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The Conflicting Ways to Dissect Intra-Industry Trade

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Abstract

Theoretical literature states that intra-industry trade (IIT) should be divided into horizontal and vertical flows (or trade in products with homogeneous and heterogeneous quality) that are influenced by different factors. Yet, the economists are still not sure about the proportion between horizontal and vertical IIT. Traditional approach relies on unit value as an indicator of product quality. However, it is associated with a number of problems such as arbitrariness of the threshold used to separate the types of trade. We propose the two alternative approaches to dissecting IIT: first, applying another product quality indicator (PRODY – per capita GDP associated with exporting a product) and, second, relying on countries' product-level differences in the revealed comparative advantage (RCA). We also argue in favor of the new continuous treatment of the index-based unit value approach (in the spirit of the overlap calculation of the IIT itself) that finally helps to get rid of the arbitrary thresholds problem. However, then we reject the PRODY- and RCA-based approaches due to an undesirable behavior (low correlation with the share of exports to other EU countries, low shares of horizontal IIT for homogeneous products and other features), while the performance of the continuous form of the index-based unit value approach is found to be in line with the traditional unit value approach. We also argue that the two index-based modifications are preferable to the traditional unit value approach due to the higher shares of horizontal IIT for homogeneous products. We conclude that the median share of horizontal IIT for EU countries is still unknown due to fundamental uncertainty about the dissecting approach. At the same time, relative positions of countries for all forms of the unit value approach are quite stable, so there is much less uncertainty concerning the cross-country differences.

Keywords: intra-industry trade, horizontal trade flows, vertical trade flows, product quality, unit values, per capita income
JEL: F10, F14

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Andrey A. Gnidchenko[1]

Theoretical literature states that intra-industry trade (IIT) should be divided into horizontal and vertical flows (or trade in products with homogeneous and heterogeneous quality) that are influenced by different factors. Yet, the economists are still not sure about the proportion between horizontal and vertical IIT. Traditional approach relies on unit value as an indicator of product quality. However, it is associated with a number of problems such as arbitrariness of the threshold used to separate the types of trade. We propose the two alternative approaches to dissecting IIT: first, applying another product quality indicator (PRODY – per capita GDP associated with exporting a product) and, second, relying on countries' product-level differences in the revealed comparative advantage (RCA). We also argue in favor of the new continuous treatment of the index-based unit value approach (in the spirit of the overlap calculation of the IIT itself) that finally helps to get rid of the arbitrary thresholds problem. However, then we reject the PRODY- and RCA-based approaches due to an undesirable behavior (low correlation with the share of exports to other EU countries, low shares of horizontal IIT for homogeneous products and other features), while the performance of the continuous form of the index-based unit value approach is found to be in line with the traditional unit value approach. We also argue that the two index-based modifications are preferable to the traditional unit value approach due to the higher shares of horizontal IIT for homogeneous products. We conclude that the median share of horizontal IIT for EU countries is still unknown due to fundamental uncertainty about the dissecting approach. At the same time, relative positions of countries for all forms of the unit value approach are quite stable, so there is much less uncertainty concerning the cross-country differences.

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Introduction

It was a long lasting tradition in the literature to consider that factors of inter-industry and intra-industry trade (further, IIT) differ. Large IIT between developed countries was used as an argument in favor of the increasing role of monopolistic competition factors in international trade, as opposed to comparative advantage (*Deardorff*, 1984, p. 500; *Helpman and Krugman*, 1985, p. 2). However, further research showed that IIT consists of the horizontal and vertical trade flows (IIT in goods of similar and different quality, respectively) driven by different forces. The former depends on economies from scale and consumers' preferences for variety that are the factors attributed to monopolistic

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competition, while the latter is influenced by comparative advantage. This fact was demonstrated both theoretically (*Falvey and Kierzkowski*, 1987; *Flam and Helpman*, 1987) and empirically (*Blanes and Martin*, 2000; *Díaz Mora*, 2002). Moreover, *Fontagne et al.* (2006) showed that these two types of IIT differ in dynamics significantly.

The traditional approach to dissecting IIT into horizontal and vertical trade flows relies on unit values that are typically considered as proxies for export and import prices (unit value is calculated as the ratio of trade value in USD and trade volume in physical units). This approach dominates in the literature, though its particular form varies from study to study (*Abd-el-Rahman*, 1991; *Greenaway et al.*, 1994, 1995; *Fontagne and Freudenberg*, 1997, 1999; *Azhar and Elliott*, 2006). High unit values reflect high product quality, and vice versa. If unit values of an exported and an imported product are close, quality of these goods is considered to be similar. However, *Gullstrand* (2002) demonstrates that various forms of the unit value approach provide "fragile results," so that "further research on how to disentangle horizontal and vertical IIT less arbitrarily is needed." (p. 335). Recent studies focus on documenting the patterns of IIT (*Ferto et al.*, 2016; *Hoang*, 2019) or explaining its factors (*Chin et al.*, 2015; *Ferto and Jambor*, 2015; *Dautovic et al.*, 2017) that is important but not enough if the approach to dissecting IIT is not validated.

Surprisingly, the economists didn't try to use alternative indicators of product quality (that don't rely on unit values) for the purpose of differentiating between horizontal and vertical IIT, though, in our view, it can be considered as a promising alternative strategy for dissecting IIT. The second alternative strategy is applying a different theoretical basis for separating horizontal and vertical IIT: as argued by *Lüthje and Nielsen* (2002), "using indices for revealed comparative advantages combined with the degree of IIT as measured by the Grubel-Lloyd index might be a more fruitful method empirically to make the separation." (p. 602).[2]

In this paper, we make an attempt to move in two directions. First, we propose the two alternative approaches to dissecting IIT. One approach applies the PRODY indicator developed in *Hausmann et al.* (2007) as the product quality measure instead of unit values. This indicator reflects the weighted per capita GDP of countries that export a particular product (as argued by *Sutton and Trefler* (2016), a country's GDP per capita and its export product mix are both determined by its capabilities). To detect the type of a bilateral trade flow, we propose to compare the two trading countries' GDP per

[2] The index measuring the degree of IIT was proposed by *Grubel and Lloyd* (1975).

capita with PRODY of a product. Note that the ratio of the two per capita GDP's is also important: as *Linder* (1961) emphasized, countries with a similar level of development are more likely to trade in differentiated products, and quality of these products tends to be similar (*Hallak*, 2006).[3] Another approach deals with comparative advantage as a theoretical basis for dissecting IIT, as recommended by *Lüthje and Nielsen* (2002). We consider comparative advantage as the net trade concept – to check if the trading partners' comparative advantage is close, we compare the signs of the net trade.[4] Additionally, we account for the per capita GDP gap between trading countries. The key advantage of both approaches is the absence of *a priori* product-level threshold that is required to dissect IIT for the traditional unit value approach (though there is still a country-level threshold used to detect if two countries are close in per capita income).

Second, we develop a continuous treatment of the index-based unit value approach proposed in *Azhar and Elliott* (2006, p. 484), thus relaxing the need even for the country-level threshold. We argue in favor of the direct usage of "Grubel-Lloyd based" product quality dissection measure in "its simplest form" (with the modulus operator) that was a starting point for *Azhar and Elliott* (2006). So, we do not introduce the index itself, but we are first to calculate the share of horizontal IIT based on this index and demonstrate its good performance according to a number of simple intuitive tests.

To check the validity of the approaches, we propose three simple tests. First, the share of horizontal IIT of the EU country should be higher for trade with other EU members than for trade with the world on average (due to many firms competing on the basis of their variety and lower differences in per capita GDP between EU member countries – see *Durkin and Krygier*, 2000; *Andresen*, 2003). Second, the share of horizontal IIT should be higher for large economies in terms of GDP (due to the higher role of scale effects). Finally, the share of horizontal IIT should tend to 100 per cent for homogeneous products (that, by definition, are not differentiated in quality and thus prices – see *Rauch*, 1999).[5]

The paper is structured as follows. In Section 1, we present descriptive evidence for IIT in the EU. We show that IIT covers the large share of trade for most EU countries, argue

[3] From the perspective of firm-level data, it has been showed by *Bastos and Silva* (2010) that export unit values are generally higher in shipments to richer nations. Interestingly, the direction of trade also affects the wage premium in the exporting country (*Brambilla and Porto*, 2016).

