On the Measurement of Changes in Product Quality in Marginal Intra-Industry Trade

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ABSTRACT

There is a long established thread of the international trade literature concerned with the measurement of intra-industry trade (IIT). Two distinct strands of the literature have developed: First, measures of marginal IIT that are concerned with the adjustment implications of volume-based changes in IIT; second, measures of vertical and horizontal IIT that are concerned with quality-based differences in IIT. This paper marries the two literatures to provide a new perspective on the smooth adjustment hypothesis debate and suggests the use of the marginal product quality index, a new measure of changes in quality in matched trade changes that complements dynamic measures of volume-based IIT.

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1 Introduction

A considerable literature on the measurement of intra-industry trade (the simultaneous import and export of goods from the same industry) has accumulated over the previous thirty years following in the footsteps of Balassa (1966) and Grubel and Lloyd (1975).[1] More recent developments concentrate on specific aspects of the measurement of intra-industry trade (IIT). First, adopting a volume-based approach, a series of dynamic or marginal IIT (MIIT) indices were developed to enable the researcher to investigate the relationship between matched trade changes and the costs of adjustment associated with changes in trade patterns, see Hamilton and Kniest (1991), Greenaway *et al.* (1994), Brülhart (1994), Menon and Dixon (1997) and Azhar and Elliott (2003). Second, a quality-based methodological approach was developed to enable the researcher to examine the simultaneous import and exports of quality-differentiated goods or, in other words, to disentangle so-called vertical intra-industry trade (VIIT) from horizontal intra-industry trade (HIIT), see Abd-el-Rahman (1991), Greenaway *et al.* (1994, 1995), Fontagné and Freudenberg (1997) and Azhar and Elliott (2006).

In this paper we marry these two strands of the literature to present an index and a methodology that allows us to measure the changing structure of product quality associated with changes in IIT consistent with recent developments in the measurement literature. We call the new index *marginal quality* (*MQ*). This terminology follows the convention of Hamilton and Kniest (1991), Greenaway *et al.* (1994) and Brülhart (1994) in the use of the term *marginal* whilst product quality relates to the recent Azhar and Elliott (2006) paper that looks at static measures of product quality in IIT.[2]

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[1] Surveys of the empirical, methodological and theoretical aspects of IIT can be found in Greenaway and Milner (1986) and Greenaway and Torstensson (1997).
[2] Menon and Dixon (1997) prefer the term dynamic intra-industry trade. In this paper the terms marginal product quality and dynamic product quality are used interchangeably.

In this paper we discuss two related issues: First, what is the relationship between changes in the quality of products in matched trade changes and the nature and severity (or otherwise) of the adjustment costs associated with such changes. In this paper the terms matched trade changes and MIIT are used interchangeably. Second, we use the information gleaned from this discussion to shed light on the smooth adjustment hypothesis (SAH) debate that may go some way to explain why empirical evidence for the existence of the SAH, although generally supportive, is limited despite its intuitive appeal. To understand how or why adjustment costs may differ depending on whether changes in matched trade involve changes in the quality of the products that constitute IIT it is necessary to revisit the foundations of both the marginal and quality differentiated IIT literature.

The proposition that there is a relationship between the nature of volume-based trade changes and adjustment costs is known as the SAH that states that if increases in trade are matched (or *intra*-industry in nature), then the associated adjustment costs will be less severe than if the trade changes were inter-industry in nature.[3] This is because resource transfers, as a result of sectorally matched increases in imports and exports, can be contained within individual industries or possibly firms. Inter-industry trade changes are however likely to require resources to be transferred between industries, most commonly from those contracting to those expanding. The greater the factor requirement differences between industries and the more geographically dispersed production, the more severe the adjustment implications. Theoretically, the specific-factors model suggests two sources of adjustment costs, factor-price rigidity and factor specificity with the empirical manifestations being unemployment and factor-price disparities respectively. In practice we are likely to find both phenomena occurring. Empirical tests of the SAH include Brülhart (2000), Brülhart and Elliott (2002), Erlat and Erlat (2003), Elliott and Lindley (2006), Brülhart *et al.* (2006) and

Cabral and Silva (2006). The results are now fairly consistent and show that the SAH is related to measures of MIIT but that trade is generally found to be a source of labour adjustment that is of second-order magnitude.

However, an implication from the vertical and horizontal IIT literature is that there are significant differences in the quality of the products that constitute IIT. It has therefore been argued that changes in the share of vertical and horizontal IIT in matched trade changes could be an indicator of how severe, or otherwise, trade induced adjustment costs are likely to be (see e.g. Greenaway *et al.* 2002 and Brülhart and Elliott 2002). This is analogous to the distinction in the original definition of the SAH between inter-industry and intra-industry trade. Now it is argued that, over and above the difference between intra- and inter-industry trade, changes in matched trade that involve changes in product quality will have higher adjustment costs than those associated with little or no change in the quality of the products in matched trade changes for similar *ease of factor reallocation* reasons (Brülhart and Elliott 2002). One explanation is that labour requirements are likely to be significantly different between vertically differentiated products within a given industry so that job movers between firms making products of different quality will require greater retraining to undertake such a move or may remain under or unemployed. Simply put, quality differentiated or vertical IIT is more akin to inter-industry trade with horizontal IIT retaining the properties associated with intra-industry trade in the traditional sense.

So how prevalent is vertical IIT? Empirical evidence has shown that a large proportion and indeed the majority of IIT is in products of different quality (see e.g. Greenaway *et al.* 1999, Celi 1999 and many others).[4] Given the apparently high levels of VIIT we suggest in this paper that being able to measure the extent to which changes in matched trade reflect

[3] Balassa (1966) was the first to mention the SAH directly although many authors including Krugman (1981), OCED (1994) and Cadot *et al.* (1995) have since alluded to it directly or indirectly.
[4] Actual levels of VIIT in total IIT depend on the level of categorical aggregation. It is usual in the literature to calculate IIT at the 5th digit of the Standard International Trade Classification (SITC).

differences in quality is an important and yet un-researched area of the measurement literature. If adjustment costs associated with quality changes are similar to inter-industry adjustment costs and quality changes constitute a large proportion of matched trade changes then it is not surprising that evidence for the SAH is relatively scarce, as a significant proportion of the adjustment costs associated with intra-industry trade may be similar to those associated with inter-industry trade and hence acting to bias downwards the coefficient on MIIT in traditional econometric tests of the SAH.

