Price as Indicator for Quality?

by

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Abstract

This paper examines the relation between price differences and quality differences in an oligopoly model with intra-industry trade, where goods are horizontally as well as vertically differentiated. The analysis demonstrates that the ratio of prices is not linked to the ratio of qualities in any simple way. The paper therefore questions the procedure of using unit value differences between exported and imported goods as criteria for disentangling intra-industry trade in a vertical and a horizontal part.

Keywords: Horizontal product differentiation; Vertical product differentiation; Intra-industry trade; Price ratio; Quality ratio; Unit values.

JEL: F12, F13.

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1. Introduction

A substantial part of international trade is intra-industry trade (IIT) that is trade in similar products or within industries. The reason for such two-way trade is internal scale economies and hence, imperfect competition on the markets. In some cases the internationally traded goods are completely homogenous and IIT is due to reciprocal dumping behavior between the producers. In other cases the goods are differentiated and the two-way flows reflect the differences of preferences or differences of income or wealth between consumers.

The products may as suggested by Lancaster (1966, 1979) be horizontally or vertically differentiated. Two products are horizontally differentiated, when both products have a positive demand, whenever they are offered at the same price. This is the case if the two products have the same set of characteristics, but in different proportions. In such cases all variants will be demanded, at least for limited price differences. Two products are vertically differentiated, i.e. differentiated with respect to quality, if the absolute amount of all characteristics between the two products differs. The variant which has more characteristics in some or all dimensions has a higher quality for all consumers and hence, the rank of prices reveals the rank of qualities.

In a seminal paper Abd-el-Rahman (1991) suggests using the ratio of export and import prices to disentangle intra-industry trade into IIT in horizontally and vertically differentiated goods. By using unit values of exports and imports as proxies for export and import prices he classifies IIT as horizontal, if the unit value of export to unit value of import differs less than a specific thresholds value of typically 15 percent, while it is classified as vertical IIT, if this ratio of unit values exceeds 15 percent. This procedure for classification of IIT has been followed in a large number of empirical studies, see e.g. Greenaway et al. (1994, 1995); Greenaway et al. (1999); Aturupane et al. (1999); Hu and Ma (1999); Blanes and Martin (2000); and Gullstrand (2002).

Based on Shaked and Sutton (1987) we claim that in practise two-way trade flows very often consist of products which are differentiated both horizontally and vertically. To illustrate this point let us look at footwear. 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 quite much 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).

A classification of IIT into two categories is therefore strictly speaking a misrepresentation. In a less rigorous approach, applying a benchmark of +/- 15 percent difference of unit values may illustrate a simple grouping of trade data into a category, where quality difference seems to be less important and a category, where it seems to be more important. However, such a procedure is problematic unless a strong positive correlation exists between prices and qualities.
The aim of this paper is to analyse the relation between price and quality in a duopoly model with both horizontal and vertical product differentiation. The analysis is purely theoretical and to avoid unnecessary formal complications several simplifying assumptions are introduced. Basically, we assume that one producer is located in each of two countries. Moreover, we assume the producers have access to the same technology and face the same factor prices, i.e. cost symmetry exists. What differentiates the quality of each of the two producers’ product is difference in market size and trade costs. The solution for prices and qualities in Nash equilibrium offers a framework for an analysis of prices as proxy for qualities in international trade characterized by intra-industry trade. The results show that even though price and quality ratios are positively correlated in some, but not all cases, the expressions for qualities and prices differ and the ratio of prices is thus in general an imprecise indicator of the ratio of qualities. Especially the role of marginal production costs (relative to the costs of developing quality) are shown to be crucial for the weak price-quality ratio association.

The paper is organized as follows. Section 2 develops and solves the model which builds on Hansen and Nielsen (2006). Section 3 applies the solutions of the model to an analysis of the (possible) link between the ratio of qualities and the ratio of prices and based on this formal analysis the empirical disentangling of intra-industry trade in a vertical and horizontal part is discussed. Section 4 discusses the issue in a more general framework referring also to empirical investigations. Section 5 concludes.

