is, therefore, the difference between the normal value and the export price. Very often the company sells identical products in the domestic and foreign markets. Hence, it makes no problem to calculate the dumping margin whether or not the foreign company's product differentiates from the products of competitors<sup>2</sup>.

Besides the existence of a positive dumping margin, *injury* is also a requirement for implementation of an AD measure. Article 3.1 of the *Agreement on Implementation of Article VI of the General Agreement on Tariffs and Trade 1994* (in the following called the *Agreement*) states that "A determination of injury [...] shall involve an objective examination of both (a) the volume of the dumped imports and the effect of the dumped imports on prices in the domestic market for like products, and (b) the consequent impact of these imports on domestic producers of such products". And in article 3.2 "[...] With regard to the effect of the dumped imports on prices, the investigating authorities shall consider whether there has been a significant *price undercutting* by the dumped imports as compared with the prices of a like product of the importing Member [...]" (our italics). So, in case of injury determination a 'like' product is the good produced in the importing country, which has to be 'like' the exported product. In the following the term 'like

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<sup>1</sup> "What is less clear is whether administered protection plays the role of a villain or a hero in contemporary trade policy" (Falvey and Nelson (2006:1), since governments may be unwilling to enter sizable MFN trade liberalizations without having some kind of ad hoc procedure of release for domestic protectionist pressure.

<sup>2</sup> If the foreign company produces in a non-market economy, the normal value is based on prices or costs in an analogue (market economy) country. If quality differences exist between the dumping country and the chosen analogue country, the selection of an analogue country may be of importance for the outcome of an AD-investigation in such a situation (Nielsen and Rutkowski (2005)). In the following we do not have the case of non-market economies in mind.

products' is discussed strictly in the context of injury determination (and not dumping margin determination) and price undercutting is used synonymously with injury margin<sup>3</sup>.

From a theoretical point of view 'like product' refers to cases where we have either homogeneous products or horizontally differentiated products, but not to cases of vertically differentiated products i.e. products which differ in quality. According to Lancaster (1966, 1979) two products are *horizontally differentiated* when both products have a positive demand, whenever they are offered at the same price. Furthermore, the different variants in the product group have the same characteristics, but in different proportions, and no variant dominates the others in relation to the content of its characteristics. *Vertical product differentiation* on the other hand exists - according to Lancaster- in a situation where the amount of characteristics of a given product is different, and all its potential consumers rank these amounts of characteristics in the same order. Hence, at the same price only the highest available quality of a group of vertical differentiated goods will be purchased and at the equilibrium, higher quality products will therefore sell at higher prices.

The central key to understanding a possible link between AD measures and product quality differences is the practical interpretation of the concept '*like product*'. 'Like product' is defined, according to article 2.6 of the *Agreement*, as "[...] a product which is identical, i.e. alike in all respects to the product under consideration, or in the absence of such a product, another product which, although not alike in all respects, has characteristics closely resembling those of the product under consideration". Implicitly, from this definition of 'like product' it is reasonable to assume that quality differences between imported products and domestically produced products in the exporting country should be taken into consideration in the AD investigation.

However, the Agreement does not give a list of criteria to be considered in determining the 'like product'. Furthermore, even the ambition to correct for quality differences seems bleak to put it mildly, as the GATT/WTO leaves it an open question whether calculation of price undercutting should at all include quality differences. In the WTO published *Handbook on Anti-dumping Investigations* (Czako et al., 2003) the authors suggest that authorities *may* correct price undercutting for quality differences. The word 'may' does not commit very much and practice among the WTO members on the interpretation of 'like products' also shows a wide margin for discretion with different factors being applied<sup>45</sup>.

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<sup>3</sup> Article 9.1 of the AD Agreement states that "it is desirable [...] the duty be less than the margin if such lesser duty would be adequate to remove the injury to the domestic industry". This policy is to a large extent followed by the EU, cf. article 9 (5) in Council regulation (EC) no 384/96 of December 1995, while in the US, AD measures have to offset the dumping margin. According to Vermulst and Waer (1991) in 44 per cent of EU AD cases the injury margin was lower than the dumping margin, while in the other 56 per cent of cases the injury margin was higher than the dumping margin (based on EU cases from 1980-1990).

<sup>4</sup> It also complicates the analysis that quality may refer to the consumers' perception and not to objective measurable differences between the domestically produced product and the 'dumped' import, see (Czako et al, 2003) for a specific discussion of this aspect.

<sup>5</sup> As far as we know, there has not been any systematic investigation of the practice on the area, but scattered observations found in the AD literature all point in the same direction, namely that AD-authorities

International trade models with vertical product differentiation (e.g. Falvey, 1981 and Shaked and Sutton, 1984) predict a positive correlation between quality and price. If quality is neglected or not taken fully into account, high quality producers will have the upper hand in claiming injury. Furthermore, both international trade theory (e.g. Falvey, 1981, Flam and Helpman, 1987) and empirical investigations (e.g. Torstensson, 1991 and 1996; Schott, 2004; Nielsen and Rutkowski, 2005; Hallak, 2006) suggest a positive association between the level of economic development and product quality. In general, rich countries are in a better position to claim injury compared with poor countries. This fits in with the fact that the historically heavy users of AD – USA and the European Union<sup>6</sup> – to a large extent have targeted their AD policies against countries at a lower level of economic development.<sup>7</sup>

The purpose of this paper is to provide a theoretical analysis of the protectionist bias from the neglect of quality in the present anti-dumping procedures. A two-country duopoly model with international trade is developed based on both horizontal and vertical product differentiation. One producer is located in each country, and because of trade costs both producers are price discriminating. Quality is a strategic variable for each producer and this, in market equilibrium, links the levels of qualities for the products from each of the two producers to the markets sizes (country sizes) and trade costs. The model allows for a distinction between formal and real injury (price undercutting) where the first concept is related to GATT/WTO negligence of quality, while the latter is anchored in the theoretical framework of the model.

Two other papers in the literature have looked at somewhat similar problems related to how product quality matters for dumping. Vandebussche and Wauthy (2001) found that EU anti-dumping policy in the form of price-undertakings may be disadvantageous to EU firms through reversals of quality rankings between high quality EU producers and low quality dumping producers. Products are vertically differentiated in their model, but dumping behaviour (price discrimination) is not modelled and the cost side is suppressed. Furthermore the model is not able to figure out, which country produces the high quality product. Some of these shortcomings are covered in Moraga-González and Viaene (2005), who also operate in a two-country duopoly model, with vertical product differentiation. Country sizes (or income differentials) are of importance and price differences across countries are determined by quality differences. They explicitly take

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“[...] can acknowledge the difference in quality that may exist [...], but nevertheless decide to consider the products as similar” (Vandebussche and Wauthy, 2001: 103; see also Nielsen and Rutkowski, 2005; and Bronckers and McNelis, 1999). Recently Tharakan et al (2006) have investigated 354 EU anti-dumping cases and found the reported injury margins from the Commission to be inflated, not due to influence by lobby groups, but because of a flawed estimation procedure. But their investigation does not specifically look at quality differences.