[4] *Hallak and Schott* (2011) showed that the trade balance reflects product quality: a country with the highest trade balance (*vis a vis* the world) should be considered to possess the highest product quality, assuming equal unit values.

[5] Note that a number of other ways to test the validity of the methods of dissecting IIT were proposed in the literature. For instance, Gullstrand (2002) tests econometrically if the factors that influence the two trade flow types are in line with the theory, while Lüthje and Nielsen (2002) examine the stability of the results by performing run tests at the product level. In further research, it would be reasonable to use all of these methods, while in this paper we limit our activity in this area.

that IIT should be measured at the detailed product level and demonstrate that the issue of dissecting IIT into horizontal and vertical components is far from being resolved. In Section 2, we discuss the features of the traditional approach based on unit values and then develop a continuous treatment of the index-based unit value approach. In Section 3, we present the two alternative approaches to dissecting IIT (PRODY- and RCA based approaches). Then, in Section 4, we calculate the share of horizontal IIT according to different approaches for all EU members, and verify these approaches by applying three simplified tests. In the Conclusion, we make final remarks and discuss the relevance of different indicators.

1. Descriptive evidence

1.1. Share of IIT in the EU

As widely accepted, IIT is becoming more and more important in today's international trade. *Brulhart* (2009, p. 426) has documented an upward trend in global IIT share that is linked with "a process of worldwide structural convergence: economies are becoming more similar over time in terms of their sectoral compositions." He also emphasized that, first, IIT is dominated by high-income countries, and, second, IIT trade shares are quite high for the EU. *Ito and Okubo* (2012) showed that the unit value differences between major EU countries and Eastern European countries is gradually declining, and thus the role of horizontal IIT (trade in products of a similar quality) for EU is growing.

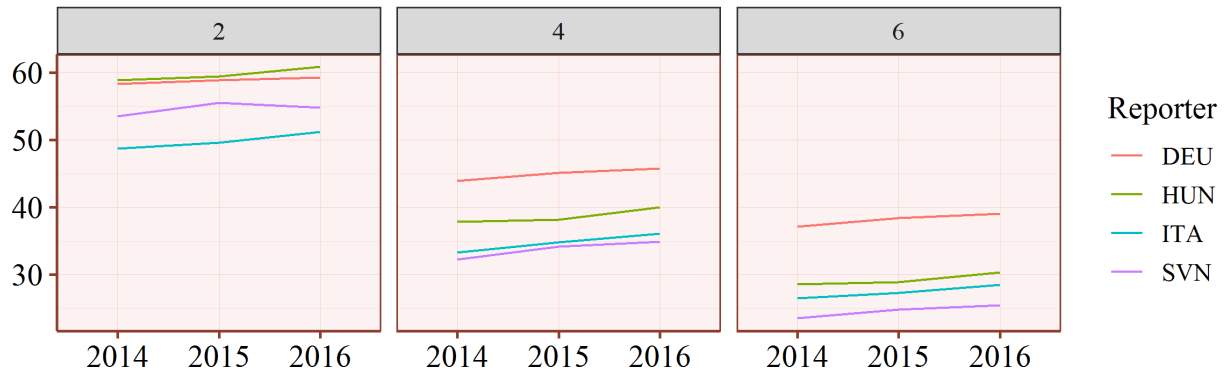
Intra-industry trade is calculated with the widely-known Grubel-Lloyd index (*Grubel and Lloyd*, 1975):

$$\mathrm{GL}_{i,c} = 1 - \frac{\left|v_{i,c}^{(x)} - v_{i,c}^{(m)}\right|}{v_{i,c}^{(x)} + v_{i,c}^{(m)}}, \qquad (1)$$

where v stands for trade value in USD.

Grubel-Lloyd index can be calculated for different levels of product aggregation. The possible options, in case of using the data in the HS (harmonized system) format, are: 2-digit (less than 100 "industries"), 4-digit (about 1200 product groups) and 6-digit (more than 5000 products) aggregation. *Soo* (2016) noted that the degree of IIT depends on aggregation level much: it is higher for 2-digit that for 6-digit aggregation scheme. This fact reflects the different interpretation of the index for different aggregation levels: IIT for 2-digit groups ("industries") is more close to account for fragmentation of production while IIT for 6-digit groups (products) is likely to reflect the role of trade in differentiated products. **Fig. 1** shows that countries heavily engaged in fragmentation of production

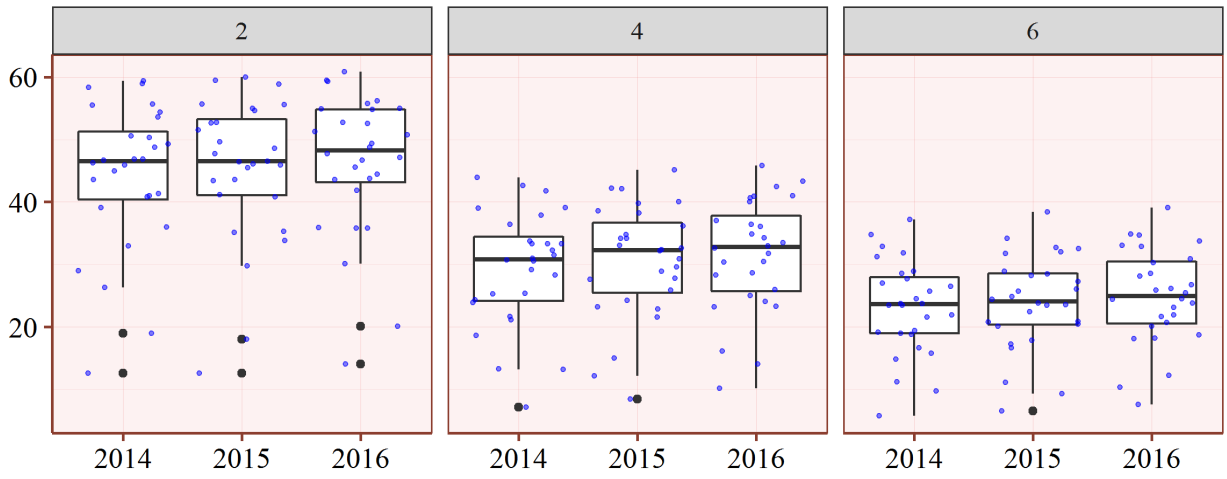
such as Hungary or Slovenia experience much higher IIT shares particularly at the most aggregated 2-digit level, while they are not among the IIT leaders at the finer levels of product disaggregation.



Calculated based on: UN COMTRADE (aggregated to 2-, 4- and 6-digit product groups)

Fig. 1 – The share of IIT for different aggregation levels by selected countries

Countries that experience relatively high IIT shares at the 6-digit product level include Germany, Austria, Belgium, Netherlands and France, while relatively low IIT shares are reported for Cyprus, Malta, Greece and Bulgaria. The median share of IIT is far higher for aggregated data, though it is not less than 25 per cent even for the 6-digit level (**Fig. 2**). So, IIT stands for a big share of trade turnover between EU members and, moreover, it is more important for core EU countries with higher GDP and thus trade volumes. In further calculations, we rely on the 6-digit data.



Calculated based on: UN COMTRADE (aggregated to 2-, 4- and 6-digit product groups)
Note: points reflect EU countries

Fig. 2 – The share of IIT by all EU countries for the three aggregation levels

At the same time, there is a fundamental issue of dissecting IIT into two subsections – horizontal and vertical IIT, that reflect IIT in products with similar and different quality, respectively. In Section 1.2, we show that this issue is far from being resolved.

