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Abstract

In this study, we argue that the conventional intra-industry trade (IIT) index does not address the quality issue directly and propose a methodology to make full use of unit-price gap information to deduce quality differences between simultaneously exported and imported products. By applying this measure to German trade data at the eight-digit level, we study the quality improvement of Chinese export goods in its IIT with Germany. We compare the case of China with those of Eastern European countries, which are also major trading partners of Germany. Our results show that the unit-value difference in IIT between Germany and Eastern European countries is clearly narrowing. However, China's export prices to Germany are much lower than Germany's export prices to China, and this gap has not narrowed over the last 23 years. This is at odds with the common perception that China's product quality has improved, as documented by Rodrik (2006) and Schott (2008). Our results support Xu (2010), which argued that incorporating the quality aspect of the exported goods weakens or even eliminates the evidence of the sophistication of Chinese export goods in Rodrik (2006).

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Product Quality and Intra-Industry Trade[*]

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ABSTRACT

In this study, we argue that the conventional intra-industry trade (IIT) index does not address the quality issue directly and propose a methodology to make full use of unit-price gap information to deduce quality differences between simultaneously exported and imported products. By applying this measure to German trade data at the eight-digit level, we study the quality improvement of Chinese export goods in its IIT with Germany. We compare the case of China with those of Eastern European countries, which are also major trading partners of Germany. Our results show that the unit-value difference in IIT between Germany and Eastern European countries is clearly narrowing. However, China's export prices to Germany are much lower than Germany's export prices to China, and this gap has not narrowed over the last 23 years. This is at odds with the common perception that China's product quality has improved, as documented by Rodrik (2006) and Schott (2008). Our results support Xu (2010), which argued that incorporating the quality aspect of the exported goods weakens or even eliminates the evidence of the sophistication of Chinese export goods in Rodrik (2006).

1. INTRODUCTION

The last twenty years have witnessed rapid growth in the Chinese economy and its exports. As the Chinese economy expanded dramatically, its export structure shifted from labour-intensive to capital-intensive sectors and from cheap low-quality products to expensive high-quality products. In particular, Chinese exports in the machinery sectors are of increasingly high-tech products. There are studies of these substantial changes in Chinese exports. As "sophisticated" (namely high-tech and/or high-quality) products are exported, the economy grows faster. Using an index of export

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sophistication and per capita income across countries worldwide, Rodrik (2006) concluded that Chinese export products are already capital intensive and that China is "special" in the sense of exporting sophisticated products regardless of its still low per capita income.[1] Traditional trade theory cannot explain this phenomenon fully.[2] Furthermore, Schott (2008), using product-level trade data, found that Chinese export products substantially overlap the range of Organisation for Economic Co-operation and Development (OECD) countries' exports.

However, there are pros and cons to this argument. Some researchers conclude that the changes in exports are limited to trade related to foreign direct investment (FDI) in China. According to Amiti and Freund (2010), Fu (2011), Xu and Lu (2009) and Wang and Wei (2010), export platforms and FDI to China from OECD countries contribute to skill upgrading in Chinese exports. Thus, if trade related to foreign FDI is eliminated, Chinese exports lose their skill upgrading and sophistication. Similarly, Athukorala (2009) focused on Asian fragmentation, which crucially influences the upgrading of Chinese exports.[3]

Although researchers have pointed out omissions in Rodrik's (2006) work, such as the impact of FDI on skill upgrading, using the export sophistication index is problematic. The first problem involves measuring quality. The sophistication index for a product is derived from the weighted average of GDP per capita for all countries exporting that product. This assumes that countries with higher GDP per capita tend to produce and export higher quality goods, which results in so-called "export sophistication". However, as discussed in the quality trade literature, many other factors determine patterns of quality trade, such as the capital–labour ratio (Falvey, 1981; Flam and Helpman, 1987) and distance (Alchian and Allen, 1964; Hummels and Skiba, 2004). GDP per capita is just one of the determinants.[4] As Xu (2010) pointed out, product quality cannot be fully conveyed by the export sophistication index of Rodrik (2006), which overestimates export sophistication. Taking into

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[1] Rodrik (2006) defines the export sophistication index as a weighted average of per capita income for all exporting countries.

[2] In this vein, Jarreau and Poncet (2012) find substantial regional variation in export sophistication within China. The urban areas where many foreign affiliates are located see much higher export sophistication. Zhu and Fu (2013) investigate the determinants of Chinese export sophistication.

[3] Athukorala (2009) finds that there is an increase in high-tech products in manufacturing in Chinese exports, but this increase is associated with low added value. Labour-intensive products, such as parts and components, are still dominant in Chinese exports, which is a key driving force in Asian fragmentation.

[4] There is a supply-side hypothesis behind the export sophistication index; i.e., richer countries produce higher quality products. However, the demand side is also important. Hallak (2006) studies the relationship between per-capita income and the aggregate demand for quality. He finds that rich countries import more from countries that produce high-quality products. This contrasts sharply with the notion of export sophistication. Furthermore, firm heterogeneity might affect trade patterns, as argued by Baldwin and Harrigan (2011) who investigated quality trade and production when there is firm heterogeneity.

account product quality reduces export sophistication. Khandelwal (2010) and Hallak and Schott (2011) investigated quality upgrading by using per-unit prices. Following the quality trade literature, we adopt per-unit prices to study export quality sophistication. The second problem is that the export sophistication index is product based. The index takes one value for each product across all countries. It is worth measuring how China has switched its exports from low- to high-quality products. However, this index cannot identify how transitionally each export product changes its quality. The third problem is that the index ignores changes over time in two-way trade between two countries. Changes in quality might be affected by several cross-country factors related to the business cycle, economic growth and price levels. [5] For this reason, although many researchers using the sophistication index found evidence of substantial quality upgrading in Chinese exports, our two-country analysis finds that there is still a substantial quality gap between China and Europe. To overcome these drawbacks, we use per-unit price gaps at the product level between two countries rather than the export sophistication index. Unlike Xu (2010), who used a sophistication index à la Rodrik (2006), albeit weighted by per-unit product prices, we directly measure the per-unit-price differences between two countries and examine how prices change between two countries over time.

We use IIT data to develop a new measure of product quality and apply it to shed light on product quality in Chinese trade. By using German product-level trade data, we compare German IIT with China to German IIT with Eastern European economies. One point of interest is how the quality of China's IIT products with Germany evolved over the 1990s and 2000s, when China rapidly emerged as a major player in world trade and became the number one trading partner of the European Union (EU). We also examine Eastern European countries, which have rapidly deepened their economic ties with Germany and finally joined the EU. Our measure of quality differences in IIT allows us to see the evolution in the quality gap for the period 1988–2010, which covers important changes in the trade patterns of China and Eastern European countries.

Our analysis yields interesting findings. First, the unit values of China's exports to Germany are much lower than the unit values of China's imports from Germany. Moreover, this price gap has not narrowed over the last 23 years. This finding indicates that while China has rapidly expanded its range of export products, and that its spectrum of export products is now closer to that of developed countries, there remains a large gap in unit values that, contrary to what is documented by Rodrik (2006) and Schott (2008), is not narrowing. Second, our analysis reveals a clearly decreasing unit-value difference in German IIT with Eastern European countries. This implies that Eastern European countries have climbed up the "quality ladder".

The rest of the paper is organized as follows. In Section 2, we present a literature review. In Section 3, we explain the data and propose our methodology. In Section 4, we propose a way to capture

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[5] Exceptionally, Fontagné et al. (1999) used the IIT framework to investigate quality in bilateral trade relationships and found evidence of a quality ladder within Europe.

quality differences in IIT and apply this method to several EU countries. The final section concludes the paper.