<sup>6</sup> 25 % of the AD Measures for 1995-2004, but earlier a much higher share ([http://www.wto.org/english/tratop\\_e/adp\\_e.htm](http://www.wto.org/english/tratop_e/adp_e.htm)).

<sup>7</sup> For the EU, 21% of AD measures (one country and one product) for the period 1995-2004 have been targeted against low income countries, 38% against low-middle income countries, 23% against upper-middle income countries and 18% against high income countries. (The income groups are based on World Development Report 2003 (GNI per capita in 2001) and the AD measures on WTO [http://www.wto.org/english/tratop\\_e/adp\\_e/adp\\_stattab3\\_e.xls](http://www.wto.org/english/tratop_e/adp_e/adp_stattab3_e.xls)).

the foreign exchange rate into consideration and show that a loss of competitiveness due to an exchange rate change raises the likelihood of AD-protection of the high-quality firm. Only unilateral dumping is a possibility in their model.

Our model differs from the above mentioned by including horizontal as well as vertical product differentiation. This aspect is important in relation to the definition of ‘like products’, since pure horizontal product differentiation seems to be fully in accordance with a theoretical definition of ‘like products’, while (extensive) vertical product differentiation is in contrast to ‘like products’. Since many differentiated products in the “real world” reasonably have both a horizontal and vertical dimension, our model framework may come closer to the real world application (misuse) of anti-dumping procedures, when quality differences exist.<sup>8</sup>

The main finding from our model is that country size matters for producers’ choice of product quality as well as for formal and real injury creation in foreign markets. Producers from both countries dump in the other producers’ market in the sense that they practice price discrimination. However, only the producer in the large market, who produces the high quality product, may be successful in getting AD-protection based on formal injury, i.e. price undercutting, without taking quality differences into account. Ironically, it is only the low quality producer in the small market who in some cases is exposed to real injury, i.e. price undercutting, when quality is taken into account. Neglecting quality differences in implementing AD-measures, the ‘convicted’ is therefore in some cases mixed with the ‘victim’. Furthermore, the model predicts that market integration is to the disadvantage of the producer on the large market since his profit decreases, while the profit of the producer from the small country may increase. Market integration might therefore induce the producer from the large country to play the card of anti-dumping measures based on (formal) injury even though market integration has reduced the dumping as well as the injury margins.

The rest of the paper is organized as follows. In section 2, we lay out the general structure of the model. Section 3 determines dumping and injury margins. The analysis highlights the role of country sizes and the horizontal dimension in the preference structure. Section 4 investigates the importance of market integration for the incentives to claim dumping and injury. Section 5 concludes, emphasizing the policy implications.

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<sup>8</sup> Take the recent EU anti-dumping case on certain footwear with uppers of leather against China and Vietnam (see Commission Regulation (EC) No 553/2006) as an example. Footwear is certainly a good with many different functions depending on weather conditions etc. (e.g. sandals, boots, urban footwear and city shoes). And also qualities may differ a lot depending on the materials (e.g. leather or composition leather) and design. And besides, within a given quality segment for a given function (e.g. city shoes of leather for men) many different brands may be available with some consumers preferring one to another and other consumers the opposite (for identical prices). That footwear varies a lot is also evident from the EU trade statistics which at 8-digit includes 33 different CN codes. It therefore seems obvious that product differentiation both along a vertical and horizontal dimension is relevant for a good like footwear.

## 2. The basic model<sup>9</sup>

### *Introduction*

On markets for differentiated products, product quality is a strategic variable for firms. In the pioneering work of Gabszewicz and Thisse (1979), product quality has been analysed formally in a duopoly model based on vertical product differentiation. This analysis has been followed by a large number of analyses of determination of product quality in duopoly models. Basically, market equilibrium in these models is determined in a two-stage game between the two companies. Product qualities are determined in the first-stage game leaving prices or output to be determined in the second-stage game. Duopoly models with vertical product differentiation have been analysed by Boom (1995), in a two-country case, but the trade aspect is only dealt with rudimentarily. Trade costs are neglected and hence the location of the two producers is without importance for prices, quantities and qualities. Recently, a similar two-country model has been developed by Lutz (2000). Also in his model, markets are completely segmented, so there is no arbitrage between countries.

Shaked and Sutton introduced a model with vertical as well as horizontal product differentiation claiming that “[...] results obtaining in the cases of the “pure vertical” and “pure horizontal” differentiation literatures are sharply different, but the – empirically relevant – case in which both types of attribute are present, has not been widely studied” (Shaked and Sutton, 1987: 137). Garella (2003, 2006) has recently developed such a generalized model where consumers’ tastes differentiate both vertically and horizontally. If one of the producers in this set-up raises the quality level of his product, he gains a larger market share although the gain is limited by the consumers’ horizontal preferences. The other producer will react defensively and save quality development costs by lowering the quality of his product and only produce for his most loyal customers. Quality levels are thus strategic substitutes i.e. when one company raises its quality level, the other company will react by lowering its quality.

The model presented below bears close affinity to the model of Garella (2003, 2006). The model includes horizontal as well as vertical product differentiation and is basically based on the same specifications of utility and technology (costs) as the model of Garella. However, the analysis introduces two countries with one producer located in each country. The goods are traded freely internally in each country contrary to cross border trade where trade costs exist. The markets in the two countries are thus partially integrated as trade costs prevail, i.e. the producer in each country has a competitive advantage in the domestic market.

Two main findings follow from this extension of Garellas model. First, the relative size of the markets plays a role for the ranking of qualities between the two producers. If the producers are equally cost effective in production and developing quality, the high quality producer will appear in the country, where the domestic market is largest. In

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<sup>9</sup> In Hansen and Nielsen (2006) we have formulated a duopoly model with international trade and horizontal as well as vertical product differentiation, but without market segmentation and price discrimination.

previous analyses, the ranking of producers with respect to quality is either described as a first mover advantage (see e.g. Ronnen, 1991) or as a result of cost efficiency asymmetries (see e.g. Garella, 2003, 2006). Quality development is assumed to involve fixed costs and in the model developed in the following, a large domestic market offers more favourable conditions for development of quality as fixed costs might be spread over more units on the large market. Market integration, i.e. a decrease of trade costs weakens the importance of a big domestic market and hence, quality increases for the producer in the small market, but decreases for the producer in the big market.

