On the Measurement of Product Quality in Intra-Industry Trade

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Abstract: The world has witnessed a dramatic increase in trade over the last forty years. Much of this growth in trade is intra-industry in nature. A relatively recent development in the intra-industry trade (IIT) literature is the measurement of the simultaneous import and export of quality-differentiated products, commonly known as vertical and horizontal IIT. In this paper we compare the Greenaway, Hine and Milner (1994) and Fontagné and Freudenberg (1997) approaches to disentangling vertical and horizontal intra-industry trade and examine some of the implications of employing simple ratios to define the boundary between product quality types. We present a complementary approach based on the traditional Grubel and Lloyd (GL) index and demonstrate with numerical examples its versatility and applicability at the product level. JEL no. F19

Keywords: Globalization; vertical and horizontal intra-industry trade; product quality

1 Introduction

The evolution of trade patterns remains a key area of international economics. One important observation is that much of the post-war expansion of trade has taken the form of intra-industry trade (IIT), commonly defined as the simultaneous imports and exports of goods from the same industry. As the study of IIT has developed, there has been a proliferation of empirical research in a strand of the literature that examines the simultaneous import and export of quality-differentiated goods. This empirical work has, in turn, led to a renewal of interest in the theoretical models of Falvey (1981), Falvey and Kierzkowski (1985) and Flam and Helpman (1987) who demonstrate...
that, even without increasing returns to scale, large numbers of firms will produce varieties of different quality.¹

The standard empirical approach builds on the tradition of the seminal studies of Balassa (1966) and Grubel and Lloyd (1975) who viewed product differentiation as an important part of the explanation of IIT. The task for empiricists has been to develop a methodology for differentiating between qualitatively different bilateral trade in goods from the same industry. The first stage for empirical researchers is to somehow split matched trade flows into those that are similar in quality from those that are significantly different in quality, commonly known as horizontal intra-industry trade (HIIT) and vertical intra-industry trade (VIIT) respectively. To date, two, broadly similar, methods have been employed: the first, suggested by Greenaway, Hine and Milner (1994) (hereafter GHM), builds upon a methodology proposed by Abd-el-Rahman (1991); the second, developed by Fontagné and Freudenberg (1997) (hereafter FF) builds upon Abd-el-Rahman (1984, 1986).

Both GHM and FF employ the ratio of export to import crude unit values to reveal quality differences as follows: For each product a unit value (UV) is calculated by dividing the monetary value of trade by the quantity to give a price per tonne. The ratio of export to import (or import to export) UV’s is then generated and a dispersion percentile, α, chosen to separate the horizontally from the vertically differentiated products.² The main difference between the GHM and FF approaches is how they define IIT, related to the degree of trade overlap, λ, required for the structure of trade to be considered IIT.

Econometric studies employ one or both of these methods to measure quality differences in IIT with the goal of testing separately for the determinants of vertical and horizontal IIT following the theory that the

¹ Shaked and Sutton (1984) provide an alternative approach to modelling vertical product differentiation with a small number of firms and increasing returns to scale. Dixit and Stiglitz (1977) and Lancaster (1980) describe horizontal product differentiation in terms of “love of variety” and “ideal variety” respectively. Krugman (1979) explicitly models the former. See Helpman and Krugman (1985) for a summary of models of horizontal IIT.
² The premise for using UV’s is that goods of a higher quality should command a higher price (Stiglitz 1987) so that price can be considered an (albeit imperfect) indicator of quality. Other solutions such as hedonic pricing (Cooper et al. 1993) and price elasticities (Brenton and Winters 1992) are harder to apply to the data in multi-country, multi-product studies. Torstensson (1992) suggests using UV per item as an alternative to UV per tonne although this also suffers from practical limitations. See Greenaway et al. (1994) for further discussion.
industry and country characteristics associated with IIT may differ depending on the type of product differentiation. The GHM approach has been employed by Greenaway et al. (1995), numerous country studies in Brülhart and Hine (1999), Greenway et al. (1999) and in more recent studies by Aturupane et al. (1999), Hu and Ma (1999), Celi (1999), Blanes and Martin (2000), and Gullstrand (2002). The European Commission (1996) and Fontagne et al. (1998) use the FF approach while the two are compared in Crespo and Fontoura (2004). Brülhart and Elliott (2002) take a step further and link different types of product differentiation to the costs of adjustment associated with changing trade patterns where it is assumed that factors are relatively less mobile between vertically differentiated rather than horizontally differentiated industries (known broadly as the smooth adjustment hypothesis). One explanation is that labour requirements are more likely to be significantly different between vertically differentiated industries hence job movers require greater retraining to undertake such a move resulting in higher trade induced adjustment costs.³