However, there are two problems with trying to measure the adjustment costs associated with changes in product quality in IIT. The first is the relative nature of existing static indices of product quality. The second is that in the existing volume-based MIIT literature, adjustment costs are related to actual changes in the volume of imports and exports where this actual increase or decrease can be related to inputs (most usually labour) and the adjustment costs are apparent and intuitive. However, what we are striving to measure in this paper are changes in the quality of a country's goods relative to another country or group of countries in a dynamic sense.

The difficulty revolves around the fact that the relative quality of a country's exports can increase or decrease for two reasons. First, the Home country may change its production techniques while the trading partner retains the same methods or second, the trading partner may change their production methods resulting in a higher quality offering while the Home country maintains existing production techniques. Hence, in any bilateral trading relationship it could appear that a county moves from being an exporter of relatively high quality varieties of a particular product to the producer of relatively low quality products with no change to its current production methods. Therefore, although it would seem that the home country has lost competitiveness in quality vis-à-vis the Foreign country this does not have the same clear adjustment implications as it is possible that, in the short run, no labour is displaced and no retraining or skill upgrading is required. So although the adversely affected country could be thought of as being pushed into a "low quality trap" the short-term adjustment costs are less clear. Thus, in effect, all that matters for adjustment is how the quality of exports change. This means we have to be careful in the commentary of this paper.

Our solution and the contribution of this paper is to develop and then to demonstrate how a new framework and a new index can be employed, along-side existing measures of changes in the volume of matched trade, to show that changes in the quality of the products that constitute MIIT matter for any analysis of trade induced adjustment. From this dual approach we are then able to discuss the possible adjustment costs associated with changes in product quality in MIIT that has not previously been considered in the literature.

We believe that the introduction of our index and methodological approach completes the range of tools required by empirical researchers investigating changes in net trade, changes in IIT, product quality and changes in product quality in MIIT and the associated trade induced adjustment costs.

The remainder of this paper is organised as follows. In section 2 we briefly review the MIIT and quality differentiated IIT literatures. In section 3 we present our three-stage approach for investigating the adjustment implications of changes in product quality in IIT. Section 4 suggests an empirical approach for empirical researchers and a simple numerical example while Section 5 concludes.

2 Literature Review

2.1 Marginal Intra-Industry Trade

When Hamilton and Kniest (1991) first considered the possible adjustment implications of IIT they concluded that the level of IIT has no *a priori* predictive power of future change in trade patterns. The dynamic nature of any reallocation of resources means that an observed change in a measure of static IIT (measured by the *GL* index) can mask a range of different trade flows including an increase in IIT. Various proposals for a measure of dynamic or marginal intra-industry trade have been suggested beginning with Hamilton and Kniest (1991) and followed by Greenaway *et al.* (1994), Brülhart (1994), Menon and Dixon (1997), Azhar *et al.* (1998) and Azhar and Elliott (2003).[5]

Azhar and Elliott (2003) suggest four simple criteria that a measure of trade induced adjustment should satisfy to be considered an appropriate index for testing the SAH. These are: (1) the greater the sectoral disparity in trade flows the greater the factor market disruption and so an index should be an increasing function of the net change in trade (monotonicity); (2) the factor reallocation requirements associated with a given level of unmatched trade changes are equal and opposite for bilateral trade partners so that the adjustment costs associated with an industry expansion are equal to those associated with an industry contraction (consistency); (3) to be able to recognise if a country is specialising *into* or *out of* an industry (country specificity); (4) if firms have identical factor requirements then matched trade changes will have no resource reallocation costs because matched increases or decreases in exports and imports means that an industry's total demand *ceteris paribus* is unaffected and hence no resource reallocation is required.

Consequently, Azhar and Elliott (2003) develop the Trade Adjustment Space (TAS) and derive the *S* index that satisfies criteria (1)-(4) defined as;

$$S_t = \frac{(\Delta X - \Delta M)_t}{2\max\{|\Delta X|, |\Delta M|\}} = \frac{1}{2L}(\Delta X - \Delta M)_t \qquad (1)$$

[5] Dixon and Menon (1997) and a number of country specific studies in Brülhart and Hine (1999) apply a range of measures to the estimation of the adjustment effects of increased integration in Australia and selected EU countries respectively.

where $\Delta X_t = X_t - X_{t-1}$, $\Delta M_t = M_t - M_{t-1}$ and subscripts in the numerator belong to the set of years in the period of study i.e. for *N* years, $t = \{1, 2, 3, ...N\}$, while *L* in the denominator is the single absolute maximum value of either ΔX or in ΔM in *N*. i.e. *L* is the length of one side of a TAS defined as the largest change in *X* or *M* in the period studied.

The index has a range of $-1 \leq S \leq 1$ with each change in trade pattern (represented by a cartesian point in the *TAS)* having a corresponding adjustment value. The S index provides a measure from the perspective of the home country so that S is a simple monotonically increasing function of $\Delta X - \Delta M$ that also satisfies consistency and country specificity. As we shall observe in Section 3, the *S* index in unit value space provides one of the foundation stones for our *MQ* index.

2.2 Vertical and Horizontal Intra-Industry Trade

The development of the quality differentiated IIT literature has followed a similar path to that of MIIT. 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 and 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.