### *Producers and consumers*

The world consists of two countries, 1 and 2, with one producer of a differentiated product in each. The products are differentiated both vertically and horizontally. Vertically, the quality of the product is characterised by a quality indicator  $\theta$  ( $\theta \geq 0$ ). In the horizontal dimension, each consumer has an address or ideal variant characterised by  $x$ , where  $x = [0,1]$ . Each consumer is assumed to consume one unit only of the differentiated good. The consumer chooses the variant, which offers the largest utility gain, given by the gross utility of consuming the good minus the costs of acquiring it. These costs consist of the price at the gate of the producer plus trade costs, in case the consumer prefers the foreign good. The consumers in each country are uniformly distributed with respect to  $x$  in the interval 0 to 1. However, the two countries might be asymmetrical in size. The number of consumers is normalised to 1 in country 1 and to  $\sigma$  in country 2, and throughout in the following analysis, it is assumed that  $\sigma \geq 1$ .

The producer's horizontal position is exogenously given contrary to the vertical position, where the quality level is a strategic variable. Horizontally, the producers are assumed to have opposite locations, so the country 1 based firm is located within the territorial boundary of the respective country<sup>10</sup>. Hence, for a consumer at the address  $x$ , the horizontal distance to the producer in country 1 is  $x$  and  $(1-x)$  in country 2, respectively. However, if the consumer demands the foreign good, he incurs trade costs at  $g$  per unit. Each of the producers aims to maximise his profit and might price discriminate as the markets are partially integrated.

For the consumer in country 1, the utility of consuming one unit of the good produced by the domestic or the foreign producer is given by an additive separable specification of the vertical and horizontal dimensions<sup>11</sup>:

$$u_{11} = v + \theta_1 - tx - p_{11} \tag{1a}$$

and

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<sup>10</sup> D'Aspremont et al. (1979) have shown that two producers choose maximal horizontal distance at the market if the transport cost or utility loss is a quadratic function of distance. However, in the following we use linear distance costs.

<sup>11</sup> The additive specification of quality in the utility function has been suggested by Mussa and Rosen (1978) and has later been used in several analyses e.g. Tirole (1988). Another specification of quality in the utility function is to use a multiplicative specification, where basic utility depends on consumption of other (non-differentiated) goods, which varies proportionately with the quality indicator of the differentiated good. This alternative specification has been introduced by Gabszewicz and Thisse (1979) and later used by Shaked and Sutton (1982) and Boom (1995), among others.

$$u_{12} = v + \theta_2 - t(1-x) - p_{12} - g \quad (1b)$$

For a consumer in country 2, the utility of consuming one unit of the foreign good or alternatively the domestic good is given by:

$$u_{2,1} = v + \theta_1 - tx - p_{21} - g \quad (1c)$$

and

$$u_{2,2} = v + \theta_2 - t(1-x) - p_{22} \quad (1d)$$

where  $v$  is an exogenously given parameter,  $t$  a parameter for utility loss per unit increase in the horizontal distance between a consumer and a producer,  $p$  prices obtained by producers and  $g$  trade cost<sup>12</sup>. The first subscript indicates the market (country) and the second the supplier (producer). We assume that the consumer's attachment to the preferred variant measured by the size of the parameter  $t$  is strong. As appears from the following formal analysis, this assumption secures that qualities are strategic substitutes for the two companies.

The producers are assumed to share the same technology and, hence, to be symmetrical with respect to cost effectiveness. The variable unit costs are assumed to be independent of quality and constant with respect to quantity produced. Quality is output from the firm's R&D activity. To develop quality, the firm incurs all sunk costs. The flow equivalent fixed costs to the sunk costs for the firm is assumed to be a quadratic function of quality, i.e. the costs functions for the two producers are specified by (2):

$$C_i = cQ_i + \frac{1}{2}\theta_i^2; \quad i=1,2 \quad (2)$$

where  $Q_i$  ( $i=1,2$ ) is the quantity of the good produced by the two producers and  $c$ , variable unit costs.

### *Nash equilibrium*

The producers use the quality level and price as strategic variables. It is assumed that each producer in a first-stage game chooses his quality level and subsequently chooses prices in the second-stage game. The Nash equilibrium is derived by backward induction i.e. by deriving the prices for given qualities, and then determination of qualities.

To simplify, the formal analysis is based on a set of constraints on the parameters, which rule out special cases and corner solutions. Especially two simplifying assumptions should be noticed. First, it is assumed that the two markets are fully covered, i.e. each consumer in both countries buys one unit of the good. Secondly, it is assumed that the horizontal preference is relatively strong with the implication the quality of goods is substitutes in the competitive game between the two producers. Formally the constraints are presented in the Appendix.

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<sup>12</sup> The specification of the utility function disregards diversity of tastes with respect to quality. In most other papers in this tradition, the effect on utility of quality in the individual utility function is assumed to depend both on a good specific indicator of quality and a consumer specific parameter related to the weight the consumer puts on quality, see e.g. Tirole (1988).

On a given market, a competitive edge exists between the two producers defined as the location of a marginal consumer, who is indifferent whether to buy the variant from one or the other producer. In country 1, the competitive edge  $\tilde{x}_1$  is determined by:

$$v + \theta_1 - tx - p_{11} = v + \theta_2 - t(1-x) - p_{12} - g$$

which gives

$$\tilde{x}_1 = \frac{1}{2t} [t + (p_{12} - p_{11} + g) + (\theta_1 - \theta_2)] \quad (3a)$$

Similarly, the competitive edge in country 2 is given by

$$\tilde{x}_2 = \frac{1}{2t} [t + (p_{22} - p_{21} - g) + (\theta_1 - \theta_2)] \quad (3b)$$

The operating profit of producer  $i$  on the market in country 1,  $\pi_{1,i}$  ( $i=1,2$ ) is given by:

$$\begin{aligned} \pi_{11} &= (p_{11} - c)Q_{11} \\ &= (p_{11} - c)\tilde{x}_1 \end{aligned} \quad (4a)$$

$$\begin{aligned} \pi_{12} &= (p_{12} - c)Q_{12} \\ &= (p_{12} - c)(1 - \tilde{x}_1) \end{aligned} \quad (4b)$$

where  $Q_{1,i}$  ( $i=1,2$ ) is the two firms' sale in market 1<sup>13</sup>.

For given qualities each of the two producers optimises his price or output separately in each market as the marginal production costs is independent of the total output level. The producers are assumed to play Bertrand, maximising perceived profit in each market with respect to the price of the producer's own product, given the price of the competitor's product.