2. The basic model

The model presented below describes in a two country/two producer context market equilibrium and trade pattern in a market where the products are differentiated both horizontally and vertically. The basic specification of these two dimensions of tastes of the consumers has been suggested by Garella (2003, 2006) in a closed economy and later used for analysing foreign trade in Hansen and Nielsen (2006).

The world consists of two countries, 1 and 2, with one producer of a differentiated product in each. Vertically, the quality of the product is characterised by a quality indicator \( \theta \) \((0 \geq 0)\). 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 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\(^1\). 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. Although the markets are partially segmented by trade costs, it is assumed impossible for the producer to distinguish between domestic and foreign buyers. Each producer therefore charges a uniform price i.e. price discrimination is neglected\(^2\).

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\(^3\):

\[
\begin{align*}
    u_{11} &= v + \theta_1 - tx - p_1 \\
    u_{12} &= v + \theta_2 - t(1-x) - p_2 - g
\end{align*}
\]

(1a) and (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:

\[
\begin{align*}
    u_{2,1} &= v + \theta_1 - tx - p_1 - g \\
    u_{2,2} &= v + \theta_2 - t(1-x) - p_2
\end{align*}
\]

(1c) and (1d)

where \(v\) is the consumer’s reservation price for that good, \(t\) 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\(^4\). 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.

Turning to the costs, quality may influence costs through two channels. First, marginal production costs may depend on quality. For example, cars are typically produced with

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\(^1\) 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.

\(^2\) In subsection ‘Price discrimination’ we discuss the implication for our result for the case where producers price discriminate in the foreign market (reciprocal dumping).

\(^3\) 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.

\(^4\) 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).
and without extra equipment, and installing extra equipment in the car raises unit variable production costs. Secondly, higher quality of a good often appears as a result of an R&D activity and in such cases the firm also incurs sunk costs when it develops quality.

Most price theory predicts a pass-through of marginal production costs on prices, and if quality only affects marginal costs, it seems quite obvious that prices would reflect quality. This link between prices and qualities is less obvious if sunk costs are needed to develop quality, and in the following we therefore concentrate on this case. To keep the analysis simple we assume that the two firms’ costs functions are symmetric and given by:

\[ C_i = cQ_i + \frac{1}{2} \theta_i^2; \quad i = 1, 2 \]  

where \( c \) is (constant) marginal production costs and \( \frac{1}{2} \theta_i^2 \) is the flow equivalent fixed costs of the sunk costs for developing quality. The fixed costs increase more than proportionately with respect to quality due to diminishing returns of R&D activity. By convenient choice of units for costs, the parameter in the fixed term of the cost function is set to \( \frac{1}{2} \), and hence \( c \) captures also the weight of variable costs to fixed costs.\(^5\)

**Market 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 determining qualities\(^6\).

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:

\[ v + \theta_1 - tx - p_1 = v + \theta_2 - t(1 - x) - p_2 - g \]

which gives

\[ \tilde{x}_1 = \frac{1}{2t} \left[ t + (p_2 - p_1 + g) + (\theta_1 - \theta_2) \right] \]  

(3a)

Similarly, the competitive edge in country 2 is given by

\[ \tilde{x}_2 = \frac{1}{2t} \left[ t + (p_2 - p_1 - g) + (\theta_1 - \theta_2) \right] \]  

(3b)

Total demand for product 1 and 2, \( Q_1 \) and \( Q_2 \), respectively, is given by:

\(^5\) The assumed cost function is a special case of the costs function : \( C_i = (c + \lambda_i \theta_i)Q_i + \frac{1}{2} \phi_i \theta_i; \quad i = 1, 2 \), where \( c \) is constant marginal costs independent of quality, \( \lambda_i \theta_i \) is marginal production cost dependent on quality with the parameter \( \lambda_i \) indicating the dependence of production costs on quality, \( \phi_i \) the cost effectiveness of the firm in developing quality. For \( \lambda_i = 0 \) and \( \phi_i = 1 \), for \( i = 1, 2 \) we get (2).