1.2. Horizontal and vertical IIT in the EU

The standard approach to account for product quality is assuming that export and import prices reflect product quality. This idea was first adapted to dissecting IIT by *Abd-el-Rahman* (1991), and further developed by *Greenaway et al.* (1994), *Fontagne and Freudenberg* (1997), *Azhar and Elliott* (2006). Different forms of this approach are shortly outlined in **Table 1**.

Most of the forms are based on simple export-to-import unit value ratios and use some threshold to mark IIT trade flows as vertical or horizontal (let's combine them under the "*traditional unit value approach*" label). In contrast, *Azhar and Elliott* (2006) proposed to apply the thresholds to the index that varies from 0 to 2 (let's name this method the "*discrete index-based unit value approach*"):

$$\mathrm{PQH}_{i,c} = 1 - \frac{p_{i,c}^{(x)} - p_{i,c}^{(m)}}{p_{i,c}^{(x)} + p_{i,c}^{(m)}}, \qquad (2)$$

where subscripts *i* and *c* stand for product and country, *p* stands for unit value (proxy for price, US dollars per ton), and superscripts *(x)* and *(m)* stand for exports and imports.

Tab. 1 – Different strands of literature on dissecting IIT with unit values

Author(s)	Criteria for		
	IIT	Horizontal IIT	Vertical IIT
Abd-el-Rahman (1991)	Reversal import (export) flows are more than 10 per cent compared with the other flows ("trade-type approach")	The difference between export and import unit values is less than 15 per cent	The difference is more than 15 per cent
Greenaway et al. (1994)	Grubel-Lloyd index ("overlap approach")	The ratio of export and import unit values is within the limits of [0.85; 1.15]	The ratio is beyond the limits of [0.85; 1.15]
Fontagne and Freudenberg (1997)	Imports represent at least 10 per cent of exports or reciprocally ("trade-type approach")	The ratio of export and import unit values is within the limits of [0.8; 1.25]	The ratio is beyond the limits of [0.8; 1.25]
Azhar and Elliott (2006)	Not specified	PQH index is within the limits of [0.85; 1.15]	PQH index is beyond the limits of [0.85; 1.15]

Source: Compiled by the author.

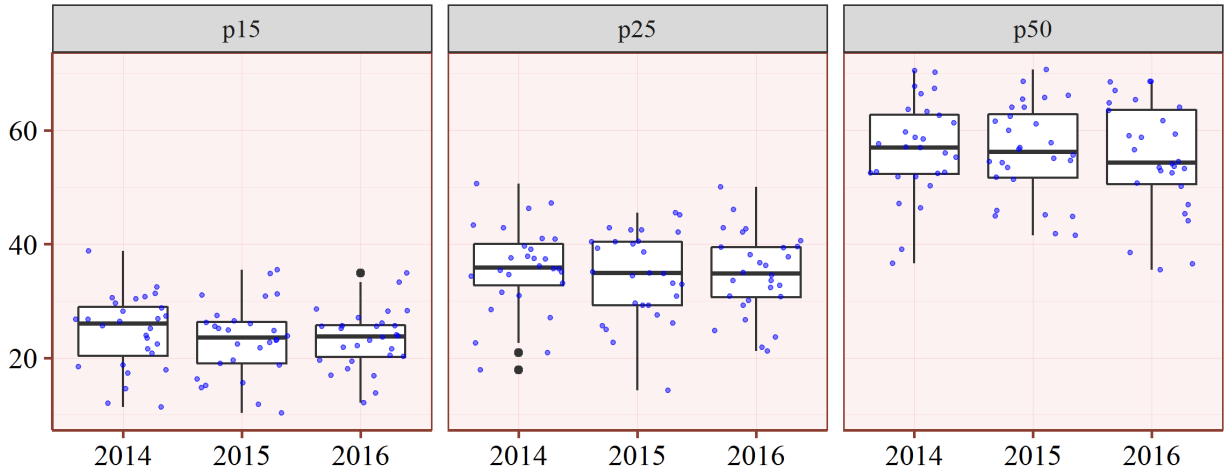
This index is calculated in the spirit of Grubel-Lloyd (*Grubel and Lloyd*, 1975) index that separates intra- and inter-industry trade by subtracting the trade overlap from unity – see **(1)**.[6]

[6] *Azhar and Elliott* (2006) intentionally skip the modulus to be able to distinguish between high-quality and low-quality vertical intra-industry trade. However, it forces them to use arbitrary thresholds for the index.

To dissect IIT according to any of these methods, one should calculate the value of IIT first. We prefer to use Grubel-Lloyd index presented in **(1)** that indicates the share of IIT as it allows dividing each bilateral trade flow into two parts (the absolute value of the trade overlap reflects IIT, while the absolute value of net exports represents inter-industry trade).[7] The alternative way of comparing the reversal import (or export) flows with a threshold is problematic since this threshold is arbitrary: as shown by *Crespo and Fontoura* (2004), IIT value is quite sensitive to the overlapping criterion. Also, it would be impossible to divide each trade flow into two parts using the alternative approach. Hereinafter, we refer to IIT as the product of total trade value and Grubel-Lloyd index.[8]

The basic principle of the next step is comparing the ratio of export-to-import unit values with some threshold. High export unit value compared to import one indicates that a vertical IIT flow is of a high-quality nature, and vice versa. For close export and import unit values, an IIT flow is considered to be of a horizontal nature.

The problem is that the threshold is arbitrary. Changing the threshold, one also changes the results much: starting from the 15 per cent threshold, the share of horizontal IIT would rise from a quarter to more than a half for the 50 per cent threshold (**Fig. 3**). This issue is critical for both the median share of horizontal IIT across EU countries and for the whole distribution: for the case of the 50 per cent threshold, the least share of horizontal IIT are equal or even higher than the largest share for the case of 15 per cent threshold.



Calculated based on: UN COMTRADE

Fig. 3 – The share of horizontal IIT by all EU countries for the three arbitrary thresholds

[7] *Gullstrand* (2002, p. 323) states that using the "overlap approach" instead of the "trade-type approach" helps to account for relative factor endowment differences (that are important for inter-industry trade) more carefully, as the "trade-type approach" just ignores this factor if the reversal trade flows exceed a fairly low threshold of 10 per cent.

[8] Dissecting total trade value into intra- and inter-industry components is not the purpose of the paper. So, we do not discuss this problem in detail here.

2. Discussing the unit value approach

2.1. Features of the unit value approach

The most important advantage of using unit values to indicate product quality is that they are product specific: they are available at the most disaggregated product level (for the worldwide analysis, 6-digit HS product groups).[9] Generally, unit values correlate with the abundance of capital and per capita GDP (and thus quality), as shown by *Schott* (2004, p. 647-648) and *Aiginger* (1997, p. 581), among many others.

However, associating them with quality directly was found to be an oversimplification. Several problems are mentioned here. First, unit values may be affected by size or other characteristics of the product such as durability, finish and reliability (*Greenaway et al.*, 1994). Second, they often reflect monopolistic markups and international trade costs that differ among the pairs of trade partners (*Szczygielski and Grabowski*, 2012). Third, the attribution of products to different types of trade flows using unit values is not stable, while a proper quality measure should not vary much in time (*Lüthje and Nielsen*, 2002). Fourth, as showed in *Szczygielski and Grabowski* (2012), the hypothesis of proportionality of equilibrium prices and equilibrium qualities that should hold theoretically if unit values reflect quality is contradicted by the data. Fifth, prices may also vary due to differences in the product mix, even at fine levels of disaggregation (*Durkin and Krygier*, 2000). And finally, the threshold of 15 to 25 per cent traditionally applied to separate vertical and horizontal IIT is arbitrary, while its choice affects the result much (*Fontagne et al.*, 2006). Moreover, mean ratios of export-to-import unit values for many countries differ from this standard threshold: for example, the mean ratio for China is 2.84 (*Ito and Okubo*, 2014) that is well above the standard threshold.