Inserting (3a) into (4a) and (4b) and taking the first-order derivative of profits with respect to own price gives the following *price reaction functions* for the two producers in market 1:

$$p_{11} = \frac{1}{2} [p_{12} + g + (\theta_1 - \theta_2) + (t + c)] \quad (5a)$$

$$p_{12} = \frac{1}{2} [p_{11} - g - (\theta_1 - \theta_2) + (t + c)] \quad (5b)$$

Solving (5a) and (5b) and using (3a) and (4a) and (4b) gives the following results for the Bertrand equilibrium for given qualities:

$$p_{11} = \frac{1}{3} [g + (\theta_1 - \theta_2) + 3(t + c)] \quad (6a)$$

$$p_{12} = \frac{1}{3} [-g - (\theta_1 - \theta_2) + 3(t + c)] \quad (6b)$$

$$Q_{11} = \frac{1}{6t} [g + (\theta_1 - \theta_2) + 3t] \quad (6c)$$

$$Q_{12} = \frac{1}{6t} [-g - (\theta_1 - \theta_2) + 3t] \quad (6d)$$

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<sup>13</sup> Remember that prices are exclusive of trade costs. Consumers who prefer the foreign good are charged the producer price plus trade costs,  $g$ .

$$\begin{aligned}\pi_{11} &= \frac{1}{18t} [g + (\theta_1 - \theta_2) + 3t]^2 \\ &= \frac{1}{3} Q_{11}^2\end{aligned}\tag{6e}$$

$$\begin{aligned}\pi_{12} &= \frac{1}{18t} [-g - (\theta_1 - \theta_2) + 3t]^2 \\ &= \frac{1}{3} Q_{12}^2\end{aligned}\tag{6f}$$

Using the same procedure and noting the possible market size asymmetry  $\sigma$ , the Bertrand equilibrium in the market in country 2 is given by:

$$p_{21} = \frac{1}{3} [-g + (\theta_1 - \theta_2) + 3(t + c)]\tag{7a}$$

$$p_{22} = \frac{1}{3} [g - (\theta_1 - \theta_2) + 3(t + c)]\tag{7b}$$

$$Q_{21} = \frac{\sigma}{6t} [-g + (\theta_1 - \theta_2) + 3t]\tag{7c}$$

$$Q_{22} = \frac{\sigma}{6t} [g - (\theta_1 - \theta_2) + 3t]\tag{7d}$$

$$\begin{aligned}\pi_{21} &= \frac{\sigma}{18t} [-g + (\theta_1 - \theta_2) + 3t]^2 \\ &= \frac{1}{3} Q_{21}^2\end{aligned}\tag{7e}$$

$$\begin{aligned}\pi_{22} &= \frac{\sigma}{18t} [g - (\theta_1 - \theta_2) + 3t]^2 \\ &= \frac{1}{3} Q_{22}^2\end{aligned}\tag{7f}$$

The results above illustrate the role of qualities for prices and output for the two companies. If one of the companies, say company 1, raises the quality of its product, the company will charge a higher price (in both markets), but the price increase will only partly match the quality increase in the consumers' eyes. Hence, company 1 increases its market share on behalf of company 2, which will lower its price (in both markets) to mitigate the pressure on its market shares. Output will thus increase for company 1, but decrease for company 2. The horizontal preferences ( $t$ ) represent the degree of loyalty of the individual consumers to the product from either company 1 or 2. Strong horizontal preferences therefore allow for high prices relative to variable unit costs, see (6a), (6b), (7a) and (7b). For similar reasons the effects on market shares (output) of an increase in quality of one of the companies' products is more modest in case of strong horizontal preferences.

The results (6a) - (6f) and (7a) - (7f) allow us to deal with the first game: determination of quality levels. Total profit  $\Pi$  for each of the two producers is given by:

$$\Pi_1 = \pi_{11} + \pi_{21} - \frac{1}{2}\theta_1^2\tag{8a}$$

$$\Pi_2 = \pi_{12} + \pi_{22} - \frac{1}{2}\theta_2^2\tag{8b}$$

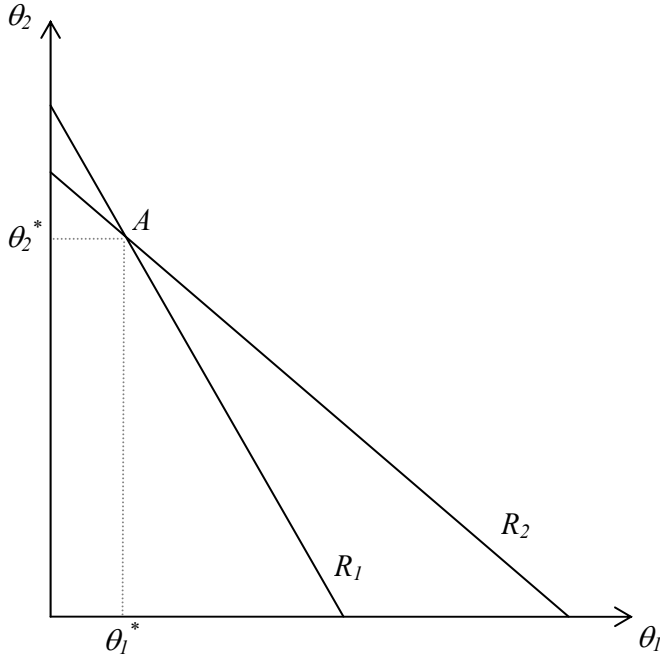
Maximizing  $\Pi_1$  with respect to  $\theta_1$  and  $\Pi_2$  with respect to  $\theta_1$  by using profits (6e), (6f), (7e) and (7f) gives the *quality reaction functions* for the producer in country 1 ( $R_1$ ) and country 2 ( $R_2$ ) respectively:

$$\theta_1 = \frac{1}{(9t-(1+\sigma))} [-(1+\sigma)\theta_2 - (\sigma-1)g + 3(1+\sigma)t] \quad (9a)$$

$$\theta_2 = \frac{1}{(9t-(1+\sigma))} [-(1+\sigma)\theta_1 + (\sigma-1)g + 3(1+\sigma)t] \quad (9b)$$

Figure 1 illustrates the quality reaction functions  $R_1$  and  $R_2$  and the resulting Nash equilibrium A.

Figure 1: Quality reaction functions and Nash equilibrium



The quality reaction functions are negatively sloped i.e. qualities are strategic substitutes. This is only the case when the horizontal preferences are relatively strong i.e.  $t$  exceeds  $(1+\sigma)/9$ . The intuition behind this feature follows from the effects on market share of quality changes. As previously noticed, if one of the companies increases its product quality, it captures a larger market share on behalf of the other company. The smaller market left for the other company induces this company to lower the quality of its product to reduce development costs of quality.

In case the horizontal preferences are relatively weak, the return of a quality improvement is larger, since the quality increase will attract relatively more consumers from the other producer. In such cases the high quality producer may persistently get more profit by raising his quality and the low quality producer may gain by lowering his quality and hence, the outcome will be maximum quality differentiation.<sup>14</sup> This result is

<sup>14</sup> See Appendix A in Hansen and Nielsen (2006) for further explanation.

similar to the extreme case of pure vertical product differentiation in the model of Gabszewicz and Thisse (1979).