2. LITERATURE REVIEW AND THIS PAPER

2.1. *The Grubel–Lloyd index and horizontal and vertical IIT indices*

The measure of IIT most commonly used in the literature is the Grubel–Lloyd (GL) index. In the literature, conventional IIT is classified into two types, horizontal IIT (HIIT) and vertical IIT (VIIT). HIIT is defined as IIT *without* a substantial per-unit export and import price gap, whereas VIIT is defined as IIT *with* a substantial per-unit export and import price gap. The HIIT and VIIT indices were first proposed by Greenaway et al. (1995) (hereafter, GHM) and subsequently used by many authors. Using UK trade data from 1988 at the Standard International Trade Classification (SITC) five-digit level, GHM empirically investigated the determinants of HIIT and VIIT. Aturupane et al. (1999) and Jensen and Lüthje (2009) studied the determinants of HIIT and VIIT using trade data between the EU and Central and Eastern European transition economies from 1990–1995 and from 1996–2005, respectively. Closer to our interest, Hu and Ma (1999) investigated China's IIT and found that, as China has moved towards a market-oriented economy, it has followed similar patterns to those of developed countries.[6] Brülhart (2009) provided a comprehensive description of global IIT and inter-industry trade patterns using worldwide trade data at the Harmonized System (HS) six-digit level.

2.2. *Beyond GHM*

The IIT indices mentioned above are all static. It is also important to illustrate transitional changes in trade patterns in the long run. To deal with the dynamic aspect, the notion of marginal IIT (MIIT) is proposed to measure structural change in trade patterns. An important issue in MIIT is labour market adjustment. Many researchers found a negative relationship between MIIT and adjustment pressure. For example, Brülhart and Elliott (2002), Brülhart et al. (2006) and Cabral and Silva (2006) proposed empirical tests of the smooth-adjustment hypothesis (SAH) associated with MIIT. To discuss the SAH, a conventional decomposition into HIIT and VIIT is appropriate (Greenaway et al., 2002; Brülhart and Elliott, 2002; Azhar and Elliott, 2008a). According to the SAH, the adjustment costs associated with inter-industry trade are higher than those associated with IIT because a change in the former generally requires greater resource reallocation.[7] However, the distinction between HIIT and VIIT is much more important. In VIIT, the product quality of exports and imports is different. Thus,

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6 Fukao et al. (2003) and Okubo (2007) showed that a crucial factor in VIIT is FDI-related trade. In Asia, VIIT is driven by Japanese FDI.

[7] Early contributions on this issue were by Hamilton and Kniest (1991), Greenaway et al. (1994), Brülhart (1994) and Azhar et al. (1998).

the resource requirement of the high-quality variety differs from that of the low-quality variety. In other words, VIIT entails higher adjustment costs than HIIT. A rapid increase in VIIT generates a sharp increase in adjustment costs, whereas a rise in HIIT does not generate the same pressure.

As the importance of the decomposition into HIIT and VIIT increased, researchers have proposed new ways of gauging unit-value differences in IIT to refine the distinction between HIIT and VIIT. Azhar and Elliott (2006) proposed the Product Quality Vertical Index, and Azhar and Elliott (2008b) applied their methodology to China's IIT with Malaysia, Thailand and the Philippines in 2002 at the five-digit SITC level. They found that China exported lower-priced products to these countries.

2.3. *Ito and Okubo (2012)*

Ito and Okubo (2012) pursued refinement of the decomposition into HIIT and VIIT. They overcame two limitations of the IIT literature:

(i) (Arbitrary threshold values) The threshold values of the export–import unit-price gaps used to decompose into VIIT and HIIT are arbitrary. Many researchers use a threshold value of 15 per cent in the unit-price gap, although others use 25 per cent.[8] However, there is no firm theoretical support for either choice.

(ii) (Idiosyncratic upper and lower sides of VIIT index) The upper and lower sides of the VIIT index are idiosyncratic and thus should be decomposed.

2.4. *Contribution of the present paper*

Our paper contrasts with previous ones. Unlike Ito and Okubo (2012) and others, whose arguments are based on the IIT index (the share of the overlap of IIT), we focus on unit-price differences and thereby deduce product quality. This is clarified in the next section. Instead of relying on indirectly unveiling quality changes by decomposing IIT into HIIT, upper-sided VIIT and lower-sided VIIT, as in Ito and Okubo (2012), we propose a simple method of using the price gap at the product level to deduce product quality. Furthermore, although the main purpose of Ito and Okubo (2012) is to qualify the use of the HIIT and VIIT indices, our aim is to detail the structural changes in Chinese exports by focusing on the German–Chinese trade relationship, which is one of the most important bilateral trade relations in the world.

Our approach has three advantages. First, whereas previous studies of Chinese export sophistication, such as those of Rodrik (2006) and Schott (2008), were based on Chinese export data, we sample data on German trade because Germany is China's largest trading partner in Europe. By using German trade data, we can highlight differences in Chinese and Eastern European trade. Second, we focus on unit-price gaps in two-way trade. As pointed out by Xu (2010), the export sophistication

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[8] Fukao et al. (2003) raised the threshold level to take into account exchange rate fluctuations. Nevertheless, there is no firm theoretical justification for a difference of 10 per cent (25 per cent minus 15 per cent).

index cannot take into account quality. Thus, per-unit prices are used to measure quality directly. Furthermore, we use per-unit-price gaps in exports and imports of IIT products to control for worldwide price fluctuations. Third, whereas the current literature on export sophistication is based on the export sophistication index, which is regressed on macroeconomic factors to determine impacts on economic growth, we directly discuss quality upgrading by using data on product-level price gaps between imports and exports.

3. DATA, THE GL IIT INDEX AND MEASURES OF UNIT-VALUE DIFFERENCES

3.1. *Data, the GL IIT index and HIIT/VIIT indices*

We use Eurostat trade data, which cover exports and imports at the HS eight-digit level from 1988–2010. The data have several advantages over those of other countries. First, they are available at the highly disaggregated HS eight-digit level and are consistent across all EU member countries. Second, and more importantly, the HS eight-digit level data are identical for exports and imports, which enables us to compare the unit export and import prices of particular HS eight-digit level products. This is not the case for other countries such as the US and Japan.[9] There are 17,249 HS eight-digit level codes.[10] Because we focus on IIT and its unit-price differences, our analysis is limited to the manufacturing sector. Consequently, 13,173 HS eight-digit level codes corresponding to the manufacturing sector are used. The classical GL index of product category k is defined as follows:

$$IITindex_k = 1 - \frac{|Ex_k - Im_k|}{Ex_k + Im_k}$$

GHM decompose the IIT into HIIT and VIIT indices by using per-unit export–import price differences at product level k. The decomposition is based on a certain threshold value (x). In relation

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[9] For example, the US and Japan keep records on trade data at the 10- and nine-digit levels, respectively. However, their codes are identical between exports and imports only up to the six-digit level.