2.2. The continuous index-based unit value approach

It is possible to overcome the latter issue by modifying the approach proposed by *Azhar and Elliott* (2006). To calculate the horizontal IIT in a continuous setting, we propose to multiply the value of IIT by the version of the PQH index with the modulus operator in the numerator (then, it would be possible to separate each trade flow into two parts):

$$\mathrm{HIIT}_{i,c} = \mathrm{IIT}_{i,c}\left(1 - \frac{\left|p_{i,c}^{(x)} - p_{i,c}^{(m)}\right|}{p_{i,c}^{(x)} + p_{i,c}^{(m)}}\right), \tag{3}$$

[9] As *Greenaway et al.* (1994) note, unit values are "certainly the most accessible source of information about consumer assessments of products."

where *IIT* stands for the value of IIT in USD, and *HIIT* stands for the value of horizontal IIT in USD. The remainder part of IIT should be considered as vertical:

$$\mathrm{VIIT}_{i,c} = \mathrm{IIT}_{i,c} - \mathrm{HIIT}_{i,c}, \quad (4)$$

where *VIIT* stands for the value of vertical IIT in USD. A vertical IIT flow should be marked as a high-quality trade flow if the difference between export and import unit values is positive. Otherwise, it should be considered as a low-quality IIT trade flow.

3. The alternative approaches

However, due to the large number of other problems, we have to examine a number of alternative ways to dissect IIT. In this Section, we present the two alternative strategies to dissecting IIT. The first applies the different quality measure (PRODY), while the second relies on the cross-country differences in comparative advantage.

3.1. PRODY-based approach

Weighted per capita GDP of countries exporting a product is one of the most obvious proxies for product quality presented in the literature. It is assumed that rich country is more likely to export a high-quality product than poor country, as higher wages in richer country should be compensated by higher quality to retain competitiveness. *Lall, Weiss and Zhang* (2006) proposed to use countries' shares of world exports as weights for calculating the so-called sophistication score of a product (expressed in USD):

$$\mathrm{S}_i = \sum_c \frac{v_{i,c}^{(x)} y_c}{\sum_c v_{i,c}^{(x)}}, \quad (5)$$

where $v^{(x)}$ stands for the value of exports in USD, y stands for per capita income, and S_i is sophistication score.

Hausmann et al. (2007) proposed to apply the revealed comparative advantage index (hereinafter, RCA) of each country as weights. This insight helped to eliminate the scale effect (for this aggregation method, countries with higher relative, not absolute, shares of world exports affect the result). The proposed indicator is called PRODY[10]:

$$\mathrm{PRODY}_i = \sum_c \frac{bi_{i,c}^{(x)} y_c}{\sum_c bi_{i,c}^{(x)}}, \quad (6)$$

where $bi^{(x)}$ is the RCA index developed by *Balassa* (1965):

[10] *Corcoles et al.* (2014) shows that PRODY is a significant factor of export stability and survival. This result favors the assumption that PRODY is (at least moderately) correlated with products' quality.

$$bi_{i,c}^{(x)} = \frac{v_{i,c}^{(x)}}{\sum_i v_{i,c}^{(x)}} \Big/ \frac{\sum_c v_{i,c}^{(x)}}{\sum_i \sum_c v_{i,c}^{(x)}}, \quad (7)$$

where $v^{(x)}$ stands for the value of exports in USD, while the indices *c* and *i* are used for aggregation across countries and products, respectively.

The disadvantage of this measure is its inability to differentiate quality by the country of origin (PRODY varies across products but not across countries). Thus, it is necessary to complement this indicator with a country-specific variable to use it in IIT calculations. Conceptually, one should compare PRODY of a product with per capita income of the exporter and the importer (for each bilateral trade flow). We suppose that country is more likely to participate in a horizontal IIT flow if it's per capita GDP is close to its trade partner's one, or if PRODY of the product ranges between the two values.[11]

Mathematically, we propose to calculate the lower and the upper bounds of the range between per capita GDP's that corresponds to horizontal IIT (**Fig. 4**) as follows:

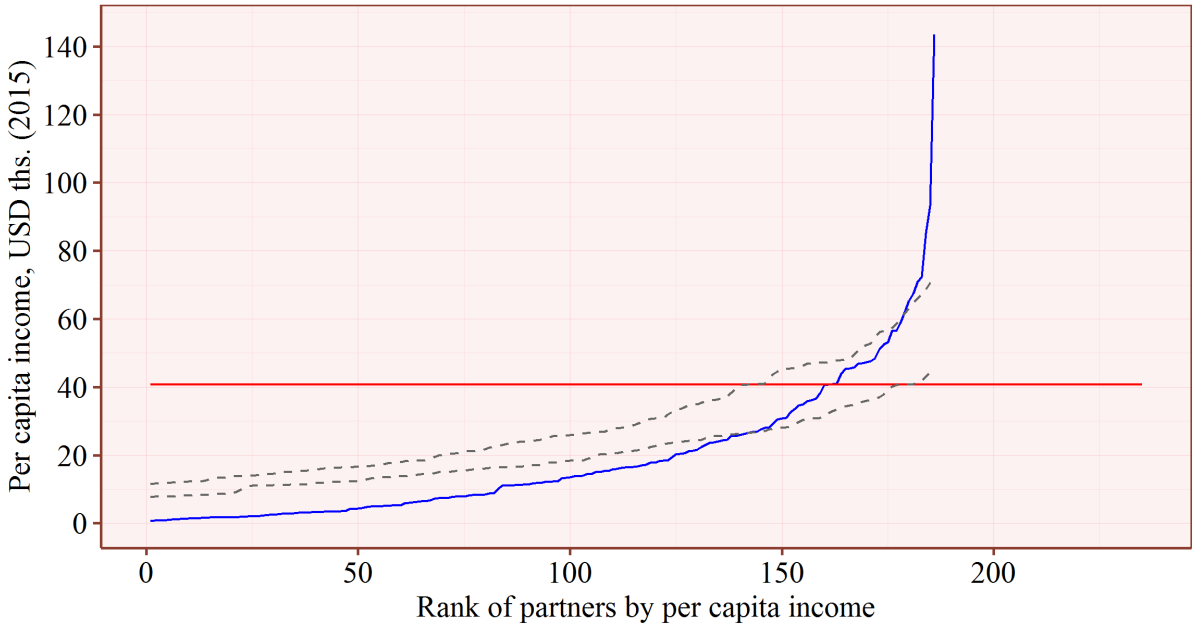
$$LB_{c,p} = \max\left(\frac{y_c^{(perc)} + y_p^{(perc)}}{2} - 0.05; 0\right), \quad (8)$$

$$UB_{c,p} = \min\left(\frac{y_c^{(perc)} + y_p^{(perc)}}{2} + 0.05; 1\right), \quad (9)$$

where *c* and *p* stand for the reporter and partner, respectively, and $y^{(perc)}$ stands for the percentile of per capita income.

If PRODY for the product falls within this range, the IIT flow is considered as horizontal. Product with the same PRODY may relate to different types of the IIT flow depending on per capita income of a trading partner. For example, if PRODY of the product under consideration is close to a country's per capita income (draw an imaginary horizontal line somewhere close to the red line at **Fig. 4**), then this country is considered to be an exporter of higher-quality varieties of the product to lower-income partners, an importer of higher-quality varieties from higher-income partners, and a participant in a horizontal IIT with partners of a similar per capita GDP. Note that, in the latter case, there is some possibility that PRODY would fall outside the values of the two per capita incomes while the trade flow would be still considered as horizontal. This is an important feature of the proposed method that helps to mitigate the undesirable influence of small variations of PRODY around per capita income on the result.