\(^6\) 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 that the quality of goods is substitutes in the competitive game between the two producers. Formally the constraints are presented in the Appendix.
\( Q_i = \bar{x}_i + \sigma \bar{x}_2 \)
\[
= \frac{1}{2t} \left[ (1 + \sigma) t + (1 + \sigma)(p_2 - p_i) - (\sigma - 1) g + (1 + \sigma)(\theta_1 - \theta_2) \right]
\] (4a)
and:
\( Q_2 = (1 - \bar{x}_i) + \sigma (1 - \bar{x}_2) \)
\[
= \frac{1}{2t} \left[ (1 + \sigma) t - (1 + \sigma)(p_2 - p_i) + (\sigma - 1) g - (1 + \sigma)(\theta_1 - \theta_2) \right]
\] (4b)

Profits, \( \pi_i \), for the two producers are given by:
\[
\pi_i = (p_i - c) Q_i - \frac{1}{2} \theta_i^2 \quad ; i = 1, 2
\] (5)

Prices and levels of output for the two producers are determined by a Bertrand optimisation for a given set of qualities for the products. The solution is reported in the Appendix and discussed more extensively in Hansen and Nielsen (2006).

Inserting the Bertrand solution into (5) translates the two profit functions to functions of qualities only. This allows us to deal with the first game: determination of quality levels. Each of the two producers is assumed to optimise the quality of his product for a given quality of the competitor’s product. This gives the final solution for qualities (6a) and (6b) and inserting this result into the Bertrand solution gives the prices (7a) and (7b). The full solution is reported in the Appendix.

\[
\theta_1^* = \frac{(1 + \sigma)}{3} - \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))} g
\] (6a)
\[
\theta_2^* = \frac{(1 + \sigma)}{3} + \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))} g
\] (6b)
\[
p_1^* = t + c - \frac{3(\sigma - 1)t}{(1 + \sigma)(9t - 2(1 + \sigma))} g
\] (7a)
\[
p_2^* = t + c + \frac{3(\sigma - 1)t}{(1 + \sigma)(9t - 2(1 + \sigma))} g
\] (7b)

Let us take a closer look at the relations between prices and qualities based on (6a)-(7b). First of all, we observe that the quality levels as well as the prices are equal in the special cases where either trade costs are zero or market sizes are equal. In the more general cases with trade costs and differences in market sizes, the producer in the large economy will choose a higher quality and charge a higher price compared to the producer in the small economy. More specifically it follows from the results (6a)-(7b) that quality and price for the producer in the large economy increases with respect to trade costs and market size, respectively, while the opposite is the case for the producer in the small economy. This pattern follows from the assumption that quality demands fixed costs. It is easier to recover fixed costs for a firm, when it is located on the big market, and quality
and price will therefore be higher for the producer on the big market compared with the producer on the small market. Moreover, for the same reason, the comparative advantage of developing quality for the producer on the big market increases with trade costs and hence, the quality and price lead for this producer therefore increases with trade costs. Notice finally that contrary to the price levels, the Nash equilibrium for the quality levels do not depend on the marginal production costs. This result follows directly from the specific assumption that variable production costs are independent of the level of quality of the product.

3. The (lack of) correlation between relative prices and relative qualities

The model presented in Section 2 questions basically a classification of trade into the two categories, intra-industry trade in vertically and horizontally differentiated products. The two products differ both by quality and by characteristics associated with individual preferences of the consumer. The model also demonstrates that prices and qualities are endogenously determined variables through the producers’ attempt to optimize profit, i.e. qualities and prices depend on a set of parameters \( \sigma, t, c, g \).