[10] Export data are based on FOB (Free On Board), but import data are based on C&F (Cost and Freight) or CIF (Cost, Insurance and Freight). That is, import values include freight charges, represented by "C" (with insurance fees represented by "I"). For example, when Germany's export price to China (the FOB price) is the same as Germany's import price from China (C&F or CIF), Germany's product price is *in fact* higher than China's product price, because China's price includes "C" (and "I").

to x, HIIT products satisfy the inequality $\frac{1}{1+x} < \frac{Export\,Price_k}{Import\,Price_k} < 1+x$, and VIIT products satisfy the

inequality $\frac{Export\,Price_k}{Import\,Price_k} < \frac{1}{1+x}$ or $\frac{Export\,Price_k}{Import\,Price_k} > 1+x$.[11]

In symbols, GHM decomposed the GL index of equation (1) below into the HIIT index and the VIIT index:

$$\underbrace{\sum_{k=1}^{K}\left(\left(\frac{Ex_{ijk}+\mathrm{Im}_{ijk}}{\sum_k\left(Ex_{ijk}+\mathrm{Im}_{ijk}\right)}\right)\bullet\left(1-\frac{\left|Ex_{ijk}-\mathrm{Im}_{ijk}\right|}{Ex_{ijk}+\mathrm{Im}_{ijk}}\right)\right)=}_{\text{IIT index}}$$

$$\underbrace{\sum_{h=1}^{H}\left(\left(\frac{Ex_{ijh}+\mathrm{Im}_{ijh}}{\sum_h\left(Ex_{ijh}+\mathrm{Im}_{ijh}\right)}\right)\bullet\left(1-\frac{\left|Ex_{ijh}-\mathrm{Im}_{ijh}\right|}{Ex_{ijh}+\mathrm{Im}_{ijh}}\right)\right)}_{\text{HIIT index}}+\underbrace{\sum_{v=1}^{V}\left(\left(\frac{Ex_{ijv}+\mathrm{Im}_{ijv}}{\sum_v\left(Ex_{ijv}+\mathrm{Im}_{ijv}\right)}\right)\bullet\left(1-\frac{\left|Ex_{ijv}-\mathrm{Im}_{ijv}\right|}{Ex_{ijv}+\mathrm{Im}_{ijv}}\right)\right)}_{\text{VIIT index}}\quad(1)$$

All IIT products must be classified as either HIIT or VIIT, i.e., K = H + V. Most of the literature is based on a threshold level of 15 per cent, but some researchers, such as Fukao et al. (2003), use 25 per cent. However, as shown by Ito and Okubo (2012), there is no firm theoretical support for either choice.

An interesting and important issue we can examine using IIT data is the extent to which trade between two countries is characterized by differences in product quality. Although the HIIT and VIIT indices incorporate information on price differences, the focus, as with the original IIT, is still on the *share* of "overlap" of exports and imports. Information on price differences is used only for *binary* categorization into HIIT and VIIT indices. In other words, products are sorted into either horizontal or vertical categories based on some threshold level, but it does not matter how much the prices differ. An illustration of this point is given in the Appendix.

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[11] Greenaway et al. (1995) proposed the following criterion: $1-x < \frac{Export\,Price_k}{Import\,Price_k} < 1+x$ for HIIT and $\frac{Export\,Price_k}{Import\,Price_k} < 1-x$ or $\frac{Export\,Price_k}{Import\,Price_k} > 1+x$ for VIIT. Fontagné and Freudenberg (1997) pointed out a problem with this threshold condition. They argued that the lower threshold of $1-x$ is inconsistent with the upper threshold of $1+x$ and that this problem is exacerbated by higher threshold levels: 'for example, the threshold of 25 per cent means that export unit values can be 1.25 times higher than those for imports to fulfil the similarity condition. The lower limit in that case is 0.75: imports unit values need to represent at least 75 per cent of export unit values. But this last statement can be formulated in a different way: export unit values can be 1.33 (1/0.75) times higher than import unit values, a condition which is incompatible with the condition on the right.'

Thus, instead of $1-x$, Fontagné and Freudenberg (1997) proposed $\frac{1}{1+x}$.

As mentioned in the previous section, when our interest is in the SAH, arguments based on MIIT apply. However, for the purpose of fully extracting information on price differences, and thus deducing product quality, we propose what we call a "unit-value difference measure". This method is composed of two stages. The first stage is to compute the unit-value differences of all IIT products and examine their distributions. The second stage is to aggregate the unit-value differences into a single value for each pair of countries.

The quality upgrading issue is the focus of the present paper. This issue was also touched on by Ito and Okubo (2012), albeit within the framework of the GL and HIIT/VIIT indices. However, the issue can only be studied indirectly if treated within this framework. (See Appendix for details.) The issue is better addressed by using the unit-value difference measure that we propose in the next section. (See Appendix for a detailed explanation of this point.)

3.2. *The unit-value difference measure: the simple unit-value difference and its distribution*

For the first stage, the unit-value difference of an IIT product is defined as the log of its export price divided by its import price, as follows:

$$UnitValueDifference = \log\left(UV^X / UV^M\right)$$

UV^X is the export unit value and UV^M is the import unit value. This index is unit free. A value of zero indicates that there is no price difference between imports and exports.

To address what Azhar and Elliott (2006) called the "scaling or proportionality problem", which is inherent in the studies by GHM and Fontagné and Freudenberg (1997), we take the natural logs of unit-value ratios, instead of following the methodology proposed by Azhar and Elliott (2006). Details of the "scaling or proportionality problem" and the advantages of the measure that we propose are given in the Appendix. For all IIT products and each pair of countries, we compute the price differences and determine their distributions. For example, approximately 5,000 data points on price differences are computed for Germany's IIT with France because there are about 5,000 IIT products traded between France and Germany. Table 1 shows the summary statistics for Germany's IIT with some of its trading partners in 2007.[12] Figure 1 shows the distribution. There is substantial variation in the unit-value differences. For example, transforming China's mean in logarithms of 1.044 back into the level of UV^X / UV^M gives 2.84. This number is far higher than the standard thresholds of 1.15 or 1.25 used for the binary categorization into HIIT and VIIT. Furthermore, the range of unit-

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[12] Data for 2007 are used as an example and also to avoid including the unusual trade collapse from 2008. We have chosen six important trading partners of Germany: France and Italy represent the developed nations; India, and China, the focus of this paper, represent large developing nations; and Hungary and Poland represent the Eastern European countries.

value differences is large. The minimum number of –4.605 for the case of China implies a level of 99.98 for UV^X/UV^M . Thus, it is important to retain information on the magnitude of these unit-value differences when our purpose is to deduce quality differences from unit-value differences. Table 1 and Figure 1 clearly show that in the case of Germany's IIT with France and Italy, the unit-price difference is centred around zero with a relatively high kurtosis and slightly positive skewness. The distributions of the unit-price differences for Germany's IIT with China and India have positive means, low kurtosis and negative skewness. The Poland and Hungary cases are between these two cases. Figure 1 only shows a snapshot of 2007. To examine the dynamic evolution of price differences, we need to compare the distributions over time.

Table 1: Summary statistics on the unit-value differences of Germany's IIT with several trading partners

Country	mean	variance	skewness	kurtosis	min	max
China	1.044	1.434	−0.502	4.625	−4.605	4.596
France	0.031	0.750	0.122	5.763	−4.373	4.530
Hungary	0.067	1.101	0.144	4.736	−4.411	4.534
India	0.597	1.774	−0.419	4.070	−4.537	4.431
Italy	0.126	0.809	−0.157	5.919	−4.461	4.590
Poland	0.141	0.912	0.140	5.178	−4.439	4.579
Total	0.292	1.170	0.123	4.601	−4.605	4.596

Figure 1: Distribution of IIT product-price differences between Germany and selected countries, 2007