[11] PRODY is calculated based on per capita GDP's of all exporting countries, so it would be reasonable to compare it with per capita GDP's of the two countries participating in a certain bilateral trade flow.



Calculated based on: UN COMTRADE

Fig. 4 – The range that corresponds to horizontal IIT: an illustration

Of course, the threshold of 0.05 used in **(8)** and **(9)** is set arbitrarily and means that the two countries are considered as close in their per capita GDP if they are relatively close in its distribution (within half of a decile to the left and to the right). This threshold may vary from zero (then all IIT is vertical) to 0.5 (and then all IIT is horizontal). However, even this low threshold of 0.05, as we show later, results into the high share of horizontal IIT.

Finally, it is necessary to emphasize that using PRODY as an indicator of product quality is only one of the many possible ways to bring this strategy to data. One may use other product quality measures,[12] or apply a modified version of PRODY: for example, *Huber* (2017) proposes 75 variants of PRODY measures, and *Tacchella et al.* (2012) develop an iteration process to calculate a version of PRODY that gives more weight to exports by developing countries.

3.2. RCA-based approach

After finishing the critique of the unit value approach to dissecting IIT, *Lüthje and Nielsen* (2002, p. 602) stated that "an alternative method worth considering would be to take point of departure in comparative advantages as the theoretical basis for separating

[12] For instance, one may rely on trade diversification to detect both products' and countries' sophistication, just according to the following stylized fact established by *Hausmann and Hidalgo* (2011, p. 318): "poorly diversified countries export products that are, on average, exported by many other countries, whereas highly diversified countries make products which are made, on average, by fewer other countries," because such products require specific capabilities that are not wide-spread (have low "ubiquity").

trade in horizontally from trade in vertically differentiated goods." Starting from this notion, we try to add the dimension of comparative advantages to the whole story.

It has been shown empirically that the difference in comparative advantages between countries (measured as the difference in human and physical capital endowments or technological levels) is an important driver of inter-industry and vertical IIT (*Díaz Mora*, 2002), while the economies of scale, number of firms within an industry and per capita GDP influence horizontal IIT (*Gullstrand*, 2002). That's why, conceptually, it is important to know if there is a difference in comparative advantage between countries.

Suppose that countries have wide set of capabilities defined in the spirit of *Hausmann and Hidalgo* (2011) that influence their net export at the product level. By capabilities, we mean numerous country-specific factors, both tangible and intangible, including capital, labor, skills, infrastructure, location, tastes and so on. The number of capabilities is unknown and may even exceed the number of products.

Then it is reasonable to treat countries with similar signs of net trade for a product as having close capabilities specific for this particular product. This argument is close in nature to the classic statement that the capital abundant country generally should have positive net trade for the capital intensive good and negative net trade for the labor intensive good (see *Leamer* (1984), for example). In the case of capabilities, this reasoning is extended to the almost infinite number of factors.

So, if the two countries have close comparative advantage (roughly measured as the sign of the net trade for the product) but still participate in the IIT with each other, they are likely to export goods of a similar quality (that is, participate in a horizontal IIT flow) because their positioning in the global market is close.

At the same time, there is the strong theoretical evidence that richer countries tend to be net exporters of higher-quality products and net importers of lower-quality products (*Fajgelbaum, Grossman and Helpman*, 2011). So, the above reasoning about dissecting IIT is valid for those trade partners with similar per capita income, and may be violated for trade partners with a great difference in the level of economic development. This may happen because a country can gain a strong position in the global market due to both price and non-price competitiveness.[13] Therefore, if one ignores this theoretical evidence, the IIT flow between the two countries that base their positive net export on

[13] Distinguishing between price and non-price competitiveness is important. For example, traditionally it is assumed that developing countries gained their positions in the global market due to low costs. However, it has been showed that many developing countries including China improved their competitiveness mainly due to non-price factors (*Benkovskis and Wörz*, 2016), though price competitiveness related to reduction in costs is also important.

different competitiveness strategies would be mistakenly recorded as horizontal (while the product quality may differ significantly).

So, for every bilateral IIT flow, we propose to calculate the following:

$$type_{i,c,p} = \frac{1}{2}\left|close_{c,p} - coincide_{i,c,p}\right|, \text{ where} \quad (10)$$

$$\left\{\begin{array}{l} close_{c,p} = -1 \text{ if } \left|y_c^{(perc)} - y_p^{(perc)}\right| > 0.1 \\ close_{c,p} = 1 \text{ if } \left|y_c^{(perc)} - y_p^{(perc)}\right| \leq 0.1 \end{array}\right\}, \quad (11)$$

$$\left\{\begin{array}{l} coincide_{i,c,p} = -1 \text{ if } \frac{v_{i,c}^{(x)} - v_{i,c}^{(m)}}{\left|v_{i,c}^{(x)} - v_{i,c}^{(m)}\right|} \neq \frac{v_{i,p}^{(x)} - v_{i,p}^{(m)}}{\left|v_{i,p}^{(x)} - v_{i,p}^{(m)}\right|} \\ coincide_{c,p} = 1 \text{ if } \frac{v_{i,c}^{(x)} - v_{i,c}^{(m)}}{\left|v_{i,c}^{(x)} - v_{i,c}^{(m)}\right|} = \frac{v_{i,p}^{(x)} - v_{i,p}^{(m)}}{\left|v_{i,p}^{(x)} - v_{i,p}^{(m)}\right|} \end{array}\right\}, \quad (12)$$

and $type_{i,c,p} = 0$ stands for horizontal IIT, and $type_{i,c,p} = 1$ reflects vertical IIT.

For countries with close levels of economic development (the first term in **(10)** equals +1), the signs of the net trade should coincide (the second term in **(10)** should equal +1) in case of a horizontal trade flow and differ (-1) in case of a vertical trade flows. For countries with different levels of per capita income (the first term in **(10)** equals -1), the opposite is true.[14]

Note that we intentionally select to compare signs of the net trade, not its values, as it is difficult to decide what threshold should be chosen to distinguish between vertical and horizontal IIT. The absence of an *a priori* threshold at the product level is an advantage of the approach, though there is a threshold at the country level indicating if the two trading partners are close in per capita GDP. However, note that this approach does not allow one to identify which country exports a higher-quality product (for a vertical trade flow); it simply points that the quality is likely to be different.

Similarly as for the PRODY-based approach, we do not insist that the version of the RCA-based approach developed in this paper is the only one or the best one: a researcher

[14] Imagine that China trades with Malaysia in clothes. The two countries are close in per capita GDP, and that's why they are more likely to be engaged in horizontal IIT if they are both net exporters of clothes, but they are more likely to be engaged in quality differentiated IIT if only one country is a net exporter (then, a net importer doesn't have an RCA but *may* export to the net exporter due to higher quality).

Now imagine that China trades with Italy in clothes. The two countries are certainly different in per capita GDP, so they are more likely to be engaged in vertical IIT if they are both net exporters of clothes (China is likely to be a net exporter due to price competitiveness, while Italy may act as a net exporter due to much higher quality). If only China is a net importer, despite lower costs, then it may enter the demanding Italian market only by exporting products of a quality as high as possible, so that it may be engaged in horizontal IIT with Italy (that exports higher-quality products). And if only Italy is a net importer, then its higher quality is not a good competitive strategy compared to lower costs, so that it is better for Italy to export lower-quality but cheaper products to Chinese market.

may use many RCA indices, such as proposed by *Balassa* (1965), *Bowen* (1983), *Vollrath* (1991), *Lafay* (1992), *Leromain and Orefice* (2014) and some others.[15] At the same time, we hope that the approaches outlined in the paper would stimulate a further discussion on the empirical separation of horizontal and vertical IIT.

4. Empirical results

4.1. The data and outline of the calculating procedure

Bilateral trade data for our empirical analysis comes from UN COMTRADE. We calculate the share of horizontal IIT at the 6-digit product level according to HS 2007 classification. The data on PPP-based per capita GDP comes from IMF World Economic Outlook.