To date, tests for the determinants of horizontal and vertical IIT have resulted in a rather fuzzy set of conclusions. In addition to the statistical behaviour underlying the GHM and FF approaches, some of the ambiguity in the econometric evidence may be due to the choice of \( \lambda \) and \( \alpha \) as well as the standard issues related to categorical aggregation (see Nielsen and Luthje 2002 for further discussion).

The contribution of the paper is twofold. First, we examine some of the key characteristics of the GHM and FF approaches. Second, we present a geometric tool, the “product quality space”, and two related indexes of quality differentiation that are both simple to interpret and to apply to the data. Such an approach allows us to illustrate and quantify the extent of quality differences at the product level associated with any given bilateral trade relationship. Numerical examples are provided to illustrate some of the attributes of our complementary methodology.

The remainder of this paper is organized as follows. In Section 2 we outline and discuss the existing methodologies. In Section 3 we present the “product quality space” and compare our approach with the GHM and FF methods for classifying product quality in IIT. Section 4 concludes.

2 Existing Measurement Literature

The most widely used measure of IIT is the Grubel–Lloyd (GL) index, where the share of IIT in industry \( i \) for a given country is:

\[
GL_i = 1 - \frac{|X_i - M_i|}{(X_i + M_i)},
\]

(1)

where \( X_i \) and \( M_i \) are the exports and imports of industry \( i \) during a particular time period, usually one year. The index can take any value between 0 and 1 where the upper bound represents all trade being intra-industry in nature.\(^4\)

The GHM solution for disentangling vertical from horizontal IIT follows the GL tradition. IIT is therefore measured as:

\[
IIT^h_{ik} = \frac{\sum (X^p_{lik} + M^p_{lik}) - \sum |X^p_{lik} - M^p_{lik}|}{\sum (X_{lik} + M_{lik})},
\]

(2)

where \( i \) denotes an industry, \( l \) a product and \( k \) a trading partner. \( p \) denotes horizontally (H) or vertically (V) differentiated products. This index can be aggregated across trade partners. Note that (2) measures product quality at the industry level.\(^5\)

To disentangle VIIT from HIIT, GHM use unit value information so that:

\[
1 - \alpha \leq \frac{UV^X_{lik}}{UV^M_{lik}} \leq 1 + \alpha,
\]

(3)

where \( UV \) is a unit value (defined as the value of trade per tonne). Subscripts are subsequently dropped from the rest of this paper without loss of generality. The dispersion percentile, \( \alpha \), can take any value between 0 and 1. If the crude UV ratio lies outside the range in (3), trade is considered vertically differentiated. The interpretation, from a “home” country perspective, is that exports are high quality (VIIT\(^H\)) if \( \frac{UV^X}{UV^M} > 1 + \alpha \) or low quality (VIIT\(^L\)) if \( \frac{UV^X}{UV^M} < 1 - \alpha \). In the GHM approach it is suggested that UV’s are calculated at the 5-digit SITC (Standard International Trade Classification) level and then reported at a higher level of aggregation. Hence, at any higher level of aggregation simple accounting shows us that

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\(^4\) The properties of the GL index are discussed extensively in Greenaway and Milner (1986).