Graphs by ctyname
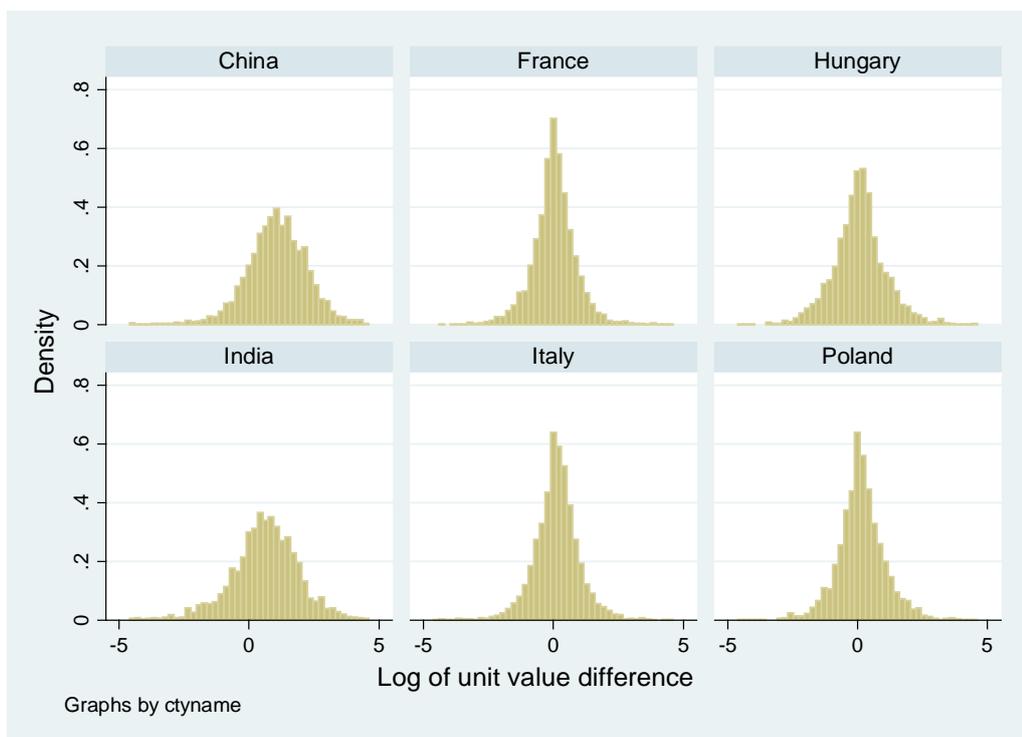
Although the figures are visually appealing and provide more information about the distributions, the measure of unit-value differences has some drawbacks. First, it is not useful for comparing many countries over long time periods, because it is difficult to make exact comparisons by simply looking at many distributions. Second, in the simple analysis of price differences described above, one data point representing the unit-value difference of a particular product is treated equally with another data point representing the unit-value difference of another product, even though the trade value and the GL index may differ substantially between these two products. Figure 1 shows that the unit-price differences of Germany's IIT with China are distributed with a mean exceeding zero. However, if those products with unit-price differences above zero represent only a small share of overall trade, the distribution would give the false impression that Germany's IIT is dominated by Germany's high-quality goods exports to China and China's low-quality goods exports to Germany. The same can be said for the product-level GL index. Recall that the GL index represents the share of overlapping trade or the two-way component of trade. If those products with unit-price differences above zero had a low product-level GL index (because the overlapping share is low), it would give us the same false impression. In other words, the simple unit-price difference measure captures neither the dimension of relative trade values nor the magnitude of the "overlap" because it is based on the price difference for each product irrespective of the trade value of each product, and irrespective of the magnitude of "overlap" (conveyed by the GL index of each product). To address these two drawbacks, the next step is to weight the unit-value differences by trade values and degrees of "overlap".

3.3. *The unit-value difference measure: aggregation*

To compute a single value that represents the unit-price difference of IIT for each trading pair for a given year, we propose the "unit-value difference measure of IIT", defined as follows:

$$
UVDiffMeasureofIIT_{ij} = \sum_k \left[\left\{ \log\left(\frac{ExUV_{ijk}}{ImUV_{ijk}} \right) \right\} \bullet \left\{ \frac{\left(1 - \frac{\left| Ex_{ijk} - Im_{ijk} \right|}{Ex_{ijk} + Im_{ijk}} \right) \bullet \left(Ex_{ijk} + Im_{ijk} \right)}{\sum_k \left(\left(1 - \frac{\left| Ex_{ijk} - Im_{ijk} \right|}{Ex_{ijk} + Im_{ijk}} \right) \bullet \left(Ex_{ijk} + Im_{ijk} \right) \right)} \right\} \right] \tag{2}
$$

where $ExUV_{ijk}$ is the export unit value of IIT product k traded between countries i and j, with

$ImUV_{ijk}$ defined analogously. The first term in the curly brackets represents the unit-value difference

for product k. The second term in the curly brackets represents product k's share of IIT trade value (the numerator) in the total IIT trade value of all IIT products (the denominator). In other words, it represents how important product k's IIT trade value is to the total IIT trade value. For example, if product k's IIT trade value represents an extremely high share of total IIT trade value, say 99 per

cent, the unit-value difference of product k is weighted by 0.99, and thus has an overwhelming influence on the overall unit-value difference measure of country i's trade with country j. A simple numerical example of this measure's computation is in the Appendix. This measure essentially captures how vertical, upper-sided or lower-sided the IIT is between a pair of countries.[13] Thus, one can term this measure the "IIT vertical specialization index".[14]

Figure 2 shows the unit-value difference measure of Germany's IIT with its ten largest trading partners plus China. The contrast between China and the other ten countries is stark. While the numbers for the other ten partner countries are close to zero, that of China is well above zero. This indicates that made-in-China products are much cheaper than made-in-Germany products.[15] A more interesting finding is the evolution of the values for China. Contrary to recent claims about China's quality improvement, there is no clear downward trend over the last 23 years.

Figure 2: Germany's unit-value difference measure with its 10 largest trading partners
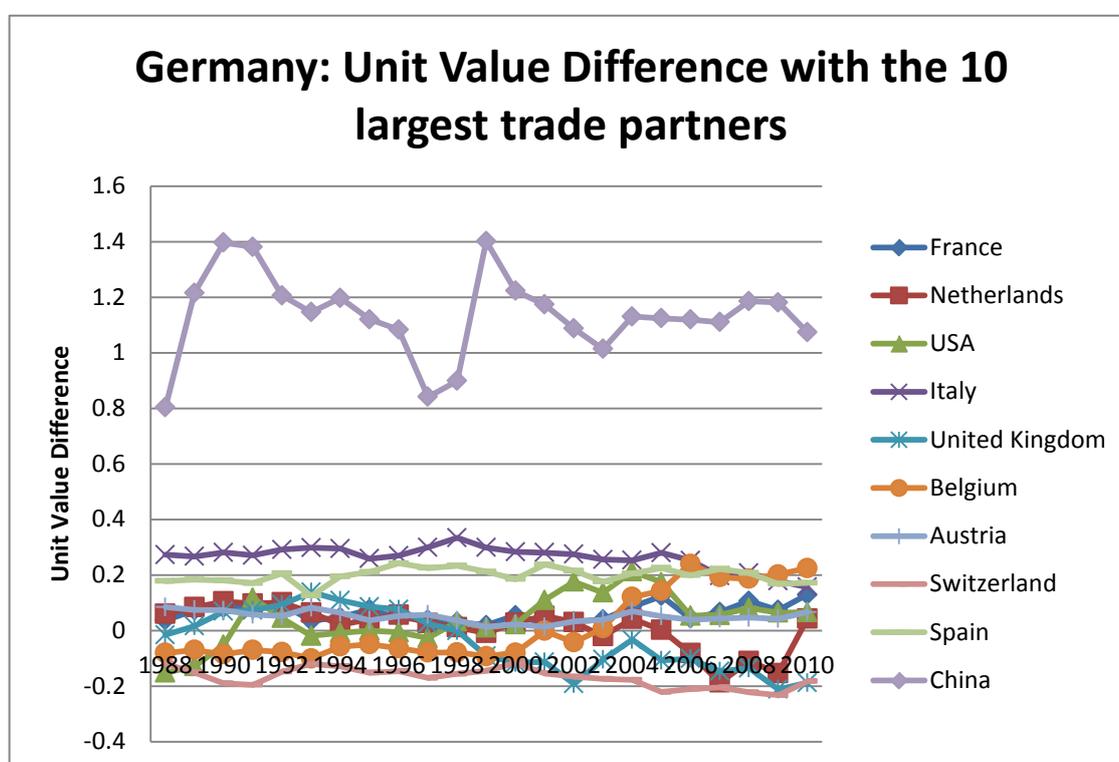
Whether the stark difference between China and the other 10 largest trading partners is a common feature of the 15 EU countries (in fact 14 countries because Belgium and Luxembourg are treated as

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[13] Azhar and Elliott (2006) used similar terms, namely, the "horizontalness" and "verticalness" of IIT (p. 486).