To calculate the share of horizontal IIT, we first obtain the share of IIT as the product of the trade turnover and Grubel-Lloyd index. Then we get the value of IIT and, for the traditional and discrete index-based unit value approaches, dissect it into three parts – horizontal, vertical and non-allocated trade flows.[16] In doing this, we follow *Greenaway et al.* (1994) who use the "overlap approach" recommended by *Gullstrand* (2002). Then we calculate the share of horizontal IIT for the cases of trade with other EU countries and trade with the world as a whole. Technically, we separately sum up the values of horizontal and total IIT over trading partners that meet the outlined conditions, and then calculate the resulting shares.

For the continuous index-based unit value approach proposed in Section 1.3, we get the value of horizontal IIT directly by multiplying the value of IIT and the version of PQH index from *Azhar and Elliott* (2006) with the modulus operator.

To calculate the share of horizontal IIT for the two alternative approaches developed in this paper, we also first obtain the value of IIT relying on the Grubel-Lloyd index. Then we follow the procedures specified earlier in Sections 2.1 and 2.2.

4.2. The results

The share of horizontal IIT in total IIT calculated according to the alternative PRODY- and RCA-based approaches have strongly different density distributions compared to the unit value approaches: the PRODY-based approach is more platykurtic, while the RCA-based approach is more leptokurtic (**Fig. 5**). They also tend to provide horizontal IIT share estimations that are much higher than estimations gained from the traditional unit

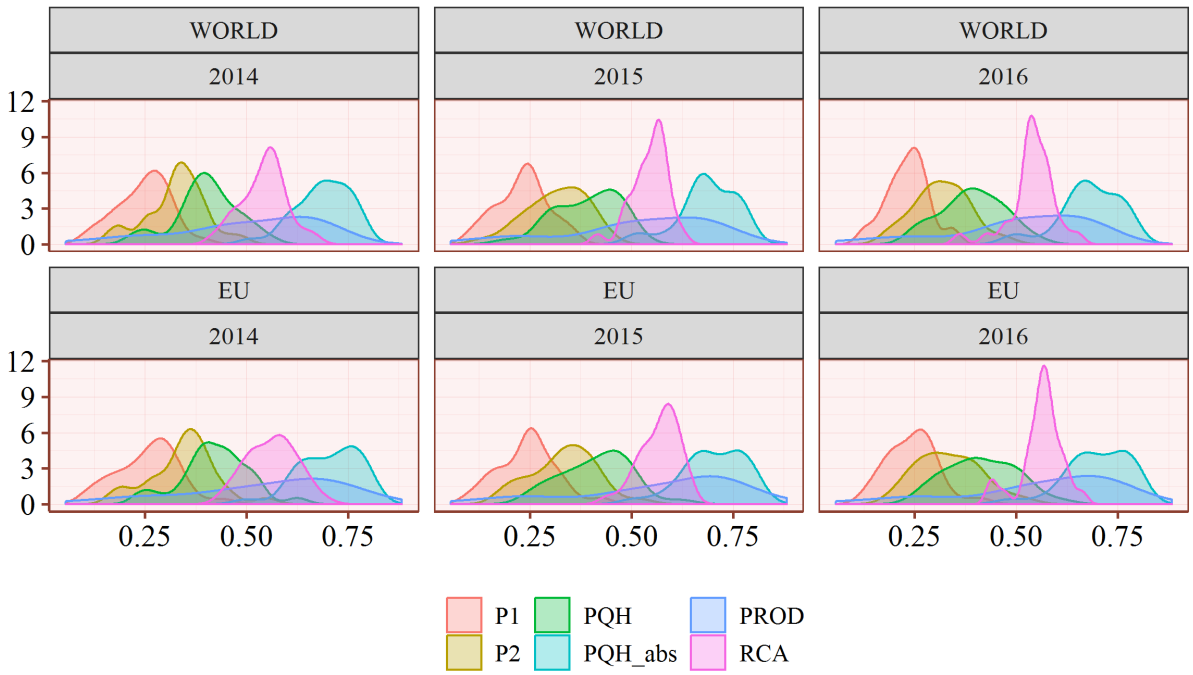
[15] For an overview, see *Gnidchenko and Salnikov* (2015).

[16] The trade flow is considered as non-allocated if it is impossible to calculate the unit value (there is no reported data in physical quantities).

value approach (P1 and P2) and the discrete index-based approach (PQH). However, the continuous version of the index-based approach (PQH_abs) reveals even higher horizontal IIT shares, though it is also in line with the unit value concept.

These facts illustrate the fundamental problem: the median share of horizontal IIT for EU countries strongly depends on the measurement strategy and vary from 0.23 to 0.7.

To check the validity of the approaches, we apply three simple tests. The first test relies on the assumption that EU countries that trade with other EU members more intensively should experience higher shares of horizontal IIT (due to closer per capita income and less pronounced differences in quality). This is definitely the case for the traditional unit value approach and the two versions of the index-based approach (**Fig. 6**). The share of horizontal IIT for the RCA-based approach is only slightly correlated with the share of exports to EU countries, while the horizontal IIT share for the PRODY-based approach is counterintuitively negatively correlated with the share of exports to EU countries. So, the unit value approaches demonstrate better behavior in this aspect. The positive news for these approaches is also the stability of countries' relative positions according to the share of horizontal IIT that insures the validity of cross-country comparison, though the absolute value of horizontal IIT share is still fundamentally unknown.



Calculated based on: UN COMTRADE

Fig. 5 – The share of horizontal IIT by approaches for different set of partners and years (density across all EU reporter countries)

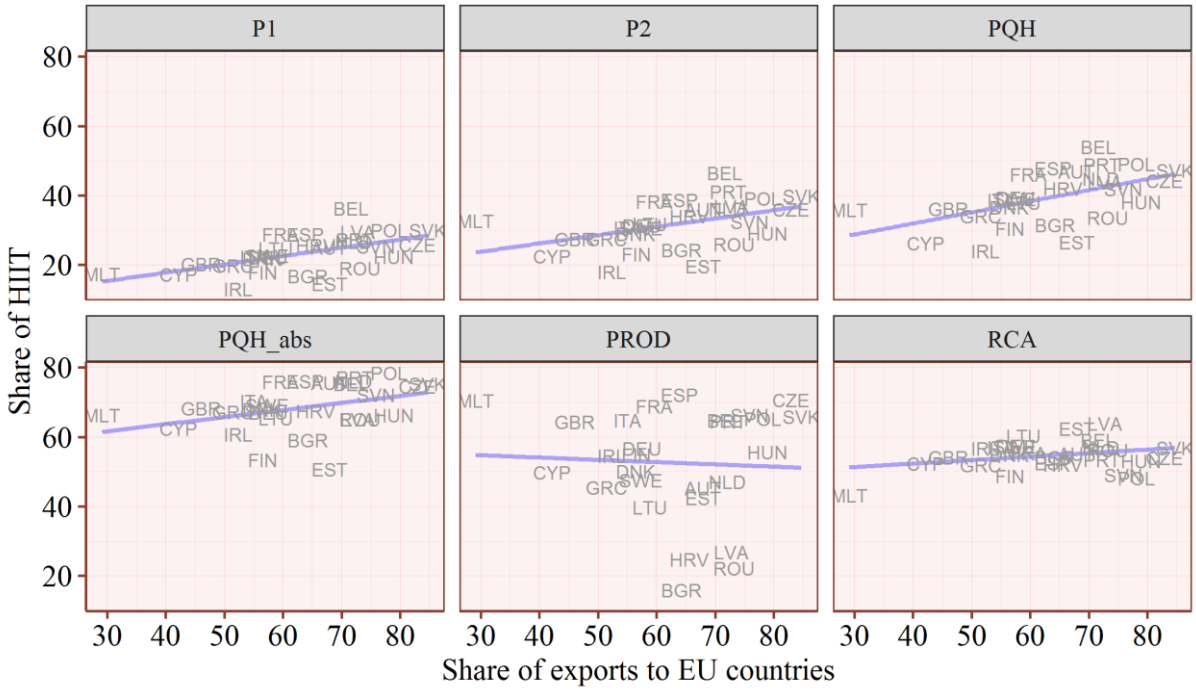


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Fig. 6 – The share of horizontal IIT and the share of exports to EU countries

The second test applied economic size as another indicator that should be related with the share of horizontal IIT positively (higher GDP stimulates scale effects and product variability). And this is the case for all the approaches except the RCA-based approach (**Fig. 7**). So, the RCA-based approach in the form proposed here should be possibly rejected due to an undesirable performance (very low variation of the index with the changes in GDP and the share of exports to other EU countries).