Solving (9a) and (9b) gives the quality levels in Nash equilibrium:<sup>15</sup>

$$\theta_1^* = \frac{(1+\sigma)}{3} - \frac{(\sigma-1)}{(9t-2(1+\sigma))}g \quad (10a)$$

$$\theta_2^* = \frac{(1+\sigma)}{3} + \frac{(\sigma-1)}{(9t-2(1+\sigma))}g \quad (10b)$$

Inserting the solution (10a) and (10b) into the Bertrand equilibrium (6a) - (7f) gives the full solution for prices, quantities and operating profits. For the market in country 1 we have:

$$p_{11} = \frac{1}{3} \left[ \frac{a}{d}g + 3(t+c) \right] \quad (11a)$$

$$p_{12} = \frac{1}{3} \left[ -\frac{a}{d}g + 3(t+c) \right] \quad (11b)$$

$$Q_{11} = \frac{1}{6t} \left[ \frac{a}{d}g + 3t \right] \quad (11c)$$

$$Q_{12} = \frac{1}{6t} \left[ -\frac{a}{d}g + 3t \right] \quad (11d)$$

$$\pi_{11} = \frac{1}{18t} \left[ \frac{a}{d}g + 3t \right]^2 \quad (11e)$$

$$\pi_{12} = \frac{1}{18t} \left[ -\frac{a}{d}g + 3t \right]^2 \quad (11f)$$

and for the market in country 2:

$$p_{21} = \frac{1}{3} \left[ -\frac{b}{d}g + 3(t+c) \right] \quad (12a)$$

$$p_{22} = \frac{1}{3} \left[ \frac{b}{d}g + 3(t+c) \right] \quad (12b)$$

$$Q_{21} = \frac{\sigma}{6t} \left[ -\frac{b}{d}g + 3t \right] \quad (12c)$$

$$Q_{22} = \frac{\sigma}{6t} \left[ \frac{b}{d}g + 3t \right] \quad (12d)$$

$$\pi_{21} = \frac{\sigma}{18t} \left[ -\frac{b}{d}g + 3t \right]^2 \quad (12e)$$

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<sup>15</sup> Strong horizontal preferences and modest trade costs relative to variable unit production costs secure that the solutions for prices and qualities are positive, see the Appendix.

$$\pi_{22} = \frac{\sigma}{18t} \left[ \frac{b}{d} g + 3t \right]^2 \quad (12f)$$

where  $a = (9t - 4\sigma)$ ,  $b = (9t - 4)$  and  $d = (9t - 2(1 + \sigma))$ .

Given the assumed strong horizontal preferences, both firms earn positive profits and the *rank* of profits coincides with the rank of qualities. The producer on the large market delivers the variant with the highest quality. Quality requires fixed costs, and easy access to the large market therefore gives this producer a competitive advantage in quality development relative to the producer located on the small market. For the same reason, price and output are also larger for the producer on the large market compared with the producer on the small market.

### 3. Country sizes, dumping and injury margins

The above model allows for an analysis of dumping and injury margins, where the latter may be divided into a formal and a real injury margin. It appears from the analysis that country asymmetries as well as the intensity of horizontal preferences play a crucial role for the size of formal and real injury margins.

#### *Dumping margins*

As mentioned in the introduction, a dumping margin is defined, according to the WTO, as the difference between the normal value (in the following the home market price) and the export price in the foreign market. For the producer in country 2, the dumping margin (*DM*) for his exports in market 1 is by using (11b) and (12b):

$$DM_{12} = p_{22} - p_{12} = (2/3)g \quad (13a)$$

and similarly for the producer in country 2 by using (11a) and (12a):

$$DM_{21} = p_{11} - p_{21} = (2/3)g \quad (13b)$$

So we find that producers are dumping reciprocally in the other country's market. Even though the two markets might differ in size and the two producers produce goods of different qualities and with different horizontal characteristics, the dumping margins equal 2/3 of trade costs. A decrease in trade costs reduces the producers' competitive advantage in their domestic market, but reduces at the same time the producers' handicap in foreign markets. Each of the two producers therefore lowers his price in the domestic market, but raises the price in the foreign market and hence, lower trade costs squeeze the dumping margin. The impact on the qualities of lower trade costs does not influence this result as changes in qualities impact prices on the domestic and foreign markets symmetrically, i.e. the dumping margin is unaffected.

These results are broadly similar to the classical Brander & Krugman (1983) model. However the Brander & Krugman model differs from the model in this paper in two respects. First, by assuming homogeneous products and Cournot behaviour by the

companies.<sup>16</sup> Secondly, in the Brander & Krugman model, exporters absorb trade costs fully to be able to offer the good at the same price as the competitor, in contrast to our model, where only two thirds of the trade costs are absorbed by the producer.

### *Formal injury margins*

The injury margin ( $IM$ ) or the degree of price-undercutting is an important part of an anti-dumping investigation. It is defined as the amount by which the dumpers' price in the export market (C.I.F., including tariffs) undercuts the price of the import-competing good in case of 'like products'.<sup>17</sup> For markets 1 and 2 such *formal injury margins* ( $IM^F$ ) are defined as follows:

$$IM_{12}^F = p_{11} - (p_{12} + g) \quad (14a)$$

and

$$IM_{21}^F = p_{22} - (p_{21} + g) \quad (14b)$$

In situations, where products are horizontally as well as vertically differentiated, but AD authorities declare the products 'alike' anyway, the following formal injury margins result by using (11a), (11b), (12a) and (12b):

$$IM_{12}^F = \left(-\frac{1}{3} - \frac{4}{3} \frac{(\sigma-1)}{(9t-2(1+\sigma))}\right)g \quad (14c)$$

$$IM_{21}^F = \left(-\frac{1}{3} + \frac{4}{3} \frac{(\sigma-1)}{(9t-2(1+\sigma))}\right)g \quad (14d)$$

In the special case with identical market sizes ( $\sigma=1$ ), formal injury margins are negative and equal to  $-(1/3)g$  for both countries. In this case qualities are identical across producers and as the producers only price discriminate by  $2/3$  of the trade costs, formal injury margins make up minus  $1/3$  of trade costs.

Generally, the formal injury margin in the small market ( $IM_{12}^F$ ) is always negative. Since the quality difference between countries 2 and 1 increases with size asymmetries, the producer in country 2 raises his export price for increasing  $\sigma$ , while the producer in country 1 lowers his price for producing to his domestic market. The negative value of the formal injury margin ( $IM_{12}^F$ ) therefore increases for increasing  $\sigma$ . The small country will therefore never be exposed to formal price injury.