The first stage for empirical researchers is to somehow separate those matched trade flows that are similar in quality from those that differ significantly in quality: in other words, to disentangle horizontal IIT from vertical IIT. There are now three, broadly similar, methods that 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); and the third, constructed by Azhar and Elliott (2006) addresses a number of concerns with the GHM and FF approaches and presents a geometric tool called the Product Quality Space (PQS) and a related set of indexes that allow the researcher to estimate more accurately the level of unit value dispersion so that the researcher can measure differences in product quality in IIT. This third approach provides a starting point and the second foundation stone for the construction of our *MQ* index.

The former two approaches employ the ratio of export to import crude unit values to reveal quality differences. That is, 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 (or kilogram). In GHM and FF the ratio of export to import (or import to export) UVs is then generated and a dispersion percentile (α) chosen to separate the horizontally, from the vertically, differentiated products.[6] FF suggest calculating unit values as follows;

$$\frac{1}{1+\alpha} \leq \frac{UV_{lik}^{X}}{UV_{lik}^{M}} \leq 1+\alpha \qquad (2)$$

where UV is a unit value (defined as the value of trade per tonne) for each product, *i*, year, *t*, and bilateral trade partner, *k*. The left-hand side of equation (2) ensures symmetry between the setting of the upper and lower bounds in terms of the relative distance from unity, a problem that FF correctly recognised with the lower bound of the GHM approach that uses (1-*a*). The dispersion percentile, α, can take any value between 0 and 1. If the crude UV ratio lies outside the range in equation (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+α or low quality ($VIIT^{L}$) if $\frac{UV^X}{UV^M}$ <1/1+α. Simple accounting shows that at

[6] The premise for using UVs is that goods of a higher quality should demand a higher price (Stiglitz 1987) so that price can be considered, an all be it, imperfect indicator of quality. For further discussion see Greenaway *et al.* (1994) and Aiginger (1997).

higher levels of aggregation, $GL = HIIT + VIIT^{H} + VIIT^{L}$. In the literature the choice of *a* is arbitrary but values of 0.15 or 0.25 have been the most widely employed.[7]

In contrast, Azhar and Elliott (2006) present a new method of disentangling vertical and horizontal IIT using a modified GL index to differentiate between horizontal and vertical IIT in their Product Quality Space (PQS) that is independent of the choice of α. The *PQV* or its sister the *PQH* index is analogous to the *GL* index (that measures the share of IIT in total trade flows at any point in time) and can be thought of as indices that measure the dispersion of product quality in IIT flows. The *PQV* and *PQH* indices are given by;

$$PQV = 1 + \frac{UV^{X} - UV^{M}}{\left(UV^{X} + UV^{M}\right)}, \quad \text{with } 0 < PQV < 2 \tag{3}$$

$$PQH = 1 - \frac{UV^{X} - UV^{M}}{\left(UV^{X} + UV^{M}\right)}, \quad \text{with } 0 < PQH < 2 \tag{4}$$

Once we have an index value, scaled between zero and two, a decision needs to be made as to what percentage of costs 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% 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% (so they only share 50%) then it would seem reasonable to classify this IIT as $\text{VIIT}^{\text{HIGH}}$. Thus, the *PQV* (*PQH*) index can be interpreted as follows: from a Home country perspective IIT is classified as high

[7] Greenaway *et al.* (1994) test a large number of *a*'s ranging from 0.05 to 0.5. Econometric studies have employed separately either GHM or FF methods to measure quality differences in IIT with the goal of testing separately for the determinants of vertical and horizontal IIT. 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), Gullstrand (2002) and Sharma (2002). The European Commission (1996), Fontagné *et al.* (1998) and Fontagné *et al.* (2006) use the FF approach while the two are compared in Crespo and Fontoura (2004).

quality ($VIIT^{HIGH}$) if *PQV* > 1.15 (*PQH* < 0.85), low quality ($VIIT^{LOW}$) if *PQV* < 0.85 (*PQH* > 1.15) and of a similar quality (HIIT) if $0.85 \leq PQV, PQH \leq 1.15$.[8]

By construction, both the *PQV* and *PQH* indexes have symmetrical limits and are projected or scaled equally on both lower and upper bounds. The method is simple to use and is able to distinguish between high and low quality IIT from the perspective of either the Home or Foreign country. In other words, they have the desirable characteristic of being *country specific* (criteria 3).

In Section 3 we combine the different aspects of Azhar and Elliott (2003) and Azhar and Elliott (2006) to propose a new index of marginal quality that we believe completes the range of tools required by an empirical researcher investigating quality-based and volume-based changes in trade patterns and their trade induced adjustment implications both in the static and dynamic context.

3 Methodological Framework

3.1 The Product Quality Space and Unit Value Adjustment Space

We begin by reviewing the product quality space (PQS) framework from Azhar and Elliott (2006). The PQS is a square box scaled by the maximum of either $\{UV^X \text{ or } UV^M\}$ so that the dimensions of each axis are set to the maximum (largest) value of either the import or export UV for all the UV coordinates considered. 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 as horizontal IIT. The space contained within the dimensions of the

[8] 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

PQS encapsulates all possible UV coordinates or combinations in the period of study. The nature of these combinations is dependent upon what is being represented in the PQS. For example, a PQS can be used to study changes in the UV coordinates of one product over a number of years, a number of products for a given year, or indeed both.

The plot of these UV coordinates and their corresponding *PQV* values can be visualised in Figure 1. The 45 degree line of the PQS represents one hundred percent horizontal IIT. From the perspective of the Home country, UV coordinates in the top left triangle (to the left of the 45 degree line) represent products where exports are of a higher quality than imports. Similarly in the bottom right triangle (to the right of the 45 degree line), exports will be of a lower quality than imports. One benefit of the PQS is that any ray from the origin represents a locus of equal PQV values (see the equi-PQV ray in figure 1).