Additionally, we look at the link between per capita GDP and horizontal IIT share. One can see that the correlation of horizontal IIT shares with per capita GDP is pronounced only for the PRODY-based approach (**Fig. 8**). This result is rather a statistical artefact: countries in the middle of per capita GDP distribution are more likely to be engaged in horizontal IIT by construction (see **Fig. 4**). So, the version of the PRODY-based approach proposed here may suffer from implementation problems, though the idea itself may be promising. For all other approaches, horizontal IIT shares are practically uncorrelated with per capita income.

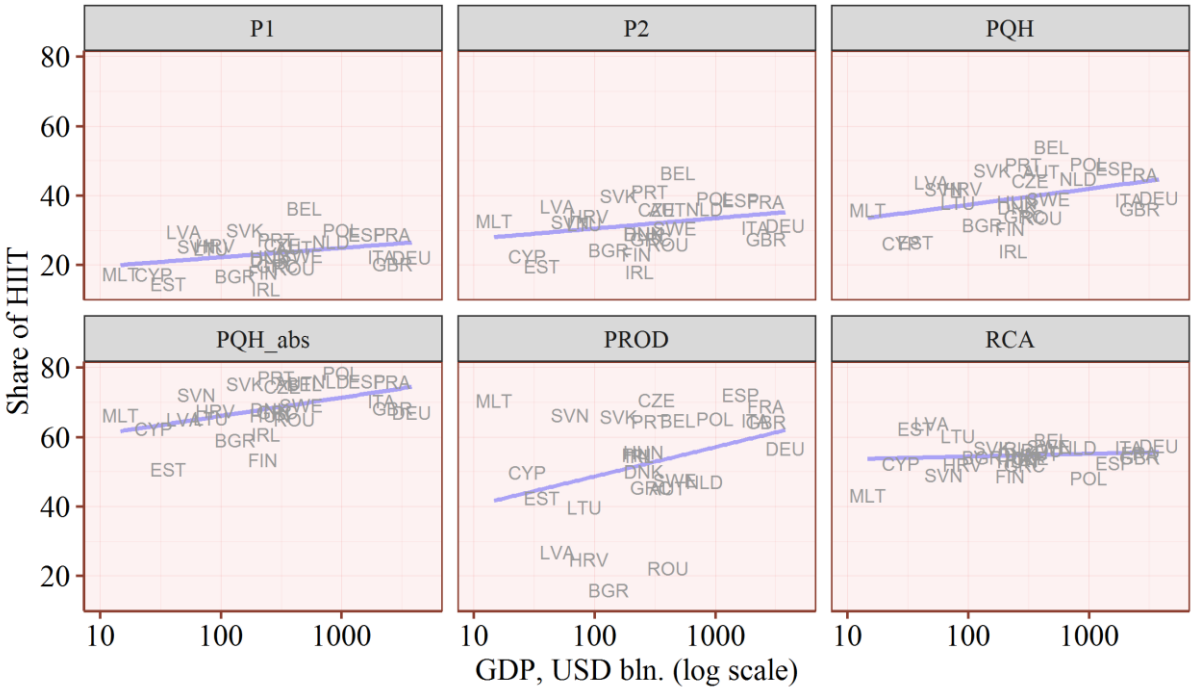

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Fig. 7 – The share of horizontal IIT and GDP

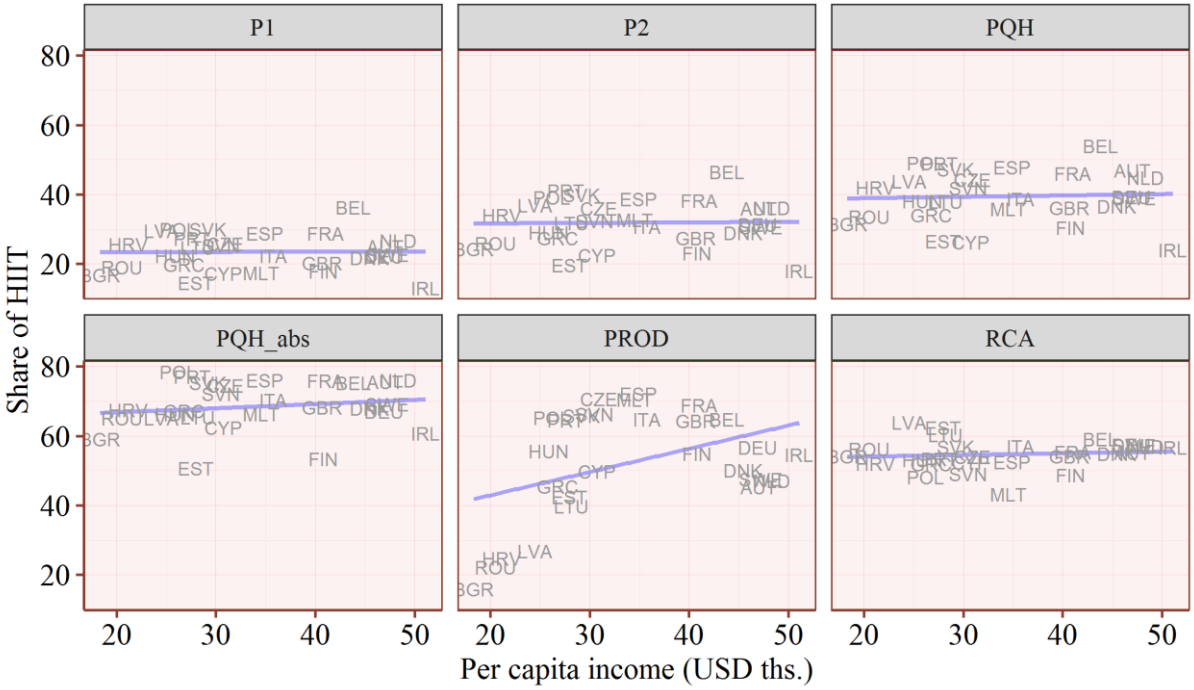

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Fig. 8 – The share of horizontal IIT and per capita GDP

The third test is comparing horizontal IIT shares for differentiated, reference priced and homogeneous products, according to classifier developed in *Rauch* (1999). The share of horizontal IIT should tend to 100 per cent for homogeneous products, since they are

not differentiated in quality and prices and thus should not be involved into vertical IIT. The two index-based modifications of the unit value approach (PQH and PQH_abs) are preferable from this perspective, while other approaches provide an unreasonably low share of horizontal IIT for homogeneous products (**Fig. 9**). Interestingly, the difference between approaches is much higher for reference priced and especially differentiated products. This fact may be studied in detail in further research.