The ratio of qualities follows from (6a) and (6b):

\[
q = \frac{\theta^*_2}{\theta^*_1} = \frac{\frac{(1 + \sigma)}{3} + \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))} g}{\frac{(1 + \sigma) + \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))} g}{3}}
\]

(8)

The ratio for prices is determined by (7a) and (7b) which gives:

\[
r = \frac{p^*_2}{p^*_1} = \frac{\left(\frac{(1 + \sigma)}{3} + \frac{c(1 + \sigma)}{3t} + \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))} g\right)}{\left(\frac{(1 + \sigma) + \frac{c(1 + \sigma)}{3t} - \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))} g}{3} \right)} = \frac{\theta^*_2 + \frac{c(1 + \sigma)}{3t}}{\theta^*_1 + \frac{c(1 + \sigma)}{3t}}
\]

(9)

If relative prices are a good proxy for relative qualities, these two ratios should have a (high) positive correlation. To find out whether this is the case, we make a comparative static analysis of the Nash equilibrium, i.e. for alternative values of the parameters \( g, \sigma, t \) and \( c \) respectively we investigate the solutions (8) and (9) and hence, conclude on the relation between relative prices and relative qualities. The formal part of the analysis is reported in the Appendix.

For trade costs \( g \) we have as explained in section 2 that \( \partial q / \partial g \) and \( \partial r / \partial g \) are both positive, i.e. a marginal increase of trade costs increase both relative quality and relative price.
This ensures a positive correlation between relative quality and relative price. The relative price thus shadows relative quality, but the link between the twin ratios is not proportionate. Turning to the impact of relative market size $\sigma$, we also have that $\partial q / \partial \sigma > 0$ and $\partial r / \partial \sigma > 0$, i.e. a marginal increase of relative market size increases both relative quality and relative price and variation in $\sigma$ therefore also leads to a positive correlation between relative quality and relative price. The producer in the larger market has an advantage in quality development through the distribution of R&D over larger sales. Quality and price will therefore increase relative to the producer on the smaller market.

The positive correlation between quality and price ratios also holds for the strength of the horizontal preference $t$, but here $\partial q / \partial t < 0$ and $\partial r / \partial t < 0$. For increasing values of $t$ consumers are more loyal to their preferred variant and therefore the benefits of quality development are diminished for both producers. They will therefore act more similar with respect to both qualities and prices. To sum up, the role of trade costs $g$, market size $\sigma$, and horizontal preferences $t$ all reveals a positive correlation between relative prices and qualities. But it should be noticed that for each of these determinants the link between relative quality and relative price is specific and not proportionate.

Variation in marginal production costs breaches this pattern of a positive link between relative quality and relative price. The marginal production cost does not influence relative quality in contrast to relative price. To be more specific; $\partial q / \partial c = 0$, while $\partial r / \partial c < 0$ and moreover, $q = r$ for $c = 0$. These relations are illustrated in Figure 1, where $q = \bar{q}$ is constant, while $r$ decreases monotonically towards 1 for increasing $c$. For especially high values of marginal costs, the relative price is thus a poor indicator of the relative quality, since high marginal costs (and at the same time relatively low R&D expenditures) influence prices only.

**FIGURE 1 HERE**

The comparative static analysis thus highlights some caveats in using the price ratio as indicator for quality. There is no link between ratio of quality and ratio of price for variation in marginal costs. To put it differently, even if marginal production costs are kept constant, a given price ratio does not correspond to a specific quality ratio as this is the outcome of the values of all determinants of the Nash equilibrium.

As discussed in relation to the cost function (2) in a more general framework quality may be related partly to sunk costs and partly to marginal production costs. However, what matters for the conclusions is that the marginal production costs influence qualities and prices differently and this will also prevail for more general specifications of the relation between costs and quality. Extension of the model to such a more general framework may improve the correlation between price and quality ratios, but the problem of using price as an indicator for quality exists, when sunk costs are important for quality.

Price discrimination

The conclusions above do not change, if producers are able to price discriminate. A recalculation of the optimization, now based on price discrimination, does not change the result for the quality ratio given by (9). The result for the price ratio in international trade
\( p_{12}/p_{21} \), i.e. producer 2’s price on market 1 (\( p_{12} \)) relative to producer 1’s price on market 2 (\( p_{21} \)), is given by an expression which functionally differs from the expression of quality ratio. Also in case of price discrimination the price ratio might therefore be a flawed indicator of quality ratio.