[Figure 1 about here]

However, there are limitations in the use of the *PQV* and *PQH* indexes in a dynamic context that are similar to the criticisms of the use of a static *GL* index when used to measure changes in trade patterns, and its associated trade-induced adjustment consequences (see e.g. Hamilton and Kniest 1991, Shelburne 1993, and Brülhart 1994). To illustrate this limitation, assume that points *A* (*PQV*=1.15), *B* and C in figure 1 represent the UVs coordinates for three individual years for a particular product.[9] A coordinate change from *A* to *B* involves only a small change in the value of the *PQV* index (say *PQV*= 1.18) indicating an increase in product quality from the "Home" country perspective. However, what remains masked and not captured by the *PQV* index will be the extent of the change in the UV of exports that in this case was significantly greater than the change in the UV of imports.

level of aggregation, certain *GL* index values are seen to reflect high IIT.

This scenario is in turn reversed in the case of a coordinate change from B to C involving a substantial contraction in UV of the Home country while the *PQV* index at C remains unchanged. (We illustrate this further in Section 4). Thus, although the product quality space (PQS) is useful in its own right, if we want to examine the implications of changes in product quality associated with different patterns of change in ΔUV^X and ΔUV^M in IIT, we need to construct a dynamic version of the *PQV* index. The solution is to translate the Trade Adjustment Space (TAS) developed by Azhar and Elliott (2003) into a unit value space (UVS). This allows us to visualise the evolution of unit value change over time.

We therefore construct the UVS that captures all changes in the unit value of exports (UV^X) and imports (UV^M) for any industry (*i*), for any period (*t*) where a change in UV^X (ΔUV^X) and UV^M (ΔUV^M) can be positive, negative or zero.[10] Let a hypothetical industry consist of the set of all ΔUV^X and ΔUV^M, for *N* years, $t = \{1, 2, 3, ...N\}$ [11]. The dimensions of the UVS are central to the construction of our *MQ* index. Similar to the TAS of Azhar and Elliott (2003), the essential ingredient is that the length of any side is set at two times the maximum of the largest absolute value of whichever is bigger from the change in unit values of import and export recorded during the considered time period. Export ΔUVs are depicted on the vertical axis (+/-ΔUV^X) and import ΔUVs on the horizontal axis (+/-ΔUV^M).[12] Each UVS depicts the relationship between a Home (*H*) and Foreign (*F*) country. Figure 2 presents a hypothetical UVS.

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[9] We confine our illustration to the *PQV* index. Similar reasoning applies to the *PQH* index.

[10] Given this papers emphasis on IIT it is simplest to think of this methodology in terms of an industry although it is equally applicable for any level of aggregation such as country, sector or even product.

[11] Unit values are usually available at uniform (discreet) time intervals, annually, quarterly or monthly. Changes in UV^X and UV^M are analysed from an initial starting point $t=0$. All trade data should be deflated to obtain UVs in constant prices.

[12] Observe that the axes in Figure 2 are labeled (+/-ΔUV^M_{max}) and (+/-ΔUV^X_{max}) for convenience. In practice the actual value depends on which of the two is the largest and this value is then applied to both axes to ensure a perfect square. E.g., if ΔUV^M_{max}=5 and ΔUV^X_{max}=10 then the dimensions of the UVAS will be 20 by 20.

[Figure 2 about here]

The axes are labelled in accordance with the Cartesian plane so the UVS consists of four quadrants I-IV. The origin (0) represents the unique (ΔUV^X, ΔUV^M) = 0 case. Quadrant I contains all positive changes and quadrant III contains all negative changes. Quadrant II consists of negative ΔUV^X and positive ΔUV^M while quadrant IV contains negative ΔUV^M and positive ΔUV^X. The 45-degree *A0B* line is that of perfectly matched UV changes. Following our definition, lines parallel to the *A0B* line are termed equi-UV lines such that any two points, such as *j* and *k* (in Figure 2), on an equi-UV line, share equal adjustment pressures. Assuming *j* and *k* represent two distinct periods for any given industry, for the Home country, in period *j*, import UVs have fallen and export UVs have remained unchanged while in period *k*, export UVs have increased and import UVs have remained unchanged. In both periods, everything else staying the same, the result is a relative increase in demand for high quality varieties of the Home country's products from that industry.

For either country, the further a point, such as *j* or *k*, is away from the *A0B* line the greater the change in the relative quality of the products that constitute matched trade changes or MIIT. For point *k* in the example above, the Foreign country's export UVs have fallen relative to its import UVs.[13] As we discussed in Section 2, relating changes in the quality of products in MIIT to adjustment costs is not straightforward. As we shall explain later the adjustment implications need to be considered in conjunction with volume based indices.

We are now in a position to propose our measure of changes in product quality in IIT. The solution is to translate the *S* index from equation (1) into the UVS. The four

[13] If we weaken our assumption of symmetry so we assume it is easier for an economy to adapt to quality expansions rather than quality contractions then the lines of equi-adjustment become non-linear and non-symmetric. However, the underlying concepts remain the same.

criteria discussed in Section 2 are now three in the context of the UVS. Therefore: (1) the greater the sectoral disparity in unit values the greater the factor market disruption and so an index should be an increasing function of the change in unit values (monotonicity); (2) the factor reallocation requirements associated with a given level of unmatched UV changes are equal and opposite for bilateral trade partners so that the possible adjustment costs associated with an increase in quality are equal to those associated with a quality contraction (consistency); (3) to be able to recognise if a country is increasing or decreasing the quality of its products within a given industry (country specificity). The forth criterion no longer holds as one can no longer argue that if firms have identical factor requirements then matched UV changes will have no resource reallocation costs as matched increases or decreases in export unit values and import unit values means that quality has changed which would mean some reallocation of resources.