\(^5\) Note that (2) corrects an error in (2) of Greenaway et al. (1995).
\[ GL = HIIT + VIIT^H + VIIT^L. \]

In the literature the choice of \( \alpha \) is arbitrary but values of 0.15 or 0.25 has been the most widely employed.\(^6\)

The FF methodology is broadly similar although they differ in how they define IIT (moving away from the standard GL approach). In this case FF take an arbitrary value for \( \lambda \) (10 per cent) to act as a cut off point where any degree of trade overlap above (below) 10 per cent means that the structure of trade reflects two-way (one-way) trade. By similar reasoning GHM assume \( \lambda = 0 \) per cent. The result of employing a \( \lambda \) of 10 per cent is that UV ratios are calculated for a smaller sample of products.\(^7\)

The other technical difference between GHM and FF is that, although they use similar \( \alpha \) values, FF rewrite (3) as:

\[
\frac{1}{1 + \alpha} \leq \frac{UV^X}{UV^M} \leq 1 + \alpha, \tag{4}
\]

where the left-hand side adjustment to (3), using \( 1/1 + \alpha \) instead of \( 1 - \alpha \), ensures symmetry between the upper and lower bounds in terms of their relative distance from unity. As Fontagné and Freudenberg (1997: 29) state, “To us the left hand side of this condition [equation (3)] is incoherent with the right side, and this incoherence increases with the value of \( \alpha \).” They then point out that a 25 per cent threshold means that export UV’s can be 1.25 times higher than those for imports to fulfil the similarity condition but in the lower threshold (0.75), import UV’s can be 1.33 times higher than import UV’s to fulfil the same criteria.

The implication of the different left-hand term in (3) is illustrated in Figure 1. Let \( \frac{UV^X}{UV^M} = \tan \theta \). The upper bound is set as \( \tan \theta = 1 + \alpha \). GHM set the lower bound to \( \tan \theta' = 1 - \alpha \) whereas FF set \( \tan \theta' = 1/1 + \alpha \).

\(^6\) Greenaway et al. (1994) test a large number of \( \alpha \)’s ranging from 0.05 to 0.5.

\(^7\) Note that technically Greenaway et al. (1994; 1995) and Greenway et al. (1999) also use a minimum cut off point to avoid possible issues of reliability associated with using very small trade values, in this case imports and exports must be greater than $50 million. Both approaches have their limitations. The FF approach, for example, means losing some potentially important information. For example, if Japan exports one million automobiles to the United States but imports just under 10 per cent or 99,999 automobiles from the United States in return, then the quality differences between the imports and exports are still of potential interest to policy makers (especially if the automobiles imported from the United States are of significantly higher quality that Japanese exports). To count all automobile trade as one-way trade therefore eliminates some potentially useful information. Likewise, however, there may be a danger in disentangling vertical and horizontal IIT from relatively small levels of IIT (if for example, the number of automobiles Japan imports is just 100 instead of 99,999). This may then lead to spurious levels of vertical or horizontal IIT that may vary significantly in magnitude and over time.
Assume $\alpha = 15$ per cent so that the upper and lower bounds are respectively 1.15 and 0.85 for GHM and 1.15 and 0.87 for FF. Figure 1 illustrates this difference in lower boundary choice.

With an $\alpha$ value of 15 per cent, the area between the 1.15 (1.15) and 0.85 (0.87) lines represents those UV ratios that will be categorized as HIIT under the GHM (FF) approach. As the choice of $\alpha$ changes then this area will increase, i.e. as $\alpha$ is increased from 15 per cent to 25 per cent the boundary lines becomes 0.8 (down from 0.87) under the FF method and 0.75 (down from 0.85) under the GHM method. The larger the HIIT ‘wedge’, the greater the possibility that the GHM and FF approaches will classify the same UV ratio as one of two different types of trade. This is an obvious result given that for all $\alpha$’s between zero and one, $1 - \alpha < 1/1 + \alpha$. For example, in the case of $\alpha=15$ per cent, a UV ratio of 0.86 with be classified as VIIT under FF but HIIT under GHM.

We now highlight a potentially undesirable characteristic shared by both the FF and GHM approaches that may have implications for the analysis of changes in product quality and associated adjustment costs. The problem relates to the functional form of a UV ratio $U^{X}/U^{M}$ or $U^{M}/U^{X}$ denoted $r$. This is best explained by the use of an example.