In contrast, formal injury margin in the large market ( $IM_{21}^F$ ) may be negative as well as positive. Increasing  $\sigma$  induces the producer on market 2 to raise the home market price for his product, while the producer in country 1 lowers his export price to country 2. The

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<sup>16</sup> In their comments to the results of their model Brander and Krugman mention that in case of Bertrand behaviour, reciprocal dumping does not arise in the homogeneous product case, although a small amount of product differentiation will restore the reciprocal dumping result.

<sup>17</sup> In Rivera-Batiz and Oliva, (2003: 462) it is defined as "[...] the amount by which its price in the export market, net of transport costs, undercuts the price[...] of the import-competing good." This definition is not as used in anti-dumping practice in e.g. the EU, where prices are made comparable in the European market.

price gap between the high quality product and the low quality product in the large market therefore increases and may, for big country asymmetries, exceed trade costs which turn  $IM_{21}^F$  to positive values. To be more precise,  $IM_{21}^F$  becomes positive for  $\sigma > (9t+2)/6$ .

So, only the large country may be exposed to formal injury in this model, and only if it is relatively large.<sup>18</sup>

A crucial parameter for the size of the formal injury margin in the large (and small) country is the size of the large country ( $\sigma$ ) relative to the intensity in horizontal preferences ( $t$ ). With increasing intensity in horizontal preferences, there is a requirement for increasing differences in market sizes (and quality differences) to make sure that the small country will be ascribed a positive injury margin. A high value of  $t$  (highly “loyal” consumers to a given variant) reduces the need for quality differentiation, leading to lower quality and prices in the large country, and for that reason makes it more unlikely that the small country producer “undercuts” prices in the large country.

#### *Real injury margins*

As far as we know, very little or at least insufficient correction for quality differences in injury margin determination is made, at least in the EU (see footnote 5). We therefore define a *real* injury margin as an injury margin with full quality difference correction, and we compare this real injury margin with the formal injury margin as defined above.

For markets 1 and 2 respectively, real injury margins ( $IM^R$ ) are defined as

$$IM_{12}^R = (p_{11} - \theta_1) - (p_{12} - \theta_2 + g) = IM_{12}^F - (\theta_1 - \theta_2) \quad (14e)$$

$$IM_{21}^R = (p_{22} - \theta_2) - (p_{21} - \theta_1 + g) = IM_{21}^F + (\theta_1 - \theta_2) \quad (14f)$$

Using (11a), (11b), (12a) and (12b) gives

$$IM_{12}^R = \left(-\frac{1}{3} + \frac{2}{3} \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))}\right)g \quad (14g)$$

$$IM_{21}^R = \left(-\frac{1}{3} - \frac{2}{3} \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))}\right)g \quad (14h)$$

Like for formal injury margins, real injury margins are equal to  $-(1/3)g$  in both countries in the special case of identical country sizes. In this case qualities are also identical and no correction for quality is therefore relevant to consider in an assessment of injury.

Generally,  $IM_{21}^R$  is always negative. Quality difference between countries 2 and 1 increases with size differences, but because of horizontal preferences the pass-through of quality increases on prices is less than one. The  $IM_{21}^R$  therefore decreases with increasing

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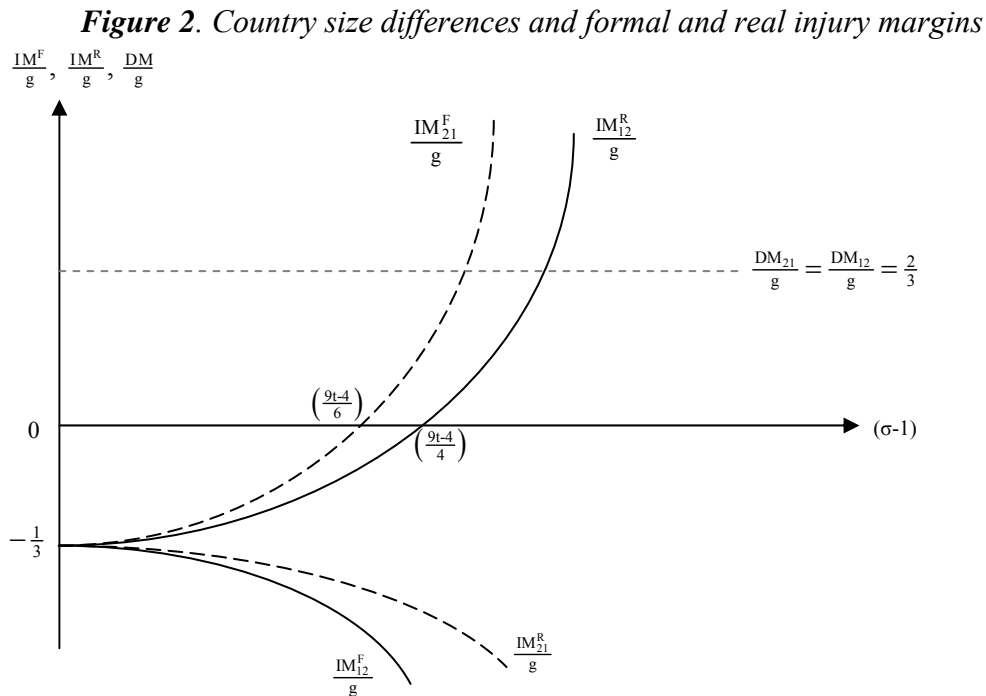
<sup>18</sup> In the Brander and Krugman model (1983), the injury margin is zero, since the two producers’ prices (inclusive of trade costs) in a given market are identical (homogeneous products).

differences in country sizes and hence, the large country will never experience real price injury.

$IM_{12}^R$  on the other hand may be negative as well as positive. Increasing  $\sigma$  leads to an increase in the export price of the large country relative to the home market price of the small country, but since the export price change is less than the quality change of the large country the real injury margin in the small market will increase and for  $\sigma > 9t/4$   $IM_{12}^R$  becomes positive.<sup>19</sup> To conclude, only the small country may be exposed to real injury in this model, and only if it is relatively small.

### Formal versus real injury margins

Formal as well as real injury margins as a function of country size differences ( $\sigma-1$ ) are shown in *Figure 2*. By inspection of the second order derivative of the formal and real injury margins with respect to ( $\sigma-1$ ), we find the shape of the curves for formal and real injury as illustrated in *Figure 2*, i.e. the slopes increase in numerical terms for all four curves.



For equal country sizes ( $\sigma-1=0$ ), all injury margins normalised with respect to trade costs are equal to  $-1/3$ . With increasing country size differences, formal (real) injury margins are growing in the large (small) market, but only becoming positive when given thresholds of  $(\sigma-1)$  are passed. And formal (real) injury margins are decreasing (always negative) in the small (large) country.