[14] We thank Richard E. Baldwin for suggesting this terminology.

[15] Given the difference of FOB (exports) prices and CIF (imports) prices, as mentioned in footnote 5, the true gap in product prices between Germany and China is larger than that shown here based on the unit-value difference measure. This reinforces our finding of a large price gap between Germany and China.

one (BLX).) is revealed by the box-and-whisker plots in Figure 3.[16] Except for Finland and Greece, the unit-value difference measures with China are clear outliers.

Figure 3: Box-and-whisker plots of the unit-value difference measure for China with its major trading partners
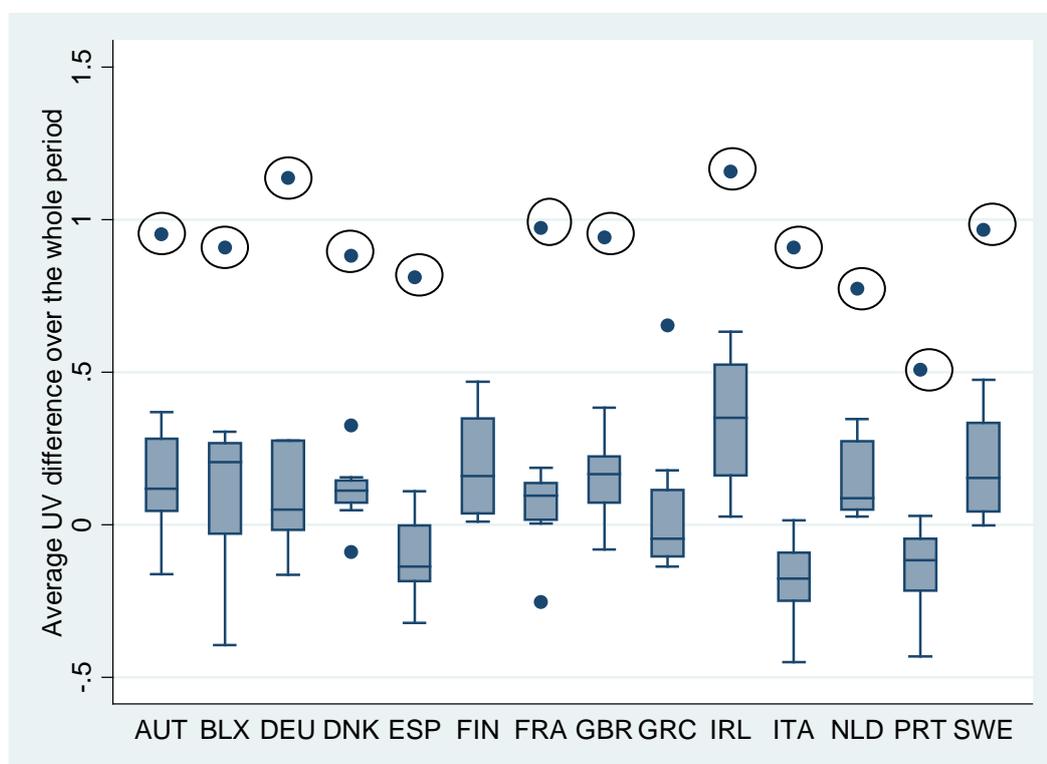

Note: The circles indicate China.

Germany's unit-value difference measure with the Eastern European countries is illustrated in Figure 4. A clear decreasing trend is apparent. All the Eastern European countries have been climbing up the quality ladder vis-à-vis Germany. It is also worth emphasizing that in 2010, the Eastern European countries each achieved a difference of close to zero.

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[16] The boxes cover the interquartile range from the lower quartile to the upper quartile. The whiskers, denoted by horizontal lines, extend to cover most or all the range of the data. In the box-and-whisker plot of Figure 3, we have placed the upper whisker at the upper quartile plus 1.5 times the interquartile range or at the maximum of the data if this is smaller. Similarly, the lower whisker is the lower quartile minus 1.5 times the interquartile range, or the minimum should this be larger. A box-and-whisker plot is a useful tool for identifying outliers. See Cameron and Trivedi (2009) for details.

Figure 4: Germany's unit-value difference measure with Eastern European countries

Germany: Unit Value Difference with Eastern European countries
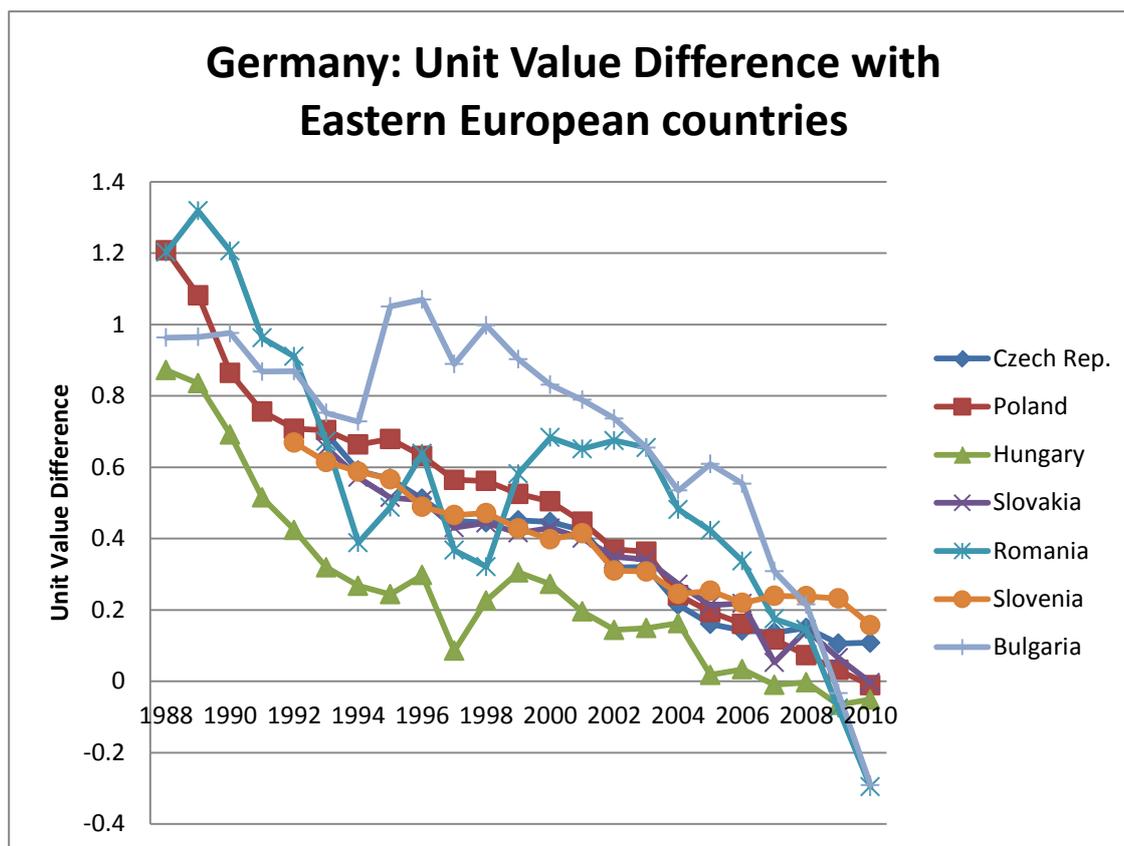
4. POLICY IMPLICATIONS

As shown in the previous section, Chinese goods exported to Germany remained cheap over time, whereas Eastern European countries' exports have largely increased in quality. There are three policy implications of this result. First, FDI might affect Chinese exports. Germany is one of the largest providers of FDI to China among European countries. German affiliates in China take advantage of low wage rates in China to export parts and components and intermediate or final products at low prices to Germany, which is typical of vertical FDI and outsourcing. For this reason, the prices of Chinese exported products have remained low over time. Second, China's accession to the World Trade Organization in 2001 seems to have had no dramatic effect on Chinese exports. Trade control by Chinese government such as exchange control and trade policy might still be strongly affecting trade flows. Third, rapid economic growth in China has shifted its exports to high-quality products, but this effect might be limited. Although some Chinese exports to some countries might have climbed the quality ladder, this is not evident in the Germany–China trade relationship. Thus, we conclude that Rodrik's findings overestimated the quality of Chinese trade.