Our proposed measure of changes in product quality in MIIT, the marginal quality (*MQ*) index is therefore given by[14];

$$MQ_t = \frac{\left(\Delta UV^X - \Delta UV^M\right)_t}{2\max\left\{\left|\Delta UV^X\right|,\left|\Delta UV^M\right|\right\}} = \frac{\left(\Delta UV^X - \Delta UV^M\right)_t}{2L} \tag{5}$$

where $\Delta UV_t^X = UV_t^X - UV_{t-1}^X$, $\Delta UV_t^M = UV_t^M - UV_{t-1}^M$ and similar to equation (1) subscripts in the numerator belong to the set of years in the period of study i.e. for *N* years, $t = \{1, 2, 3, ...N\}$, while *L* in the denominator of the index is the single absolute maximum value of either ΔUV^X or ΔUV^M in *N*. i.e. *L* now is the length of one side of a UVS defined as the largest absolute change in ΔUV^X or ΔUV^M.

Thus this *MQ* index is similar to the *S* index from equation (1) but translated for use in the UVS where for *N* years, for $t = \{1, 2, 3, ...N\}$ we have $-1 \le MQ \le 1$ i.e. This index shares the properties of the S index in that it satisfies criteria (1) to (3) but for product quality. The index is also similarly scaled by the maximum of the unit values changes for any given time period or range of products.[15]

4. An Empirical Strategy and Numerical Example

So how would one utilise the tools we now have at our disposal to examine the possible implications associated with changes in product quality in MIIT or matched trade? We suggest a three-stage approach.

Stage 1: We suggest a return to the TAS methodology proposed by Azhar and Elliott (2003) to initially identify those industries that have witnessed significant changes in their trade patterns. There will be a number of industries that have experienced large changes in inter-industry or net trade that are likely to have incurred significant levels of adjustment cost. There will be a second group of industries that reveal little change in their trade patterns over time so will have experienced little in the way of adjustment pressures. However, there may also be an important, potentially large, third group of industries that record large changes in matched trade that, according to the SAH, are likely to have incurred relatively little adjustment pressure or costs. It is this group of industries that we believe need to investigated further at a second stage. At this point the S index values can be ranked from largest to smallest so one can observe the industries that are likely to have suffered the largest volume based adjustment costs from the perspective of the Home country.

Stage 2: Although not crucial to the analysis of this paper we now suggest that one utilises the PQV index and PQS methodology to disentangle vertical from horizontal IIT for

[14] Thus measuring changes in product quality in MIIT using the MQ index means measuring the extent of trade induced adjustment costs associated with the different patterns of changes in ΔUV^X and ΔUV^M in MIIT.

those products or industries selected from Stage 1 for illustrative purposes. If one calculates *PQV* indices for each year and for each product or industry under analysis one would be able to observe the differences in quality across products and years between bilateral trade partners. This however, will only give an indication of the static levels of quality differences between imports and exports in any given year. To get an index that measures the change in the quality of products within MIIT one needs to go to Stage 3. Stage 2 whilst not essential provides useful information to help interpret the values from Stage 3.

Stage 3: The suggestion now is to calculate *MQ* indices to capture the extent of the change in quality in MIIT. The contribution of this paper is that for example, in cases where both imports and exports similarly increase dramatically, the SAH will see such a change as benign. However, if underlying these increases in imports and exports the quality of imports remains constant but the quality of exports falls noticeably this could result in adjustment costs that would not be captured by volume-based MIIT indices alone.

The actual calculation of *MQ* indices requires a judgement on the period to be analysed in a similar way to the *A* index of Brülhart (1994) such that one can estimate 1 year, 5 year or moving average calculations of the *MQ* index depending on the question to be asked (the data is of course deflated to a constant year).

Once *MQ* indices have been calculated and presented in conjunction with the *S* indices from Stage 1 we are able to allocate each product to one of four groups from the Home countries perspective: (1) positive *S* and negative *MQ*; (2) positive *S* and positive *MQ*; (3) negative *S* and negative *MQ*; (4) negative *S* and positive *MQ*. It could be argued that for the Home country, a negative *S* and a negative *MQ* would be the products (and possibly industry) that a government should be most concerned about as this represents imports increasing faster than exports and the quality of exports falling relative to the quality of imports.

[15] See Appendix 1 for proofs of the properties of the *MQ* index and Appendix 2 for the construction of a

For reasons of brevity we leave country or industry specific empirical analysis for future research. One reason is that sheer size of possible applications for such a methodology that, depending on what one wishes to investigate, can be applied to any countries, industries, products or trade relationships. For example we might want to: (1) compare China and its bilateral trade relationships with its East Asian neighbours to investigate which products and sectors China is improving the quality of its products relative to its trading partners and to see whether the growth of China represents an opportunity or a threat; (2) compare the UK and its EU partners (where IIT levels are considerably higher) to examine whether, following the 1992 Single European Act, there have been noticeable changes in the quality of UK exports *vis-à-vis* its European neighbours; (3) to observe whether the UK (or any other country in the EU) is moving into high quality of low quality production which could have potentially important adjustment implications especially if it means a country getting caught in a low quality trap that it may prove difficult to escape later; and (4) econometrically the *MQ* index can be used to complement volume based measures of matched trade changes such as the *S* index or other trade adjustment indices (see Azhar and Elliott 2003) as a right-hand side variable in tests of the SAH. Ideally one would employ both where we hypothesise that the additional inclusion of the *MQ* index will provide stronger evidence in support of the SAH.

What follows is a simple numerical example to illustrate how the *MQ* index can be used in practice and its simplicity and empirical appeal. Table 1 presents the UV figures for five periods for a given industry and for a given bilateral or multilateral trade relationship.

[Table 1 about here]

weighted *MQ* index.

What the example in Table 1 demonstrates is that the static *PQV* index returns similar values for each individual year and hence each coordinate will be on the same, or close to, the same ray from the origin of a product quality space (PQS) diagram (see figure 3).