**The unit value approach**

As mentioned in the introduction, the ratio of unit values of exports to imports has been used as an indicator for quality differences across countries (for a given product/industry). In empirical studies flows of IIT have been disentangled into a horizontal or vertical part depending on whether the ratio of unit values were below or above a threshold value, which typically has been set to 15%.

However, this procedure for identification of the two types of IIT may in some cases be problematic as illustrated in Figure 1. Let us assume that in the special case, where the marginal production costs are zero and \( r=q \), \( r \) (and \( q \)) exceeds the 15\% threshold used in the unit value approach, that is has a value above 1.15. For modest marginal costs (\( c<\hat{c} \)) international trade is thus empirically classified as vertical, while for large marginal production costs (\( c>\hat{c} \)) trade is classified as horizontal, and in both cases the quality ratio is the same! The unit value methodology may therefore have a large element of arbitrariness in disentangling goods dependent on the relative importance of variable and fixed costs for given qualities.

*Figure 2* gives another illustration of the inbuilt problem of the unit value approach for a case where both trade costs and market size varies at the same time. As discussed above, all first order derivatives of the quality ratio and the price ratios with respect to trade costs and market size respectively are positive. For a given price ratio \( r=\bar{r} \) a trade-off therefore exists between trade costs and market size. The specific ‘iso-price ratio’ curve corresponding to the benchmark price ratio at \( \bar{r} = 1.15 \) is shown in Figure 2. The price ratios exceed 1.15 for all points above the benchmark \( r \)-curve, while the opposite is the case for all points below the \( \bar{r} \)-curve.

**FIGURE 2 HERE**

For a given quality ratio, \( \bar{q} \), a trade-off also exists between \( g \) and \( \sigma \). However, the two expressions for \( r \) and \( q \) differ in their functional form and this translates into different shapes of the trade-offs. This is illustrated in Figure 2 where the iso-quality curve \( \bar{q} \) intersects the benchmark iso-price ratio curve \( \bar{r} \) (whether the \( \bar{q} \)-curve intersects the \( \bar{r} \)-curve from below or above is irrelevant for the following arguments). The two points A and B on the iso-quality curve thus represent the same quality ratio, but different price ratios. In A the price ratio is below 1.15 and the case will be perceived as trade with

\[
\gamma = \frac{3(t+c) - (9t - 4\sigma)}{9t - 2(1 + \sigma)} g
\]
horizontally differentiated products. In B the price ratio is above 1.15 indicating trade with vertically differentiated products. The price ratio may therefore be a flawed indicator of the quality ratio, since bilateral trade between two pairs of countries with differences in size and trade costs, but with the same quality ratios, may result in different trade classifications.

4. Discussion

Price and quality are thus only loosely connected. As noticed in Nielsen and Lüthje (2002) a striking empirical observation is a large instability of the ratio of unit values over time. However, this may not surprise given the complex expressions for prices and qualities in the model presented above.

The conclusions based on our simple model are consistent with other empirical observations of IIT. Greenaway et al. (1994, 1995) and Fontagné and Freudenberg (1997) find that IIT between developed countries are dominated by vertical IIT. This is seemingly a paradox as trade between similar countries, in this case developed countries, is expected to be dominated by horizontal IIT. However, the measured large share of vertical IIT may be an optical phenomenon due to the unstable link between quality and price. For developed countries consumption and trade are dominated by quality products, i.e. categories of products, where sunk R&D costs are very important in contrast to marginal production costs. But as the ratio of prices (unit values) varies inversely with marginal production costs for a given quality ratio (see Figure 1), trade flows are thus biased to be classified as vertical IIT for developed countries, when the ratio of unit values is used as criteria.

The formal analysis above has been simplified by the assumptions of preference and cost symmetry. Countries may differ with respect to factor endowments, technology, wealth and household distribution of wealth. Each of these variables play a key role for trade as demonstrated in both old and new international trade theory. However, a generalization of the model by taking into account the above determinants for trade leads to even more complex expressions for prices and qualities and the problem of using unit values as proxy for qualities therefore persists. It is therefore not a surprise that testing trade theories based on disentangling IIT into a horizontal and a vertical part has not been very successful – to express it mildly. Especially regressions for vertical IIT have failed to confirm the expected signs for some of the explanatory variables (see Cabral et al. 2007).