5. CONCLUSION

In this paper, we argued that the conventional IIT index does not directly address the quality issue. Hence, we proposed a methodology that makes full use of information on unit-price gaps to deduce quality differences between simultaneously exported and imported products (i.e., the degree of quality divergence in IIT). By applying this measure to German trade data at the eight-digit level, we examined the quality improvement of Chinese export goods in its IIT with Germany. We compared the case of China's trade with that of Eastern European countries, which are also major trading partners of Germany. Our results show that unit-value differences in IIT between Germany and the Eastern European countries are clearly narrowing, which indicates that Eastern European countries are climbing the quality ladder. By contrast, China's export prices to Germany are much lower than German export prices to China, and the gap has not narrowed over the past 23 years. This contradicts the common perception that Chinese products have improved as documented by Rodrik (2006) and Schott (2008). Our results support Xu (2010), which argued that incorporating the quality aspect of the exported goods weakens or even eliminates the evidence of the increased sophistication of Chinese export goods in Rodrik (2006).

APPENDIX

Illustration on the "share" nature of GL index and HIIT/VIIT in Section 3.1.

Figure A1 and Figure A2 illustrate the computation of HIIT and (upper and lower) VIIT index and the virtue of our proposed unit value difference measure. The horizontal axis on the top with the scale represents the unit value ratio ($export/$import). The numbers on the axis, i.e, 0.5, 0.8, 1.2, 1.5, represent the threshold values for the binary categorization into HIIT and VIIT. (1, which represents the identical export and import unit price, is also shown.) On the left of the figure, HS codes are placed vertically. For each HS code, unit price ratio is shown under the horizontal axis. Also for each HS code, the corresponding GL index and the sum of export and import values are shown in the rounded square. Look at Figure A1. When 0.2 is taken for the threshold, those HS codes whose unit value ratio falls within 0.8 and 1.2 are classified as HIIT ("HIIT range 1" in the figure). In this example, HS 34324650 (with unit price ratio of 0.9) and 72698210 (with unit price ratio of 1.1) are such cases. On the other hand, HS 50312840 (with unit price ratio of 1.3), HS 63589240 (with unit price ratio of 2.0) and HS 85624380 (with unit price ratio of 1.7) are categorised to the upper-side VIIT because the unit price ratios are above 1.2. Then, the aggregate HIIT index is 0.5 (=0.5*(400/(400+400))+0.5*(400/(400+400))), whereas the aggregate upper-side VIIT index is computed as 0.6=(0.5*(400/(400+400+400))+0.6*(400/(400+400+400))+ 0.7*(400/(400+400+400))). If the threshold value is set at 0.5, the aggregate upper-side VIIT index increases to 0.65 (=0.6*(400/(400+400))+0.7*(400/(400+400))). In Figure A2, the unit value ratio of HS 63589240 is 50, in contrast with the case in Figure A1, in which the ratio is 2.0. However, the aggregate upper-side VIIT index does not change. This is because, as emphasised in the main text, the information on unit price difference is used only for the binary categorisation into Horizontal or Vertical IIT. As long as the ratios exceed the threshold, it does not matter whether the ratios are modest (2.0) or huge (50). Since the interest of our paper is the unit value difference, our proposed unit value difference measure takes into account how different the unit prices are. With the unit price ratio of 50 for HS 63589240, our proposed index is higher than that with unit price ratio of 2.0 for that HS code.

Figure A1: Illustration of HIIT/VIIT with the smaller difference in unit price ratio
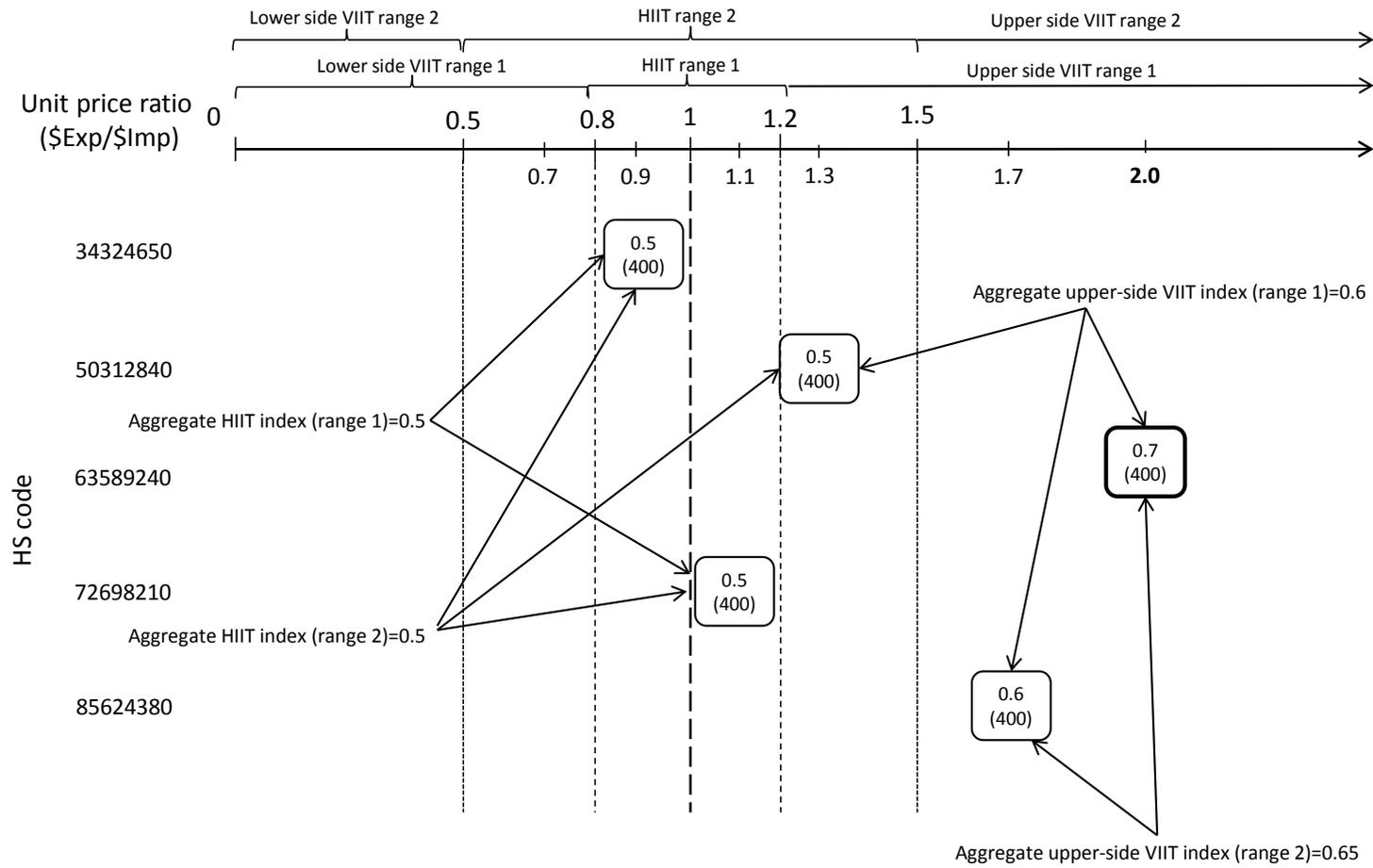
Note: Numbers inside the rounded square represent GL IIT index (top) and the sum of export and import values (bottom (in the parentheses))

e.g.   [0.8 ←——— GL IIT index
        (200) ←——— the sum of export and import values]