[Figure 3 about here]

However, to get a feel for the how the quality of products that constitute matched trade changes has changed we need a dynamic measure. For example, between 2000 and 2001 the UV of exports for the Home country declined from 8 to 4 which is matched by a fall in the UV of imports into the country from 2 to 1. The *MQ* index records a negative value of -0.21 suggesting the Home country is experiencing a negative or adverse quality move. Between 2001 and 2002 not much changes (only a small increase in the UV of exports). Thus, we would expect only a small but positive quality change and this is indeed what the *MQ* index records with a value of 0.07. We then get a negative shock between 2002 and 2003 and then a much larger positive shock between 2003 and 2004. All these values are reflected in the *MQ* index. In Figure 4 we present the UVS diagram for the numerical example above.

[Figure 4 about here]

What Figure 4 clearly shows, is that the further away from the leading diagonal, the greater the change in quality. For example, it is clear that 2003-2004 if the furthest away and has the highest absolute *MQ* index of 0.38. The furthest negative point away from the leading diagonal is 2000-2001 that translates into a *MQ* index of -0.21.

Thus, by the use of the methodology proposed in this paper, it is possible to represent any bilateral trade relationship quickly and efficiently enabling the empirical researcher to pinpoint potentially problematic industries and to reveal which industries are losing the battle, either as a result of competition or voluntarily, to remain the producer of the highest quality products. If we then combine *MQ* indices with indices of volume based changes in matched trade we can derive additional insights into the potential trade induced adjustment costs that certain products or industries may be experiencing.

4 Summary and Conclusions

This paper presents the marginal product index that satisfies our theoretical priors and captures changes in quality in matched trade changes. We develop a tool that allows us to visually represent changes in product quality in MIIT for any period and at any level of aggregation. This is coupled with an index that is both intuitive and easy to calculate. This means we can examine time series or cross sectional data for multilateral or bilateral trade flows and identify industries that, given existing trends, are likely to come under pressure from even greater increased quality competition. This new approach complements the existing MIIT indices that are volume-based and not, as in this case, quality or unit value based.

We believe that the approach outlined in this paper might be able to reveal trade induced adjustment effects that are in fact qualitatively more important that those previously detected on the basis of the volume only based indices of matched trade changes. Verification of the indices empirical strength is left for future research. Finally, we have restricted the application of the *MQ* index to the IIT domain. Such an approach could also be extended to consider changes in the quality in any trade flows whether inter-industry or intra-industry in nature.

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Appendix 1: Properties of MQ index: Scaled, Symmetric and Proportional

1. Scaling

Consider equation (5), $MQ_t = \dfrac{\left(\Delta UV^X - \Delta UV^M\right)_t}{2\max\left\{\left|\Delta UV^X\right|,\left|\Delta UV^M\right|\right\}} = \dfrac{\left(\Delta UV^X - \Delta UV^M\right)_t}{2L}$ (5)

We have $\left(\dfrac{\partial MQ}{\partial \Delta UV^M}\right) = -\dfrac{1}{2L}$ and $\left(\dfrac{\partial MQ}{\partial \Delta UV^X}\right) = \dfrac{1}{2L}$

These partials verify that the rate of change of *MQ* in the upper sector of UVS $\left(\dfrac{\partial MQ}{\partial \Delta UV^M}\right)$ is similar but opposite to that in the lower sector, $\left(\dfrac{\partial MQ}{\partial \Delta UV^X}\right)$. Hence the *MQ* index exhibits proportionate scaling.

2. Symmetry about the diagonal $\Delta \mathrm{UV}^X = -\Delta \mathrm{UV}^M$

Consider again (5), $MQ = \dfrac{\Delta UV^X - \Delta UV^M}{2L} = f(\Delta UV^M, \Delta UV^X)$

$$f(-\Delta UV^X, -\Delta UV^M) = \frac{-\Delta UV^M - (-\Delta UV^X)}{2L} = \frac{\Delta UV^X - \Delta UV^M}{2L} = f(\Delta UV^M, \Delta UV^X)$$

This shows that *MQ* index is symmetrical about the diagonal $\Delta \mathrm{UV}^X = -\Delta \mathrm{UV}^M$

3. Geometrical relation between $(\Delta \mathrm{UV}^M, \Delta \mathrm{UV}^X)$ and *MQ*

Consider again (5), $MQ = \dfrac{\Delta UV^X - \Delta UV^M}{2L}$. ie. $\Delta UV^X = \Delta UV^M + 2L(MQ)$

This shows for every *MQ* index, there is a unique straight line in the UVS with slope of unity and the y-intercept, $2L(MQ)$. This implies that *MQ* values will be the same for every point $(\Delta\mathrm{UV}^{M}, \Delta\mathrm{UV}^{X})$ on the same line.

Appendix 2: Construction of Weights for the *MQ* index

When using the *MQ* index to measure changing quality we want to have it summed at a disaggregated level. Thus appropriate weights have to be chosen to measure the changing quality of an industry. The solution is for the index to be weighted by the significance of the sector.

Consider again (5) with subscript *i* for each sector we have:

$$MQ_i = \frac{\Delta UV_i^X - \Delta UV_i^M}{2\max\left(\left|\Delta UV_i^X\right|, \left|\Delta UV_i^M\right|\right)}$$

Similarly $MQ_{TOT} = \dfrac{(\Delta UV_{TOT}{}^X - \Delta UV_{TOT}{}^M)}{2\max\left\{\left|\Delta UV_{TOT}{}^X\right|, \left|\Delta UV_{TOT}{}^M\right|\right\}}$

$$= \frac{\sum \Delta UV_i^X - \sum \Delta UV_i^M}{2\max\left(\left|\Delta UV_{TOT}^X\right|, \left|\Delta UV_{TOT}^M\right|\right)}$$

$$= \frac{\sum\left(MQ_i\, 2\max\left(\left|\Delta UV_i^X\right|, \left|\Delta UV_i^M\right|\right)\right)}{2\max\left(\left|\Delta UV_{TOT}^X\right|, \left|\Delta UV_{TOT}^M\right|\right)}$$

So weighted MQ_i becomes:

$$MQ_W = (MQ)_i \frac{2\max\left(\left|\Delta UV_i^X\right|, \left|\Delta UV_i^M\right|\right)}{\sum_i 2\max\left(\left|\Delta UV_{TOT}^X\right|, \left|\Delta UV_{TOT}^M\right|\right)}$$

Let $L = \max\left\{\left|\Delta UV_i^X\right|, \left|\Delta UV_i^M\right|\right\}$, $L_{TOT} = \max\left\{\left|\Delta UV_{TOT}{}^X\right|, \left|\Delta UV_{TOT}{}^M\right|\right\}$

So we have;

$$MQ_W = (MQ)_i \frac{L}{\sum_i L_{TOT}}$$

It is interesting to note that this formulation enables us to have a multilayered view of quality change. Thus MQ_{TOT} (as the top most layer) will encapsulate all the MQ_i cells.