Table 1 provides two cases, A and B, that consist of two equal but opposite pairs of UVs. In order to demonstrate what we call the disproportionate scaling of $r$ or the proportionality effect, consider the following equal but
opposite changes in \( r \) over four periods. In this example, we employ the standard GHM 15 per cent threshold to classify each \( r \) as vertical or horizontal IIT.

Assume two equal but opposite values for \( UV^X \) and \( UV^M \) for cases A \((1.50, 1.00)\), and B \((1.00, 1.50)\). Table 1 is constructed to generate equal but opposite signs on the change in \( r \) (\( \Delta r \)) shown in column 6. However, observe that the \( \Delta r \) values in case A and B are generated from different changes in \( UV^M \) and \( UV^X \). For example in case A, in period 1, a \(-0.50\) change in \( r \) is associated with a \( \Delta UV^M \) value of 0.50 in column 9. Under the GHM 15 per cent rule, the new \( r \) value of 1 in column 5 means that this product will be classified as HIIT. However, in case B, in period 1, a 0.50 change in \( r \) is associated with a \( \Delta UV^X \) value of 0.88 in column 8, significantly higher that the 0.50 value in case A. Using the same 15 per cent threshold rule, the new \( r \) value of 1.25 means that this product will be classified as VIITH, a different classification.

To clarify, for any two equal but opposite \( UV^X \) and \( UV^M \) coordinates, for example those presented in cases A and B respectively, an equal but opposite change in the value of \( r \) should be associated with an equal but opposite increase in \( UV^M \) in case A and \( UV^X \) in case B. However as we have demonstrated, \( r \) exhibits disproportionate scaling with respect to changes in \( UV^X \) and \( UV^M \). The implication of this scaling characteristic may be significant in studies that aim to quantify the extent of product quality

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**Table 1: The Disproportionate Scaling Characteristic of the UV Ratio \( r \)**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>1.50</td>
<td>1.00</td>
<td>1.50</td>
<td>VIITH</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1</td>
<td>1.50</td>
<td>1.50</td>
<td>1.00</td>
<td>HIIT</td>
<td>–0.50</td>
<td>0</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.50</td>
<td>1.75</td>
<td>0.86</td>
<td>HIIT</td>
<td>–0.64</td>
<td>0</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.50</td>
<td>2.00</td>
<td>0.75</td>
<td>VIITH</td>
<td>–0.75</td>
<td>0</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>1.00</td>
<td>1.50</td>
<td>0.75</td>
<td>VIITH</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1</td>
<td>1.88</td>
<td>1.50</td>
<td>1.25</td>
<td>VIITH</td>
<td>+0.50</td>
<td>0.88</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.09</td>
<td>1.50</td>
<td>1.39</td>
<td>VIITH</td>
<td>+0.64</td>
<td>1.09</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.25</td>
<td>1.50</td>
<td>1.50</td>
<td>VIITH</td>
<td>+0.75</td>
<td>1.25</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

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8 Appendix 1a provides a simple technical demonstration of the disproportionate scaling of \( r \).
changes for any bilateral trade relationship as any equal and opposite changes in UVs should be given an equal but opposite value. Although this scaling characteristic of $r$ or its proportionality effect may not result in a bias in econometric investigations, it has implications for the interpretation of adjustment costs if, as is commonly stated, the adjustment costs are more severe with changes in IIT that are vertical rather than horizontal in nature.

3 A Complementary Approach

3.1 The Product Quality Space (PQS)

One solution to the scaling problem is to use a method of measuring and comparing product quality differences based on the traditional GL measure. The result is an index that has symmetrical limits and is projected or scaled equally on both lower and upper bounds.