Factor endowments (and technology) have especially attracted attention in trade studies. Main stream theory in international trade predicts that countries, rich in human and physical capital have a high per capita income and a comparative advantage in R&D activities. Due to the relatively cheaper R&D costs, those countries are expected to export high quality products. In such cases of strong asymmetry between the countries, the unit values may roughly indicate quality as shown in a number of recent empirical studies. Schott (2004) finds that export unit values increase systematically with exporters’ per capita income and similar results are found in an analysis of Hummels and Klenow.
(2005). Turning to imports Hallak (2006) finds that rich countries tend to import relatively more from countries that produce higher quality goods. Finally, a study by Hallak and Schott (2005) deviates from the standard procedure of equating export price with quality by developing a methodology to decompose countries’ observed export prices into quality and quality-adjusted-price components, the latter measuring variations in product prices induced by factors other than quality, e.g. currency misalignment.

5. Conclusions

This paper questions the use of prices as indicator for quality. Based on a simple duopoly model with both horizontally and vertically differentiated goods it is shown that the relation between prices and qualities is complex and in some cases prices are therefore a flawed indicator of qualities.

This conclusion also appears for alternative theoretical approaches. The new-new trade theory, developed among others by Melitz (2003), assumes horizontal product differentiation of the Dixit-Stiglitz ‘love of variety type’. Firm heterogeneity is assumed as productivity or marginal costs differ between firms. Due to this intra-industry costs asymmetry firms charge different prices, although the products are not differentiated vertically at all.

Based on the above conclusions it may therefore be considered to abandon disentangling IIT data into the two categories: horizontal and vertical IIT. An alternative would be to return to IIT regressions without such a separation according to the perceived product differentiation types. Using quantile regression techniques could be a fruitful path for explaining non-disentangled IIT, since the explanatory variables may differ according to the quantile of IIT observations we operate in (see Koenker and Hallock, 2001).

References


**Appendix**

**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

\[ p_1 > (v + \theta_1 - t) \] and \[ p_2 = (v + \theta_2 - t) \]
The inverse demand function for each of the two monopolists in the uncovered market is given by:

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

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

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

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

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:

\[ v \geq c + 2t. \quad (A1) \]

*Bertrand equilibrium – the second stage game*

Inserting (4a) and (4b) in (5) and maximizing each producer’s profit with respect to his own price, gives the following price reaction functions for the producer in country 1 and 2, respectively:

\[
\begin{align*}
p_1 &= \frac{1}{2} \left[ p_2 - \frac{(\sigma-1)g}{(1+\sigma)} + (\theta_1 - \theta_2) + (t + c) \right] \\
p_2 &= \frac{1}{2} \left[ p_1 + \frac{(\sigma-1)g}{(1+\sigma)} - (\theta_1 - \theta_2) + (t + c) \right]
\end{align*}
\]

\[ (A2) \]

\[
\begin{align*}
p_1 &= \frac{1}{3} \left[ -\frac{(\sigma-1)g}{(1+\sigma)} + (\theta_1 - \theta_2) + 3(t + c) \right] \\
p_2 &= \frac{1}{3} \left[ \frac{(\sigma-1)g}{(1+\sigma)} - (\theta_1 - \theta_2) + 3(t + c) \right]
\end{align*}
\]

\[ (A3) \]

Solving (A2) and (A3) with respect to prices gives Bertrand equilibrium:

\[
\begin{align*}
p_1 &= \frac{1}{3} \left[ -\frac{(\sigma-1)g}{(1+\sigma)} + (\theta_1 - \theta_2) + 3(t + c) \right] \\
p_2 &= \frac{1}{3} \left[ \frac{(\sigma-1)g}{(1+\sigma)} - (\theta_1 - \theta_2) + 3(t + c) \right]
\end{align*}
\]

\[ (A4) \]

and:

\[
\begin{align*}
p_1 &= \frac{1}{3} \left[ -\frac{(\sigma-1)g}{(1+\sigma)} + (\theta_1 - \theta_2) + 3(t + c) \right] \\
p_2 &= \frac{1}{3} \left[ \frac{(\sigma-1)g}{(1+\sigma)} - (\theta_1 - \theta_2) + 3(t + c) \right]
\end{align*}
\]

\[ (A5) \]