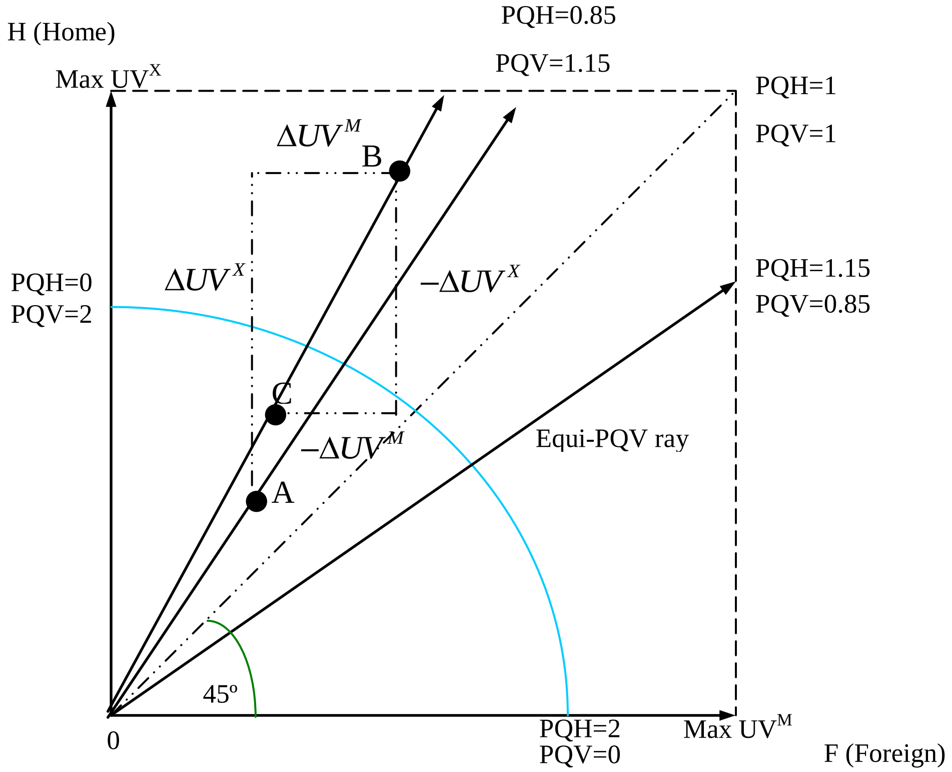

Figure 1: The Product Quality Space (PQS)