The method is also simple to use and is able to indicate the level of product quality from the perspective of either the “home” or “foreign” country. In other words, it has the desirable characteristic of exhibiting proportionate scaling, i.e. of being scale invariant but non-invariant with respect to trading partners. A geometric tool, the “product quality space” (PQS) provides a visual representation to aid our understanding of these issues.9

A PQS is a square box scaled by the maximum of either $\{UV_{X_{\text{max}}}^M \text{ or } UV_{M_{\text{max}}}^M\}$ so that the dimensions of each axis are set to the maximum value of either the import or export UV of all the ratios considered. The result is that any PQS is a perfect square. The leading diagonal is the locus where export and import UV’s are exactly matched (and equal to 1). In this extreme case all two-way trade is classified, of course, as horizontal IIT. The space contained within the dimensions of the PQS encapsulates all possible import and export UV’s in the period of study. The maximum will depend on what is being represented in the PQS. For example, a PQS can be used to study the change in the UV ratio of one product over a number of years, a number of products for a given year, or both.

Each UV coordinate can, therefore, be plotted on a PQS diagram. From the perspective of the “home” country, UV coordinates in the top left triangle

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9 The PQS is similar in construction to the industry trade box methodology developed by Azhar et al. (1998). The PQS can also be used to represent the properties of the GHM and FF indexes and provides an extra dimension to the presentation of descriptive results for studies that employ the FF or GHM approaches to consider changes in the quality of IIT for any bilateral or multilateral trading relationship.
will reflect those products where the exports are of a higher quality than imports. Similarly in the bottom right triangle, exports will be of a lower quality than imports. One benefit of such a construct is that any ray from the origin represents a locus of equal UV ratios. For example, UV’s on the axes relate to a specific level of product disaggregation within each industry, with a single observation within an industry for a specific time period being a point in that space.

3.2 Indexes of Product Quality in IIT

In this section we present a GL based measure to document systematically the levels of product quality in total IIT flows or more accurately the level of unit value dispersion. It is primarily to be used to measure the quality differences at the product level. In its simplest form we can write:

\[
\frac{HIIT}{IIT} = 1 - \frac{|UV^X - UV^M|}{(UV^X + UV^M)}.
\]

(5)

This index is symmetrical with respect to the \(UV^X = UV^M\) diagonal, but is unable to tell us how the quality of products differs between trade partners. As it is “country” invariant, it cannot distinguish between products in IIT flows which are categorized as \(VIITH\) or \(VIITL\). To handle this problem, we eliminate the modulus operator from the net UV component. The result is an index that is able to distinguish \(VIITH\) from \(VIITL\) and is given by:

\[
PQH = 1 - \frac{UV^X - UV^M}{(UV^X + UV^M)}, \quad 0 < PQH < 2.
\]

(6)

Analogous to the GL index, that measures the share of IIT in total trade flows, it is also possible to visualize this index as measuring the dispersion of product quality in IIT flows.\(^{10}\) In this form, \(PQH\) maintains symmetry and proportional scaling but is no longer “country” invariant.\(^{11}\)

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\(^{10}\) What we mean by the dispersion of product quality in IIT is similar to the interpretation of the GL index that measures the static share of IIT in total trade (TT) flows. If for example GL = 0.9, this means the share of IIT in TT at that particular point is 90 per cent of TT while the remaining 10 per cent is the share of net trade (NT) in TT. This follows from the simple accounting identity given by \(IIT + NT = TT\). Dividing through by TT we have the GL index as the share of IIT in TT. Similarly in the context of our formulation for product quality, the sum of the unit value of imports and exports of each coordinate \((UV^X + UV^M)\) is construed as total costs or quality. Hence a \(PQH\) value of 0.9 will qualify as a high quality product in the PQS. For further elaboration on the similarity in construction see Azhar et al. (1998).

\(^{11}\) We illustrate the proportional scaling characteristics of \(PQV\) and \(PQH\) in Appendix 1b.
Alternatively, the $PQH$ index can be rewritten to provide a measure of vertically differentiated quality dispersion in total IIT flows and takes the form:

$$PQV = 1 + \frac{UV^X - UV^M}{UV^X + UV^M}, \text{ with } 0 < PQV < 2.$$  \hspace{1cm} (7)

In this case, when all two-way trade flows are equal in quality (there is no vertical IIT), the $PQV$ index will be equal to unity. By construction, the sum total of these indexes is equal to 2 for any level of IIT, i.e.

$$PQV + PQH = 2 \text{ or } PQV = 2 - PQH.$$ \hspace{1cm} (8)

Therefore, all ordinates in the $PQS$ represent a $UV$ ratio and share measure of the product quality in IIT.