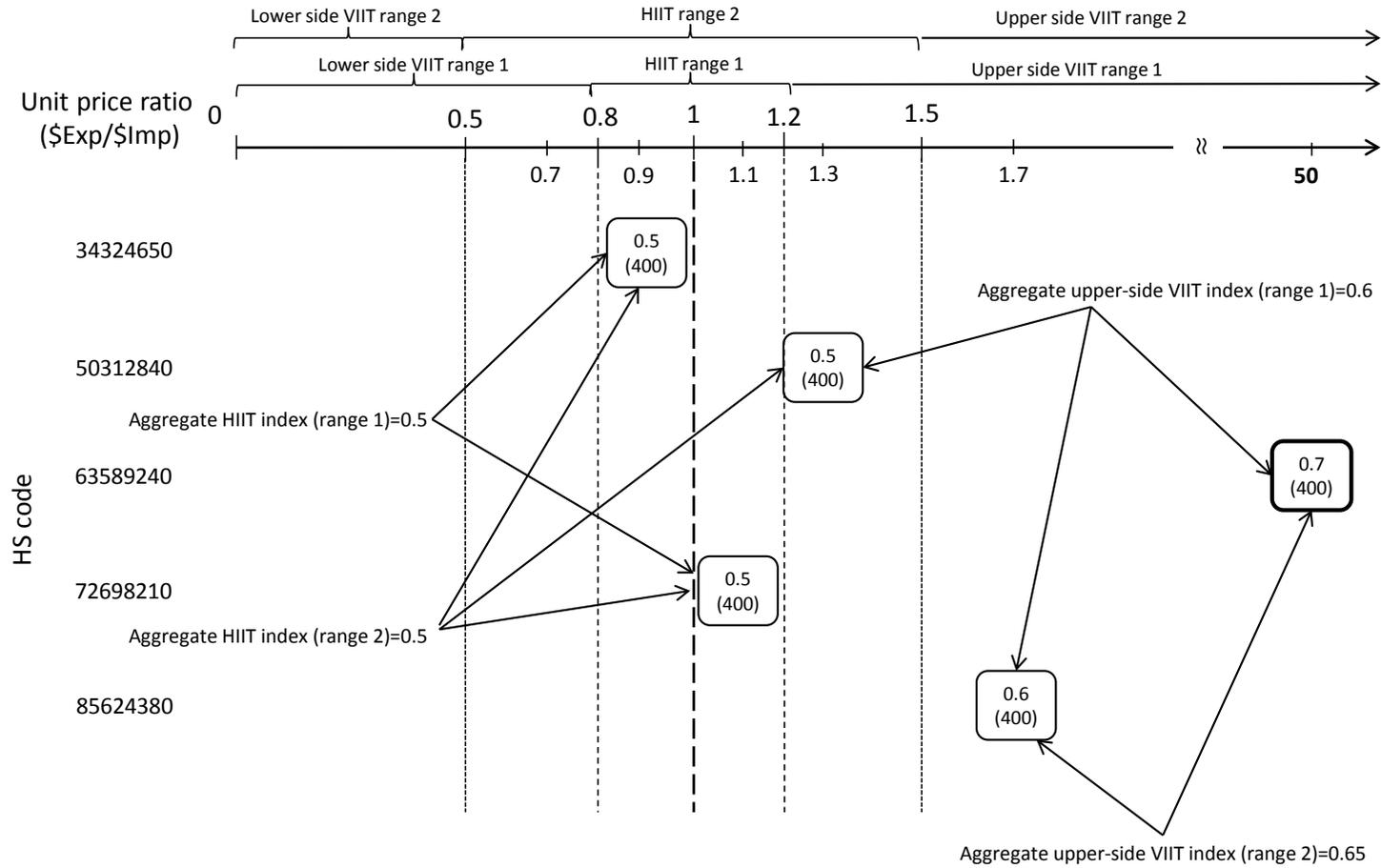Figure A2: Illustration of HIIT/VIIT with the larger difference in unit price ratio

Note: Numbers inside the rounded square represent GL IIT index (top) and the sum of export and import values (bottom (in the parentheses))

e.g.
┌─────┐
│ 0.8 │ ←─── GL IIT index
│(200)│ ←─── the sum of export and import values
└─────┘

Argument on why the quality upgrading issue is better examined by our proposed unit value difference measure than GL and HIIT/VIIT indices in Section 3.1.

Ito and Okubo (2012) argues that the dynamic changes of HIIT, upper side VIIT and lower side VIIT of China, in comparison with the cases of the Eastern European countries, indicates that the Eastern European countries have climbed up the quality ladder in the late 2000s, whereas China remains a low-price product exporter. This argument is based on the dynamic changes of HIIT, upper side VIIT and lower side VIIT shown in Figure A3. It shows the changes over time of upper side VIIT, lower-side VIIT and HIIT of Germany-China, Germany-Czech and Germany-Hungary with three threshold levels; 10 percent, 20 percent, and 50 percent. In the case of Germany-China, while there is almost no change in HIIT and lower side VIIT, upper side VIIT shows a clear upward trend. This result indicates that China's exports to Germany are moving towards products with relatively lower price than those exported from Germany to China. On the other hand, the cases of Germany-Czech Rep. and Germany-Hungary show that upper side VIIT falls whereas the lower side VIIT and HIIT increase. This result indicates that the Eastern European countries' trade with Germany are moving towards those products with relatively higher price than those exported from Germany to these countries. Moreover, notice that the gap of the upper side VIIT index between China and the two Eastern European countries narrows as the threshold levels rise from 10 percent to 50 percent. This indicates that the two-way trade of those products with higher price of Germany vis-à-vis China has become more important. Namely, as the threshold level widens, such as illustrated in Figure A1 and Figure A2, while many products are still classified as upper side VIIT and its GL index and the trade values are substantial in the case of Germany-China, the opposite (less number of products are now classified as such and its GL index and the trade value is not large) is true for the cases of Germany-Czech and Germany-Hungary. This argument of Ito and Okubo (2012) is probably correct but not directly tackling the quality issue through price gap because HIIT/VIIT indices' focuses are still "share" of overlapped (two-way) trade. I.e., it does not make full use of the price gap information. Instead of this indirect approach, our proposed unit value difference measures can directly address the quality issue, by focusing on the price gap and making full use of the price gap information.