Using (A4) and (A5) in (4a) and (4b) gives the quantity demanded or output in equilibrium:

\[
\begin{align*}
Q_1 &= \frac{1}{6t} \left[ 3(1+\sigma)t - (\sigma-1)g + (1+\sigma)(\theta_1 - \theta_2) \right] \quad (A6) \\
Q_2 &= \frac{1}{6t} \left[ 3(1+\sigma)t + (\sigma-1)g - (1+\sigma)(\theta_1 - \theta_2) \right] \quad (A7)
\end{align*}
\]

*Quality equilibrium – the first stage game*

---

8 For all lower prices the markets are covered and hence perfectly inelastic with respect to the price.
The results (A4) – (A7) allow us to deal with the first-stage game: determination of quality levels. Profits in the Bertrand equilibrium are given by (5). Maximizing \( \pi_1 \) with respect to \( \theta_1 \) and \( \pi_2 \) with respect to \( \theta_2 \) by using (A4) – (A7) gives the quality reaction function for the producer in country 1 and country 2, respectively:

\[
\theta_1 = \frac{1}{(9t-(1+\sigma))} \left[ -(1+\sigma)\theta_2 -(\sigma-1)g + 3(1+\sigma)t \right] \tag{A8}
\]

\[
\theta_2 = \frac{1}{(9t-(1+\sigma))} \left[ -(1+\sigma)\theta_1 +(\sigma-1)g + 3(1+\sigma)t \right] \tag{A9}
\]

It is assumed that:

\[
t \geq \frac{2}{9}(1+\sigma) + \frac{1}{3} \frac{(\sigma-1)g}{1+\sigma} \tag{A10}
\]

The condition secures qualities as strategic variables. It follows from (A8) and (A9) that the condition is a sufficient condition for negatively sloped quality reaction functions. Furthermore (A10) is a necessary condition for solutions for positive levels of qualities in Nash equilibrium.

Solving (A8) and (A9) gives the quality levels in Nash equilibrium (6a) and (6b). The prices and output in Nash equilibrium are derived by inserting (A8) and (A9) into (A4)-(A7). This gives for prices (7a), (7b) and for quantities:

\[
Q_1^* = \frac{1}{2} \left[ (1+\sigma) - \frac{3(\sigma-1)}{(9t-2(1+\sigma))}g \right] \tag{A11}
\]

\[
= \frac{3}{2} \theta_1^*
\]

and:

\[
Q_2^* = \frac{1}{2} \left[ (1+\sigma) + \frac{3(\sigma-1)}{(9t-2(1+\sigma))}g \right] \tag{A12}
\]

\[
= \frac{3}{2} \theta_2^*
\]

Using these results, the profits in Nash equilibrium for the two companies are given by:

\[
\pi_1^* = \left( p_1^* - c \right) Q_1^* - \frac{\theta_1^{*^2}}{2} = \left( \frac{9t-(1+\sigma)}{18(1+\sigma)} \right) \left[ \frac{3(\sigma-1)}{(9t-2(1+\sigma))}g + (1+\sigma) \right]^{\frac{1}{2}} \tag{A13}
\]

\[
= \left( \frac{(9t-(1+\sigma))}{2(1+\sigma)} \right) \theta_1^{*^2}
\]
\[
\pi_2^* = (p_2^* - c)Q_2^* - \frac{\theta_2^2}{2} \\
= \frac{9t - (1 + \sigma)}{18(1 + \sigma)} \left[ -\frac{3(\sigma - 1)}{(9t - 2(1 + \sigma))} g + (1 + \sigma) \right]^2 \\
= \frac{(9t - (1 + \sigma))}{2(1 + \sigma)} \theta_2^2
\]  