Once we have obtained an index value, scaled between zero and two, we need to be able to make a distinction between trade flows that are vertically from those that are horizontally differentiated. Unfortunately it is difficult to get away from a certain degree of arbitrariness in this decision. Intuitively, as quality reflects price it is useful to consider similarity in costs as a means of choosing a cut-off point. What percentage of costs, therefore, does two-way trade in a product need to share to be considered horizontally differentiated? For example, if the imports and exports of a product share at least 85 per cent of their costs (reflected in the price per unit of output) then it is not unreasonable to consider this as two-way trade in a horizontally differentiated product. Likewise, if the costs of the export country exceed those of the import country by 50 per cent (so they only share 50 per cent) then it would seem reasonable to classify this IIT as $VIIT^{HI}$. This process is similar to the interpretation of the standard GL index in the sense that we are looking to answer the question: “What value of the GL index constitutes high IIT?” Although this value depends, in part, on the level of aggregation, certain GL values are seen to reflect high IIT.

With a cut-off of 85 per cent the P Q H index can be interpreted in the following way. From the perspective of the “home” country, IIT is high quality in nature ($VIIT^{HI}$), if $PQH < 0.85$, or low quality ($VIIT^{L}$), if $PQH > 1.15$. IIT flows are, therefore, of similar quality if $0.85 \leq PQH \leq 1.15$. By similar reasoning, the $PQV$ index can be interpreted as follows: From a “home” country perspective IIT is classified as high quality ($VIIT^{HI}$)
if $PQV > 1.15$, low quality ($VIIT^1$) if $PQV < 0.85$ and of a similar quality ($HIIT$) if $0.85 \leq PQV \leq 1.15$.\textsuperscript{12}

Figure 2 presents a PQS with the VIIT and HIIT boundaries identified. The PQV index has more intuitive appeal in the sense that for the “home” country, values below 0.85 are low quality and values above 1.15 are high quality.

The important difference between the $PQH$ and $PQV$ measures and the GHM and FF procedures is that the latter (with the aid of the threshold $\alpha$) use $r$ to measure product quality from the perspective of the “home” (“foreign”) country. However, as our measures are based on the GL index, and hence scaled and symmetric, they provide us with a continuous measure of the verticalness or horizontalness of the quality of a product group.

An added feature of this geometric and share measure approach is that it is now possible to rank and compare the different quality levels of products within certain product groups or sectors in accordance with their respective

\textsuperscript{12} Further empirical work could investigate the sensitivity of our results to alternative cut-off choices. It might, for example, be useful to see the effect of picking a 15 per cent cut-off for direct comparison with the GHM and FF approaches.
share values of HIIT or VIIT. Such an approach would allow us, for example, to construct a continuous measure of “horizontalness” of IIT. An index of “horizontalness” could then be constructed which would be the sum across sectors of the product of sectoral IIT times the “horizontalness” of sectoral trade. This would remove the artificial dichotomy. See Appendix 2 for some weighting considerations.

Table 2 presents a set of numerical examples. The focus differs from Table 1 in that we now document the product quality types for nineteen products captured by the GHM, FF and PQV and PQH indexes for a range of UV ratios scattered around the lower and upper boundaries and two choices of α.