Figure A3: Germany-China, Upper side VIIT, Lower side VIIT, HIIT: 1988-2010
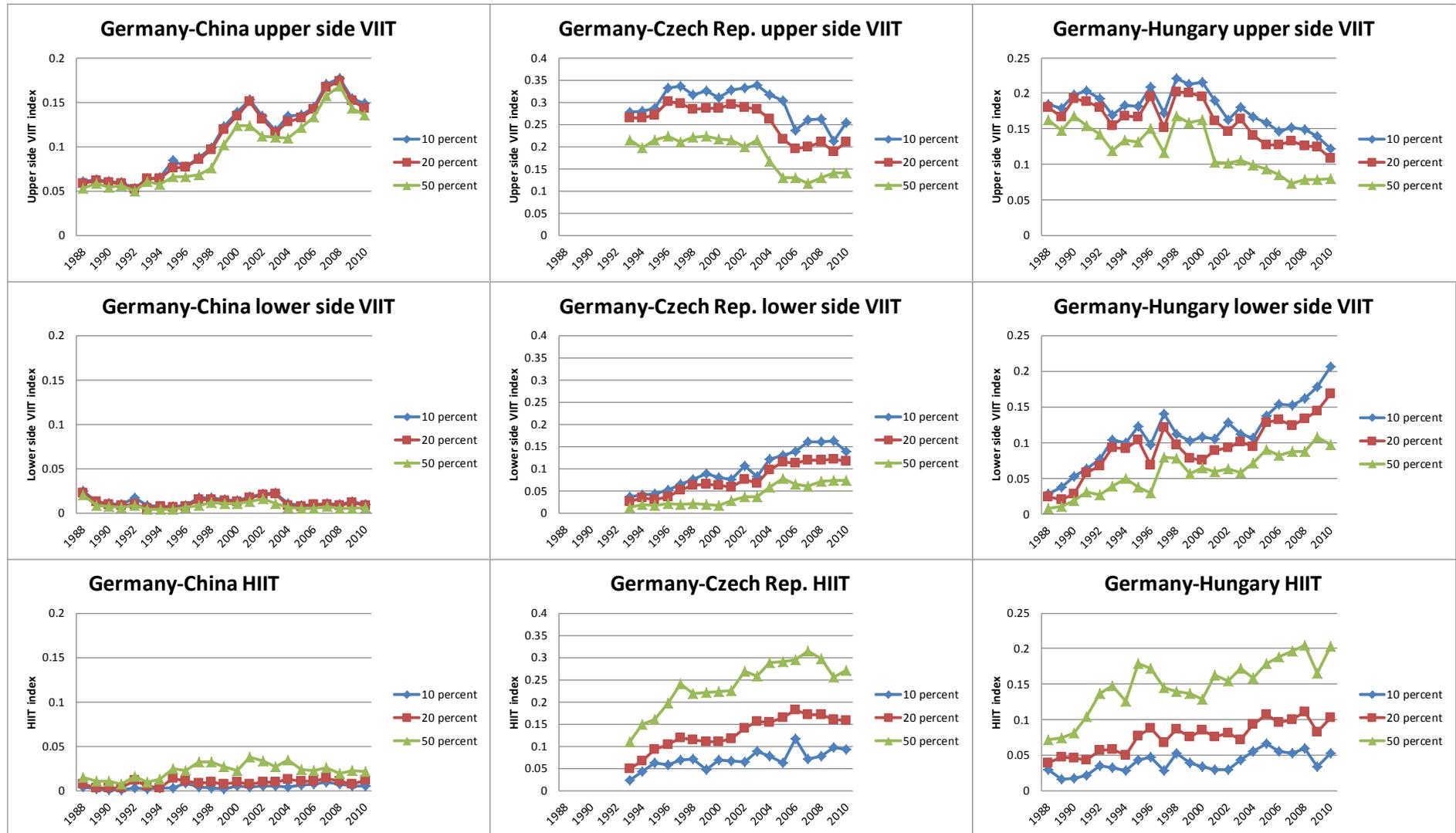
Source: Authors' computation based on Ito and Okubo (2012)

Argument on the "scaling or proportionality problem" in Section 3.2.

Azhar and Elliott (2006) explains the "scaling or proportionality problem" diagrammatically and rigorously. We interpret it here in a simple way. The "scaling or proportionality problem" comes from the functional form of a UV ratio, UV^X/UV^M. The values of UV^X/UV^M are confined in the set of $(0,\infty)$ with 1 as the case of no difference in unit value. The cases of lower unit values of exports than imports are confined in the set of $(0,1)$, while the cases of higher unit values of exports than imports are in the set of $(1,\infty)$. In other words, UV^X/UV^M for lower export unit values than import unit values are concentrated in a narrow set of $(0,1)$, while UV^X/UV^M for higher export unit values than import unit values are in an unlimited set of $(1,\infty)$. This is "scaling or proportionality problem".

To address this problem, Azhar and Elliott (2006) proposes what it calls Product Quality Vertical (PQV) index.

$$PQV = 1 + \frac{UV^X - UV^M}{UV^X + UV^M}$$

PQV index takes a value between 0 and 2. The geometrical center of 1 is the case of no unit value difference and the index value is symmetric above and below 1.

However, we think that confining the index into the limited set, i.e., $(0,2)$ is problematic when we like to compare the unit value difference of different goods or when we like to compute the index at industry level and/or country level. The virtues of PQV index and our measure as well as the problem of PQV index are best explained with numerical examples.

Numerical examples of PQV index and our measure

Case	UV^X	UV^m	PQV	UV^x/UV^m	$\ln(UV^x/Uv^m)$
1	90	90	1.00	1.00	0.00
2	90	10	1.80	9.00	2.20
3	10	90	0.20	0.11	-2.20
4	100	900	0.20	0.11	-2.20

Look at the above table. The fourth column shows the Product Quality Vertical Index of Azhar and Elliott (2006). In case 1, there is no difference in unit values of exports and imports, thus PQV takes the value of 1. Unit values of the cases 2 and 3 are opposite. PQVs have identical distance from 1, i.e., being free from what Azhar and Elliott (2006) calls the "scaling or proportionality problem". In

case 4, unit values of exports and imports are both inflated by 10 from case 3. PQV is unaffected by inflation, another virtue of the index.

We, instead, propose to take the natural logs of UV^X/UV^M. As the sixth column demonstrates, our measure also maintains the above nice features.

The next numerical example shows a problem arising from the bounded set of PQV index.

Case	UV^x	UV^m	PQV	UV^x/UV^m	$\ln(UV^x/Uv^m)$
1	90	90	1.00	1.00	0.00
2	90	60	1.20	1.50	0.41
3	90	30	1.50	3.00	1.10
4	90	10	1.80	9.00	2.20
5	90	1	1.98	90.00	4.50

Keeping unit value of exports at 90, we reduce unit value of imports. The fifth column shows the simple ratio of UV^x/UV^m. The sixth column is the natural log of the simple ratio. From case 1 to case 2, the unit value of imports goes down to 60, yielding PQV index of 1.20, which indicates a relatively higher quality of home country. From case 2 to case 3, the unit value of imports further declines to 30, giving a PQV index of 1.5 and so on. As the export unit value gets relatively higher, the PQV index approaches 2. However, as PQV index approaches the limit value of 2, it does not effectively reflect the real difference of unit values. Look at the case of 4 and 5; the export unit value is 9 times higher than the import unit value in case 4, which gives PQV index of 1.8. In the case 5, the export unit value is 90 times higher than the import value, yielding a PQV index of 1.98. Although the ratio UV^x/UV^m gets 10 times higher from 9 to 90, the PQV index changes only slightly from 1.8 to 1.98. Thus, while the PQV index succeeds to get rid of the "scaling or proportionality problem", it invites another kind of scaling problem (the "second" scaling problem). By taking the natural logarithms, we can address this "second" scaling problem. Namely, in addition to having the virtue of being free from the "scaling or proportionality problem", our measure lies in the unlimited set, $(-\infty, +\infty)$, unlike the PQV index, which confines the index into the limited set $(0, 2)$.

A simple numerical example of the computation of the overall unit value difference measure in Section 3.3.

product	export value	import value	IIT index	Overlap	Weight	export unit price	import unit price	log (exp p/imp p)	
1	9000	8000	0.941	16000	0.816	1.5	2	−0.1249	−0.1020
2	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
3	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
4	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
5	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
6	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
7	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
8	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
9	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
10	200	1000	0.333	400	0.020	2	1.5	0.1249	0.0025
Total	10800	17000		19600	1.000			Summing up	**−0.079**

Product 1's Grubel-Lloyd index is computed using export value and import value and takes the value 0.941. By multiplying the sum of export and import value, which is 17,000 in the current case, by IIT index of 0.941it gives the IIT trade value of 16,000, which, in turn, is simply the overlapped value of imports and exports, i.e., 8,000 times 2. The IIT value of 16000 of product 1 has the share of 0.816 (=16000/19600). Log of unit value difference of product 1 is -0.1249. This value is weighted by the weight of 0.816. We do the same for all the other products and sum them up to come up with the overall unit value difference measure, which is -0.079 in the current case.

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