(A14)

**Modest trade costs relative to production costs**

Meaningful solutions also require non-negative prices in Nash equilibrium. From (7a) and (7b) we have the following rank of prices:

\[ p_2 > p_1 \]

Hence, all prices are non-negative if \( p_i \geq 0 \). Inserting this constraint into (7a) gives

\[ c \geq \frac{3(\sigma - 1)}{(1 + \sigma)(9t - 2(1 + \sigma))} g - 1 \]

This is fulfilled for all non-negative values of \( c \) if:

\[ \frac{3(\sigma - 1)}{(1 + \sigma)(9t - 2(1 + \sigma))} g \leq 1 \]

i.e. non-negative prices appear if \( t \) is relatively large and \( g \) relative small.

**Comparative static analysis of quality and price ratios**

Differentiating (8) and (9) and using (6a) and (6b) gives the results below.

1) **Marginal costs, \( c \):**

\[
\frac{\partial q}{\partial c} = 0 \\
\frac{\partial r}{\partial c} = -\frac{(1 + \sigma)}{3} \frac{(\theta_2^* - \theta_1^*)}{(\theta_1^* + \frac{c(1 + \sigma)}{3t})^2} < 0
\]

2) **Trade costs, \( g \):**

\[
\frac{\partial q}{\partial g} = \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))} \frac{(\theta_1^* + \theta_2^*)}{\theta_1^*} > 0 \\
\frac{\partial r}{\partial g} = \frac{(\sigma - 1)}{(9t - 2(1 + \sigma))} \frac{(\theta_1^* + \theta_2^* + \frac{2c(1 + \sigma)}{3t})}{(\theta_1^* + \frac{c(1 + \sigma)}{3t})} > 0
\]
3) Relative market size, $\sigma$:

\[ q = \frac{\left(\frac{1}{z} + z\right)}{\left(\frac{1}{z} - z\right)} \]
\[ r = \frac{1}{3} + \frac{c}{3t} + z \]
\[ z = \frac{(\sigma - 1)}{(1 + \sigma)(9t - 2(1 + \sigma))} \]

where:

and hence we have:

\[
\frac{\partial z}{\partial \sigma} = \frac{2((9t - 2(1 + \sigma) + (\sigma - 1)(1 + \sigma)))}{(9t - 2(1 + \sigma)^2(1 + \sigma)^2)} > 0
\]

\[
\frac{\partial q}{\partial \sigma} = \frac{2}{3(\frac{1}{3} - z)^2} > 0
\]

\[
\frac{\partial r}{\partial \sigma} = \frac{2(1 + \frac{c}{3t})}{3(\frac{1}{3} + \frac{c}{3t} - z)^2} > 0
\]

4) Horizontal preferences, $t$:

\[
\frac{\partial \theta_z^*}{\partial t} = -\frac{\partial \theta_1^*}{\partial t} = -\frac{9(\sigma - 1)g}{(9t - 2(1 + \sigma))^2} < 0
\]

\[
\frac{\partial q}{\partial t} = \frac{\partial \theta_2^*}{\partial t} \left(\theta_1^* + \theta_2^*\right) < 0
\]

\[
\frac{\partial r}{\partial t} = \frac{\partial \theta_2^*}{\partial t} \left(\theta_1^* + \theta_2^*\right) - \frac{4c(1 + \sigma)^2(\sigma - 1)g}{(9t - 2(1 + \sigma))^2} < 0
\]

\[
\left(\theta_1^* + \frac{c(1 + \sigma)}{3t}\right)^2
\]
Figures to the text

*Figure 1: The dependence of quality and price ratio on marginal production costs*

\[ \sigma = A \]

\[ \frac{r}{q} = 1.15 \]

Note: $H$ and $V$ are horizontally and vertically differentiated products respectively according to the standard empirical method for disentangling differentiated products.

*Figure 2: The benchmark iso-price ratio curve and iso-quality ratio curve*

\[ \frac{q}{r} = 1.15 \]

Note: The quality and price ratio curves are just sketched.