Columns 2 and 3 present various UV combinations. For simplicity, UV^M's have been kept constant at 10. Column 4 is then the simple UV ratio that the GHM and FF approaches use to make their distinction between HIIT and VIIT. The scaling or proportionality problem is immediately apparent with the ratio ranging from 0.01 to 124.4. Columns 5 to 8 present the GHM and FF classifications for the two most widely used values of α, 15 per cent and 25 per cent. As we demonstrated earlier, the different boundary choices between FF and GHM result in some two-way trade being classified as VIIT instead of HIIT. In columns 11 and 12 we present our two closely related indexes. Notice that the index is symmetric and continuous. This means the share of HIIT in total IIT can be compared across products, time or both. In these examples, by coincidence when we classify the PQV or PQH indexes according to the 85 per cent rule the result is that UV’s are classified into the same categories as the GHM 25 per cent approach.

Figure 3 provides a PQS to demonstrate how such a geometric construct can be used to help visualise the differences in product differentiation across a range of products. Consider only products A to N from Table 1 (the first 14 products are used for ease of exposition).

The dimensions are set to 12.5 (the highest export UV in this case for product N). Note that keeping the import UV’s as 10 means that the points in Figure 3 are in a vertical line. In reality there would be a broad scattering of points. In this example, from the “home” or “export” countries perspective, there is no high quality VIIT, four low quality products (A to D) and ten horizontally differentiated products (E to N). Each product has a corresponding PQV value between zero and two. By simple reasoning, the closer a point is to the horizontal axis, the lower the quality, so product A represents exports of the lowest quality over our range of products.
Table 2: Numerical Comparisons for Nineteen Products Comparing GHM, FF, PQV and PQH

<table>
<thead>
<tr>
<th>Product</th>
<th>1</th>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>UVX</td>
<td>UVM</td>
<td>UVX/UVM</td>
<td>GHM</td>
<td>FF</td>
<td>GHM</td>
<td>FF</td>
<td>GHM</td>
<td>FF</td>
<td>GHM</td>
<td>FF</td>
<td>GHM</td>
<td>FF</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>10</td>
<td>0.01</td>
<td>VIITL</td>
<td>VIITL</td>
<td>VIITL</td>
<td>VIITL</td>
<td>-9</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>10</td>
<td>0.10</td>
<td>VIITL</td>
<td>VIITL</td>
<td>VIITL</td>
<td>VIITL</td>
<td>-5</td>
<td>15</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
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Another way to visualize the same information is simply to plot the $PQH$ or $PQV$ indexes. A line plot would be appropriate to visualise how a single product has changed its quality profile over time whereas a bar chart is more appropriate if we were to consider a number of different products. Figure 4 presents products in this form.

In this example we can see how quality differs across a country’s exports with product A being the lowest quality and product S being the highest quality. In addition to using this method for checking the sensitivity of $\alpha$ (and indeed the cut off used for $PQV$ and $PQH$) there are a number of practical applications for this methodology. For example, one could examine the IIT flows in all the products from one industry to a given partner country so that businesses and policy makers can observe for which varieties a given country has a quality advantage.13 Similarly one could examine the trade in one product from a country to a range of partner countries to see where it is a net quality exporter to and where it is a net quality importer.

13 In Appendix 2, we provide a suggestion for the possible use of weights for our indexes.
4 Conclusions

In this paper we outline the properties of existing methodologies for differentiating between qualitatively different IIT flows. Although both the GHM and FF approaches provide interesting information in their own right, our identification of the underlying functional relationship between the numerator and denominator of the standard UV ratio approaches of GHM and FF reveal the disproportionate scaling issue that may lead to possible distortions in the measurement of product quality in IIT and hence inaccurate measures of the extent of horizontal and vertical product quality in IIT.

To complement the GHM and FF approaches our geometric tool is able to represent the spectrum of vertically and horizontally differentiated IIT in a diagram. This enables us to portray import and export UV’s as Cartesian coordinates. Two indexes based on the share of VIIT and HIIT in total IIT (following the tradition of the GL index but applied to the UV space) are presented. This approach provides a simple but versatile methodology
for use as a comparative measure to examine quality differentiated trade patterns across any number of years or industries, and for any bilateral or multilateral study of trade patterns. Such information may be useful in a number of ways: to accurately measure the share of product quality in IIT that is horizontal and of high or low quality to test for the determinants of VIIT and HIIT with increased confidence and to test the robustness of the results from previous empirical studies and the sensitivity of the data to changes in the choices of $\lambda$ and $\alpha$.