<sup>19</sup> This specification of injury margin rests on our specification of quality in the utility functions (1a)-(1d), where quality ( $\theta$ ) is measured in price-equivalent units.

So, a formal injury margin can never appear in the small market, but might appear in the large market. And a real injury margin can never appear in the large market, but might appear in the small. And there might be formal injury, without real injury for intermediate values of country differences  $(9t - 4)/6 < (\sigma - 1) < (9t - 4)/4$ . Finally, for large country size differences, i.e.  $(\sigma - 1) > (9t - 4)/4$ , formal injury exists in the large market and real injury in the small, so the company from the large country might accuse the company from the small country of dumping and (formal) injuring, *but it is, anyway, the large country that is creating dumping as well as real injury*.

The intuition behind this result is that large differences in country sizes translate into large differences in qualities. But since we operate with both horizontal and vertical product differentiation, the assumed important intensity of horizontal preferences weakens the incentive to the pass-through of qualities on prices. Hence, the quality-price margin widens, leading to real injury margin in the small country.

Based on this result we should expect companies in large (high income) countries to argue for no or small quality differences (and quality corrections) in AD-investigations, while companies in small (low income) countries have an incentive to emphasize correctly the quality differences and ask for quality corrections in injury margin calculations.

#### *Anti-dumping duties*

Anti-dumping measures, e.g. in the form of duties require as previously mentioned the existence of both a positive dumping and injury margin. As appears from figure 2, the difference in country sizes should be substantial if both countries are going to introduce duties simultaneously.

If we assume that a demand for protection in an industry will always induce the political willingness to supply protection, a 'flexible' interpretation of injury condition offers an excellent condition for mushrooming of anti-dumping protection measures in both the large and the small country. The large country will claim injury by using formal injury and the small country will base its argument by referring to real injury. However, in the specific model in this paper some asymmetry exists in the availability of use of the anti-dumping protection as (a positive) formal injury margin appears for a smaller country size difference than for (a positive) real injury margin ( $(9t-4)/6 < (9t-4)/4$ ), see Figure 2). This allows the large country to use anti-dumping protection in cases where the small country is excluded from the use of this instrument.

The anti-dumping agreement envisages that the anti-dumping duty shall not exceed the margin of dumping. However, article 9.1 leaves it to the discretion of the authorities of the importing country, whether the amount of anti-dumping duty to be imposed shall be the full dumping margin or less. The article states that the duty may be less than the dumping margin, if such lesser duty would be adequate to remove the injury to the domestic industry. This non-mandatory clause is followed by several users of anti-

dumping, including the EU.<sup>20</sup> If this *lesser than duty rule* is followed, we can see that on average the larger country will use higher duties than the smaller country, but for very large country differences, the large as well as the small country will use the dumping margin as the basis for duty calculation.

Reform of the anti-dumping agreement may involve either making the lesser than duty rule mandatory and/or using real instead of formal injury margin calculation. The lesser than duty rule will work in the direction of a generally lower level of duties, while the use of real injury (in our model) eliminates large countries' use of AD-protection.

#### 4. Market integration, dumping and injury

The model above also allows for an analysis of the effects on dumping and injury margins of increasing market integration, i.e. a decrease of trade costs,  $g$ . As is obvious from Figure 2, market integration will lead to a reduction in dumping margins and injury margins in the same proportion and will therefore not change the above conclusion concerning the relation between dumping and injury margins for small and large countries.

However, market integration influences profits, and as discussed in the following the loser among the producers may react more aggressively by demanding AD measures by claiming dumping and injury.

For  $\sigma > 1$  it follows from (10a)-(10b) that:

$$\frac{\partial \theta_1^*}{\partial g} < 0 \quad \text{whereas} \quad \frac{\partial \theta_2^*}{\partial g} > 0$$

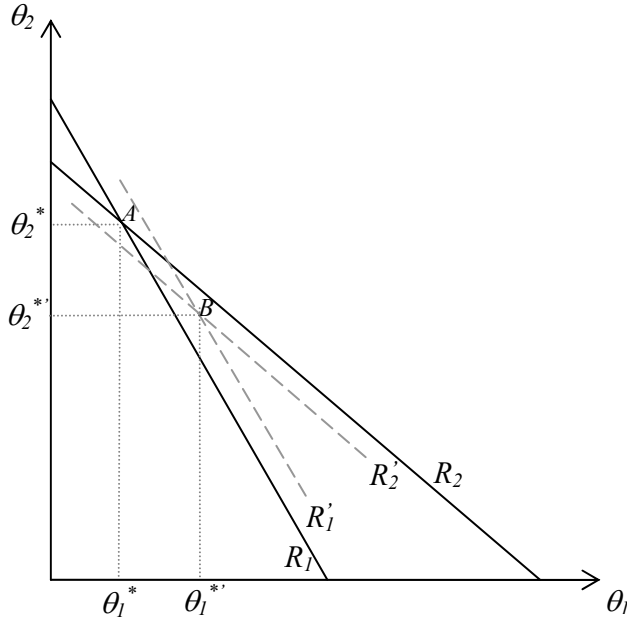
Figure 3 illustrates the effect on qualities of a decrease in trade costs.

The relative advantage of being located on the large market weakens, when trade costs decrease. Qualities, prices and output levels therefore converge between the two countries, when market integration is deepened, see (10a) – (10b), (11a) – (11b) and (12a) – (12b). Each producer will be more pressed in his domestic market with less profit. In contrast to this, each producer will improve his competitive position in the foreign market, which on the bottom line will increase his profit in this market. In the domestic market each producer will therefore lose profit in contrast to the foreign market, where the producer will gain more profit.

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<sup>20</sup> In the WTO Doha negotiations, several countries, like e.g. India, have argued to make this rule mandatory.

Figure 3: Market integration and product qualities



However, unambiguously total profit will decrease for the producer located on the large market. The loss of profit for this producer on the large domestic market will never be compensated fully by the increase of profit on the small market. To show this formally, total profit for the producer located in the large market ( $\Pi_2$ ) is determined by (15) using that the profit in each market is given by (11f) and (12f):

$$\Pi_2 = \frac{1}{18t} \left(-\frac{a}{d}g + 3t\right)^2 + \frac{\sigma}{18t} \left(\frac{b}{d}g + 3t\right) \quad (15)$$

Taking the first-order derivative of  $\Pi_2$  with respect to  $g$  gives:

$$\frac{\partial \Pi_2}{\partial g} = -\frac{1}{9t} \frac{a}{d} \left(-\frac{a}{d}g + 3t\right) + \frac{\sigma}{9t} \frac{b}{d} \left(\frac{b}{d}g + 3t\right) \quad (16)$$

which obviously is positive as  $a < b$  and  $\sigma > 1$ .