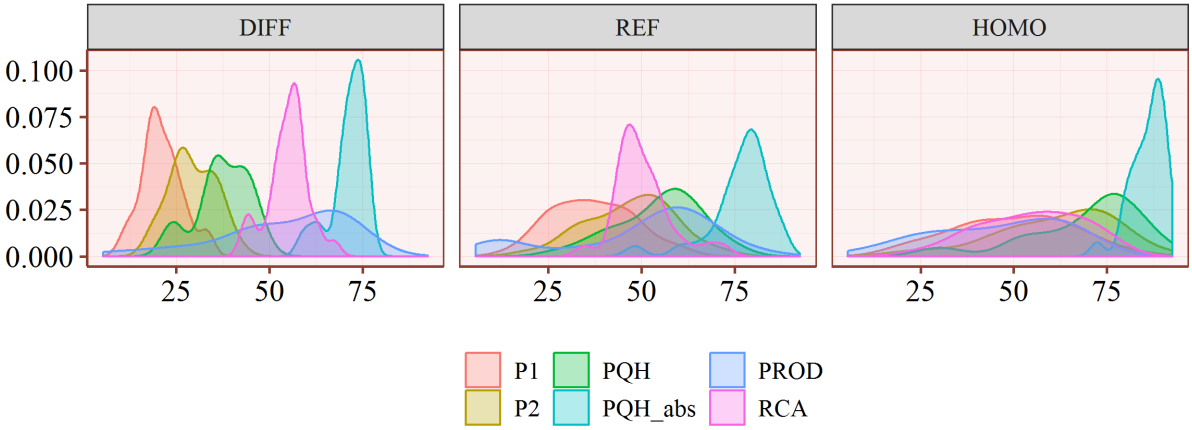

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Fig. 9 – The share of horizontal IIT by approaches for different product types (density across all EU reporter countries)

For all four versions of the unit value approach (P1, P2, PQH, PQH_abs), the share of horizontal IIT is the highest for homogeneous products, followed by reference priced and differentiated products (**Fig. 10**). This is exactly what should be expected. PRODY- and RCA-based approaches, on the contrary, violate this principle, that is the serious reason to finally reject these two approaches (at least, in the versions developed in this paper[17]). At the same time, though there are no formal limitations for the minimum horizontal IIT share for differentiated products, the median horizontal IIT share of 0.72 for the continuous index-based approach may be regarded by some economists as too high compared to conventional wisdom. So, future research in this direction is certainly needed to justify the choice of the fittest approach.

Our results raise the question about the importance of choosing a particular approach to dissecting IIT and clearly indicate that a careful analysis is needed to find a proper way to dissect IIT empirically.

[17] May be, some elegant modification would be able to correct the problems outlined above, but at this stage of the research we have to state that our alternative PRODY- and RCA-based approaches lead to a dead end. May be, a more fruitful approach should be based on combining this insights with a unit value measure.

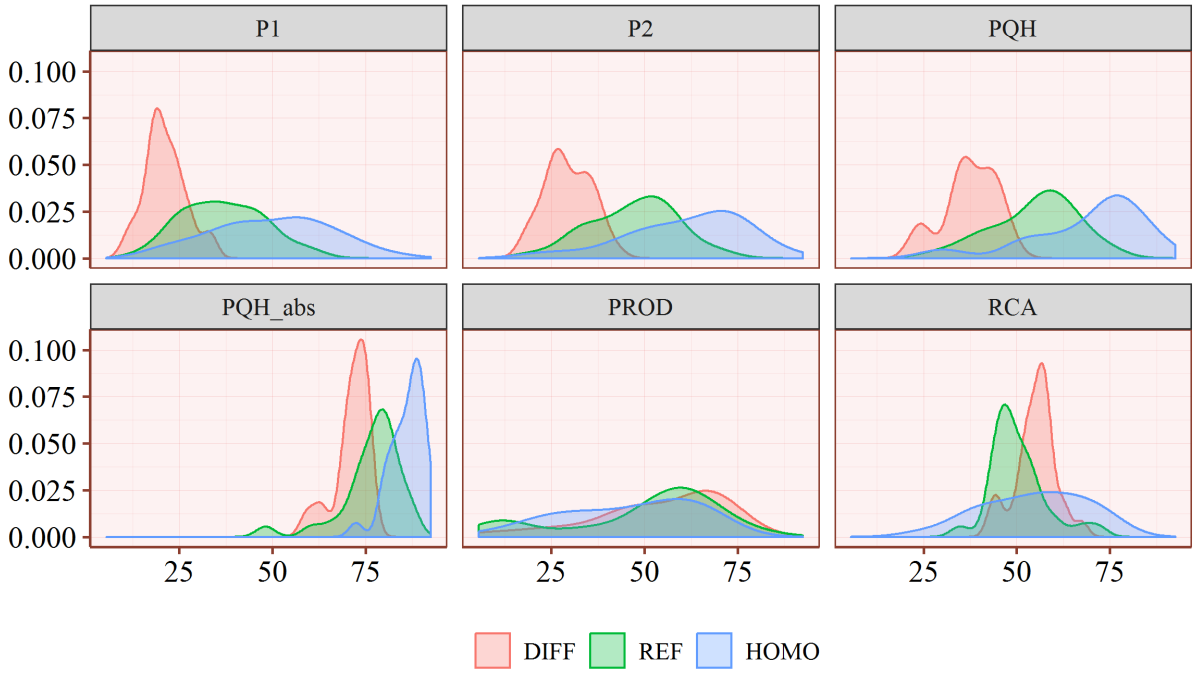

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Fig. 10 – The share of horizontal IIT by product types for different approaches (density across all EU reporter countries)

Conclusion

In the literature, IIT is dissected using unit values, without any exceptions. However, the association of unit values with product quality that underlies this procedure was found to be an oversimplification (at least six problems mentioned by different economists are summarized in the paper).

Aspiring to overcome these limitations, we take two actions. First, we propose the two alternative approaches to dissecting IIT. One approach is using another product quality indicator instead of unit values (in the version developed here, we apply the insight that a country's per capita GDP is reflected in its export product mix), and another one is applying RCA as a different theoretical basis for separating horizontal and vertical IIT, as recommended by *Lüthje and Nielsen* (2002).

Second, we develop a continuous treatment of horizontal and vertical IIT by modifying the PQH index proposed in *Azhar and Elliott* (2006) in the spirit of the overlap approach to measuring IIT itself (*Grubel and Lloyd*, 1975).

Then we apply three simple tests to check the validity of all approaches: the share of horizontal IIT of the EU country should be higher for trade with other EU members; the

share of horizontal IIT should be higher for large economies in terms of GDP; the share of horizontal IIT should tend to 100 per cent for homogeneous products.

Our quantitative results show that the PRODY- and RCA-based approaches should be rejected due to inconsistency with the expectations for most of the three tests, while all versions of the unit value approach (including the discrete and continuous index-based unit value approaches) perform satisfactorily in most cases. However, for the third test (high expected horizontal IIT share for homogeneous products), the performance differ substantially across the four versions of the unit value approach: the two index-based versions are preferable due to higher shares of horizontal IIT for homogeneous products. We conclude that that the median share of horizontal IIT for EU countries is still unknown due to fundamental uncertainty about the dissecting approach, but relative positions of countries for all forms of the unit value approach are quite stable, so there is much less uncertainty concerning the cross-country differences.

The major difficulty in dissecting IIT is measuring product quality. This process is not a mechanical one but requires some creativity. All approaches presented in the paper rely on reasonable theoretical backgrounds, but, at the moment, are not empirically implemented in the best way. It has been shown that unit values as proxies for quality has a number of drawbacks, but they are better adapted to pass most of our simple empirical tests. At the same time, we cannot recommend the alternative approaches as well, since they fail to pass most of our tests. However, both PRODY- and RCA-based approaches may be modified in many ways by applying different variations of PRODY or RCA indicators (and thus may potentially give better results).

So, there is a definite need in further research. Improving the ways of measuring quality at the detailed product-country level would be the most natural and fruitful step in this direction, but, at the same time, the most difficult. Alternative approaches presented in the paper dissect IIT without defining the quality in detail (since PRODY is product- but not country-specific, while RCA reflects product quality in an indirect manner). In case of a serious progress in measuring quality at the product-country level, these alternative approaches would be definitely not a priority. Otherwise, or until the better times, they may be helpful in studying IIT.

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