Appendix

1.a The Scaling of $r$

Recall that the ratio of export UV to import UV is given by:

$$r = \frac{UV^X}{UV^M}.$$  \hfill (A1)

From (A1), $\forall UV^X$ and $UV^M > 0; \forall UV^X > UV^M$ then $1 < r < \infty$ (upper sector of the PQS) and $\forall UV^X < UV^M$ then $0 < r < 1$ (lower sector of the PQS). This function $r$ can therefore be described as heavy on its denominator. A simple demonstration on the disproportionate scaling of $r$ is as follows:

We have $r = f(UV^M, UV^X) = \frac{UV^X}{UV^M}$

$$\left(\frac{\partial r}{\partial UV^M}\right)_{UV^X} = -\frac{UV^X}{(UV^M)^2} \Rightarrow \text{as } UV^M \to 0, \text{ we have } \left(\frac{\partial r}{\partial UV^M}\right)_{UV^X} \to \infty,$$

$$\left(\frac{\partial r}{\partial UV^X}\right)_{UV^M} = \frac{1}{UV^M} \Rightarrow \text{as } UV^X \to 0, \text{ we have } \left(\frac{\partial r}{\partial UV^X}\right)_{UV^M} = \frac{1}{UV^M}.$$  

As we show above, the rates of change of $r$ with respect to $UV^X$ and $UV^M$ are not similar. Hence we say that it exhibits disproportionate scaling or a proportionality effect.

1.b The Scaling of the PQV index

From equation (7) recall that:

$$PQV = 1 + \frac{UV^X - UV^M}{UV^X + UV^M}.$$  \hfill (A2)
From (A2), ∀UVX and ∀UVM > 0, ∀UVX > UV^M then 1 < PQV < 2 (upper sector of the PQS), and ∀UVX < UV^M then 0 < PQV < 1 (lower sector of the PQS).

A simple demonstration on the proportionate scaling of PQV is as follows:

We have \( PQV = f(UV^M, UV^X) = 1 + \frac{UV^X - UV^M}{(UV^X + UV^M)} \),

\[
\left( \frac{\partial PQV}{\partial UV^M} \right)_{UV^X} = -\frac{2UV^X}{(UV^X + UV^M)^2}
\]

⇒ as \( UV^M \to 0 \), we have \( \left( \frac{\partial PQV}{\partial UV^X} \right)_{UV^M} = -\frac{2}{UV^X} \).

\[
\left( \frac{\partial PQV}{\partial UV^X} \right)_{UV^M} = \frac{2UV^M}{(UV^X + UV^M)^2}
\]

⇒ as \( UV^X \to 0 \), we have \( \left( \frac{\partial PQV}{\partial UV^X} \right)_{UV^M} = \frac{2}{UV^M} \).

The partials presented above verify that the rate of change of PQV in the upper sector of the PQS \( (\partial PQV/\partial UV^M)_{UV^X} \) is similar but opposite to that in the lower sector \( (\partial PQV/\partial UV^X)_{UV^M} \). Hence PQV exhibits proportionate scaling. Our demonstration applies equally for PQH.

### 2 Weighting Considerations

It is also possible to present weighted versions of the PQV and PQH indexes. When product quality levels in IIT are expressed in the form we suggest, we can formulate weights \( w \) for PQV. We have from equation (7):

\[
PQV = 1 + \frac{UV^X - UV^M}{(UV^X + UV^M)}, \quad \text{with } 0 < PQV < 2.
\]

Define:

\[
w = \frac{UV^X + UV^M}{\sum (UV^X + UV^M)} = \frac{UV^T}{\sum UV^T}, \quad \text{(A3)}
\]

where superscript \( T \) refers to the sum of import and export unit values. The weighted PQV takes the form:

\[
PQV_W = PQV \frac{UV^T}{\sum UV^T}, \quad \text{(A4)}
\]

A similar formulation applies to the PQH index. Such an approach allows us to observe the importance of any one industry within the economy.
References