In contrast, for the producer located on the smaller market the impact of integration on profit is an open question. The net effect depends on how big the differences in market size are. If the market sizes are very different, the loss of profit in the domestic market might be more than offset by the gain in the big market and in that case the producer might gain from integration by reaping a larger total profit. Formally total profit for the producer located on the smaller market ( $\Pi_1$ ) is given by (17) where we use the results (11e) and (12e).

$$\Pi_1 = \frac{1}{18t} \left(\frac{a}{d}g + 3t\right)^2 + \frac{\sigma}{18t} \left(-\frac{b}{d}g + 3t\right) \quad (17)$$

The first-order derivative of (17) with respect to  $g$  gives:

$$\frac{\delta \Pi_1}{\delta g} = \frac{1}{9t} \frac{a}{d} \left( \frac{a}{d} g + 3t \right) - \frac{\sigma}{9t} \frac{b}{d} \left( \frac{b}{d} g + 3t \right) \quad (18)$$

The first order derivative might be negative, if  $\sigma$  is sufficiently large, i.e. integration increases total profit.

Integration will, therefore, always annoy the producer in the big market and might induce him to play the card of anti-dumping measures based on (formal) injury. The producer in the smaller market might be relaxed and even in favour of integration.

## 5. Conclusions

The de facto neglect of including the quality dimension in the GATT/WTO procedures in assessing injury might affect countries asymmetrically with respect to implementing anti-dumping measures. The model above predicts that the producer located in the large market specialises in producing the high quality product compared with the producer in the small market. This gives the producers in the large market the possibility to call for anti-dumping measures by claiming formal injury, although the producer in the large market not only dumps his product, but also creates real injury in the small market.

The paper also shows that market integration may be to the disadvantage of the producer on the large market since his profit unambiguously decreases, while the effect on the profit of the producer from the small market is ambiguous. In spite of waning dumping behavior and falling injury margins, when trade costs decrease, the producer on the large market may therefore be more eager to play the card of anti-dumping measures based on (formal) injury.

The analysis above assumes that the producer in each market does not take into account the risk or possibility of anti-dumping procedures in their strategic game. Anti-dumping measures belong to the extra ordinary policy measures and this may justify producers' negligence of policy responses. However, at least in some cases rational producers may include the possibility of policy reactions in the game. The high quality producer may speculate in the implementation of anti-dumping measures by raising the quality of his products to make the formal injury more conspicuous. Similarly, the low quality producer may be inclined to raise the quality of his products to avoid anti-dumping measures. The mere threat/opportunity of anti-dumping measures may therefore result in an upward 'bias' of the quality levels of both producers in the market equilibrium.

In the formal analysis of this paper market size is measured in a very simple way by the number of consumers, assuming that all consumers are identical apart from individual specificity of horizontal preferences. However, what matters for the results above is the market size or depths of demand for the products. The large market may therefore be found in developed economies rich in purchasing power. Developed countries may also, for other reasons, host producers of high quality products. Developed countries are human capital abundant and as R&D activities are human capital intensive, developed countries specialise in accordance with neoclassical theory in designing and producing

high quality products. The model in this paper may therefore realistically illustrate a North–South trade policy situation.

The analysis in this paper has been purely positive. Apart from the special case of predatory dumping, which is nearly impossible to identify in practice, anti-dumping measures are difficult to defend from a welfare point of view. Basically, such measures endanger the free mobility of goods and the overall welfare benefits from that. However, in a second best context the legality of anti-dumping measures should be based on clear rules which restrict the use of such measures to a minimum. The present practice, where anti-dumping measures can be imposed in case of formal injury, gives the upper hand for implementing protectionism to the developed countries. Switching to a principle of real injury as the necessary condition for anti-dumping measures cannot be rationalized from an overall welfare point of view, but such shift may provide the less developed countries with better possibilities to develop their industrial sector in a globalized economy.

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## **Appendix: Specification of constraints of parameters**

### *Fully covered markets*

The uncovered market appears if the price of the best buy for some consumers in one or both markets exceeds the utility of consuming the good i.e. if the price is 'too high'. The most aggressive price setting appears, if the trade costs are so high that the markets are completely segmented into two monopoly markets. In this case of segmented markets the markets are uncovered for

$$p_1 > (v + \theta_1 - t) \text{ and } p_2 = (v + \theta_2 - t)$$

The inverse demand function for each of the two monopolists in the uncovered market is given by<sup>21</sup>:

$$p_1 = v + \theta_1 - tQ_1 \text{ and } p_2 = v + \theta_2 - \frac{t}{\sigma}Q_2$$

where  $Q_1 = x_1$  and  $Q_2 = \sigma(1 - x_2)$

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<sup>21</sup> For all lower prices the markets are covered and hence perfectly inelastic with respect to the price.

Solutions for maximum operating profit in the above price interval are given by:

$$Q_1 = \frac{1}{2t}(v + \theta_1 - c) \text{ and } Q_2 = \frac{\sigma}{2t}(v + \theta_2 - c)$$

The corner solution of the covered market in case of quality levels at zero thus appears by inserting  $Q_1=1$  and  $Q_2=\sigma$  and  $\theta_1=\theta_2=0$  in these expressions. This gives  $v = c+2t$ .

A sufficient condition for fully covered markets is thus:

$$v \geq c + 2t. \tag{A1}$$

*Strong horizontal preferences*

It is assumed that:

$$t \geq \frac{2}{9}(1 + \sigma) + \frac{1}{3} \frac{(\sigma-1)}{(1+\sigma)} g \tag{A2}$$

The condition secures qualities as strategic variables. It follows from (9a) and (9b) that the condition is a sufficient condition for negatively sloped quality reaction functions.

Furthermore (A2) is a necessary condition for solutions for positive levels of qualities in Nash equilibrium; see (10a) and (10b).

*Modest trade costs relative to production costs*

Meaningful solutions also require positive prices in Nash equilibrium. From (11a), (11b), (12a) and (12b) we have the following rank of prices:

$$p_{22} > p_{11} > p_{12} > p_{21}$$

Hence, all prices are positive if  $p_{21}$  is positive i.e.:

$$p_{21} = \frac{1}{3} \left[ -\frac{b}{d} g + 3(t + c) \right] > 0$$

or:

$$3(t + c) > \frac{9t - 4}{9t - 2(1 + \sigma)} g$$

The left hand side of this inequality increases and the right hand side decreases with respect to  $t$ . The inequality is thus fulfilled for all values of  $t$  respecting (A2), if it is fulfilled for the threshold value:

$$t = \frac{2}{9}(1 + \sigma) + \frac{1}{3} \frac{(\sigma-1)}{(1+\sigma)} g$$

Inserting this threshold value in the inequality gives the condition (A3) after some manipulations:

$$c > \frac{\frac{2}{3} g}{(1 + \sigma)} \tag{A3}$$