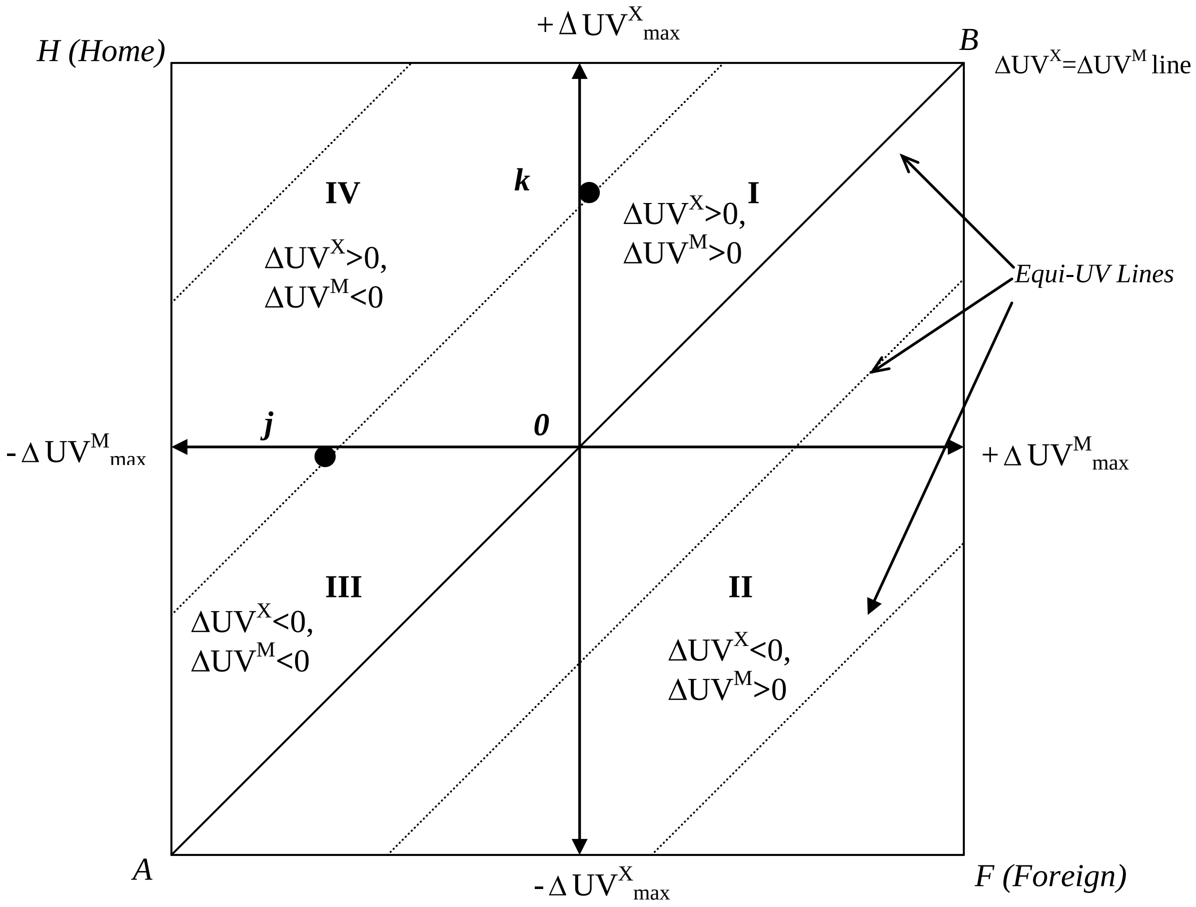

Figure 2: The Unit Value Space (UVS)

Table 1: Numerical example of the *MQ* index

Year	UV(X)	UV(M)	*PQV*	Δ(Year)	ΔUV(X)	ΔUV(M)	*MQ*
2000	8	2	1.60		-	-	-
2001	4	1	1.60	2000-2001	-4	-1	-0.21
2002	5	1	1.67	2001-2002	1	0	0.07
2003	2	0.5	1.60	2002-2003	-3	-0.5	-0.18
2004	9	2.2	1.61	2003-2004	7	1.7	0.38

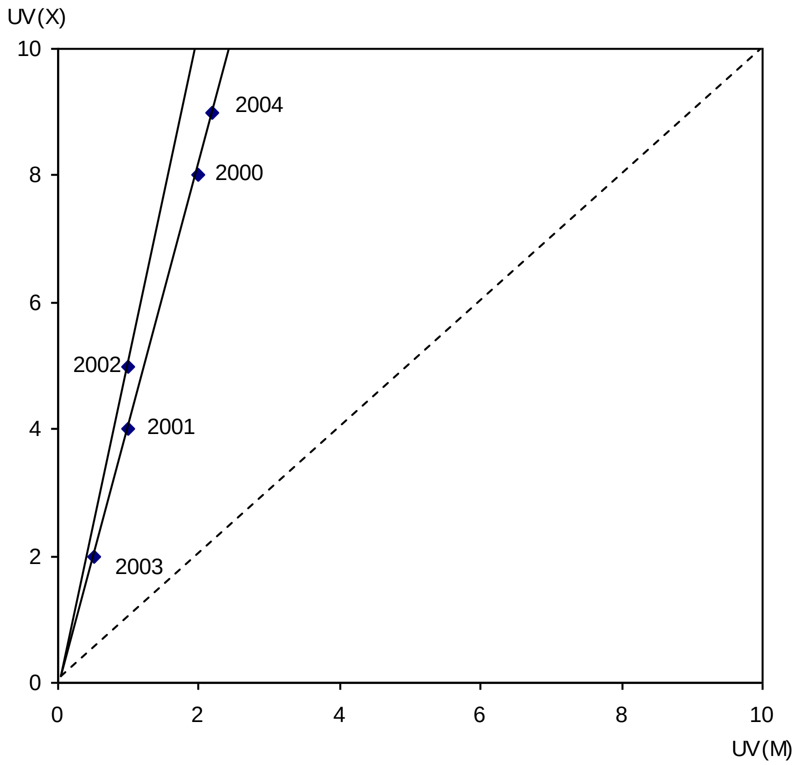

Figure 3: PQV values for the numerical example.

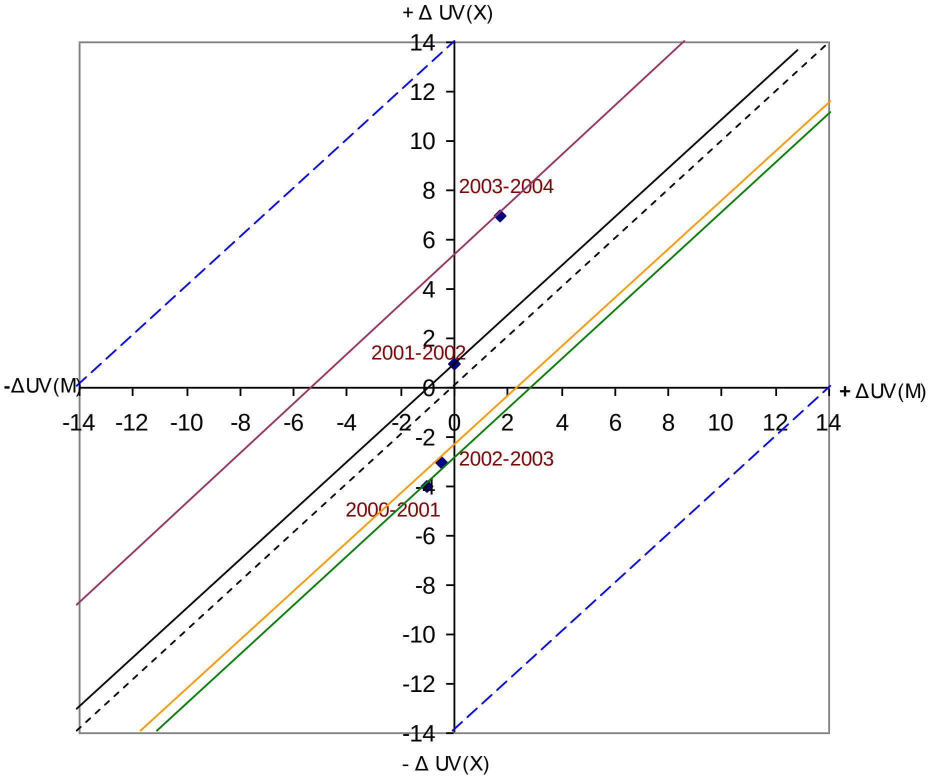

Figure 4: An UVS for the numerical example.