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STRUCTURAL TRANSFORMATION AND QUALITY LADDERS: SOLVING THE "THEIL'S CUBE"

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STRUCTURAL TRANSFORMATION AND QUALITY LADDERS: SOLVING THE "THEIL'S CUBE"[2]

We propose a decomposition of weighted Theil index of export concentration into the quantity- and quality-driven terms and calculate the proposed components for 5038 product groups and 120 countries. We link our findings to the debate on the role of quality upgrading in structural transformation. The results do not support the idea that climbing quality ladders (or quality upgrading within the actually exported products) is the best way to proceed with structural transformation: for most countries, the share of the quality-driven component of weighted Theil index doesn't exceed 20 per cent.

JEL Classification: F10, F14, L16, C43.

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1. Motivation

Structural transformation is traditionally viewed as the change in sectoral value added[3] shares. Basically, economists are interested in three sectors: agriculture, manufacturing and services (see *Duarte and Restuccia*, 2010; *Herrendorf et al.*, 2014), since classical structural transformation implies the transition from agriculture to services through manufacturing (*Kuznets*, 1973).

However, studies that link structural transformation to industry- or even product-level economic diversification started to proliferate since *Imbs and Wacziarg* (2003) revealed the hump-shaped relationship between economic diversification and development. Along the development path, countries first diversify and then specialize. *Klinger and Lederman* (2006), *Cadot et al.* (2011) confirmed this stylized fact for the case of export diversification. *Parteka* (2010) and *Mau* (2016), on the contrary, provided evidence against re-specialization at the high level of economic development. So, the debate on this issue is far from being over, and one may propose to dig deeper into the sources of export diversification in order to resolve the issue.

The most influential approach to slicing export diversification was developed by *Cadot et al.* (2011), who proposed to decompose Theil concentration index (*Theil*, 1972) into the extensive and intensive margins of export diversification.[4] They showed that re-specialization patterns are associated with the exit of some products[5] from rich-country export baskets. We are enthusiastic both about this result and about the potential to play with Theil index. Being easily decomposable, the index may be regarded as the mathematical counterpart for Rubik's cube: one may propose a lot of ways to slice the index into the meaningful components.

Our paper aims at analyzing the sources of structural transformation by decomposing Theil index into the quantity- and quality-driven concentration, thus accounting for structural transformation of exports along both quantity and quality dimensions. Thus we try to provide ground for the next research step: studying the link between economic development and export diversification shaped by quality differences. So, the paper is related to the wide literature on quality upgrading. The idea of "quality ladders" (*Khandelwal*, 2010; *Amiti and Khandelwal*, 2013) is particularly important: such quality ladders reflect the scope for quality differentiation and, thus, quality upgrading. However, the length of quality ladders varies from product to product. *Wacker and Trenczek* (2017) studied the dynamics of export unit

[3] Value added may be replaced with employment, output or exports.

[4] The extensive margin reflects export diversification due to growth in the number of active export lines, and the intensive margin reflects diversification due to equalization of export volumes among the active lines.

[5] Typically, products that stand far from countries' current endowments.

values[6] and concluded that there is a need in both quantitative and qualitative progress in export structure: diversification without quality upgrading doesn't drive productivity, but quality upgrading without diversification is hardly possible for developing countries as they typically specialize on products with shorter quality ladders.

But what is the proportion between quantity and quality dimensions? Which means more for shaping the cross-country differences in export concentration? These questions are in the center of our research interest in this particular paper.

Hausmann et al. (2007) proposed the highly cited idea that "what you export matters". Subsequent papers (*Hausmann and Klinger*, 2007; *Hausmann and Hidalgo*, 2011) developed a network approach to analyzing the structure of output and exports and provided evidence of a large heterogeneity in the distribution of capabilities (non-tradable inputs) across countries. The ideas perfectly fit into the structural transformation framework: according to *Hausmann and Klinger* (2007), countries tend to develop their export structure to the nearby products that require capabilities close to those they own. That is, the main driving force of structural transformation, according to this approach, is the change in the product mix. Nevertheless, recently the empirical study by *Papageorgiou et al.* (2017) emphasized that quality upgrading played the key role in export diversification for most East Asian countries. So, both channels are obviously important, but, again, what is the proportion?

In this paper, we try to examine the role of quality dimension for export diversification; however, unlike *Papageorgiou et al.* (2017), we do not rely on econometric specifications that estimate quality as the residual. Rather, we develop the novel direct decomposition of export concentration due to quantity and quality dimensions.

2. Methodology

2.1 Constructing the index

Theil index is famous for its ability to be decomposed into subgroups (for example, see *Bourguignon*, 1979, p. 915). However, for a long time this index was used to measure *income inequality*, though it is quite suitable for measuring *trade concentration* as well. Economists started to widely use Theil index in international trade studies after the publication by *Cadot et al.* (2011) that focused on the evolution of the intensive and extensive margins of export diversification along the economic development path. Note that *Cadot et al.* (2011) applied an unweighted Theil index formulated as follows:

[6] Unit value is the value of exports per unit of exported product (usually, per kilogram).

$$Theil^{(c)} = \frac{1}{n^{(c)}} \sum_i \frac{X_i^{(c)}}{\frac{1}{n^{(c)}} \sum_i X_i^{(c)}} ln \left(\frac{X_i^{(c)}}{\frac{1}{n^{(c)}} \sum_i X_i^{(c)}} \right), \quad (1)$$

where X_i is exports of product i in value terms, and n is the number of export lines for country c.

However, a number of researchers have adopted an alternative approach of measuring export concentration using weighted Theil index[7] (see *Parteka and Tamberi*, 2013):

$$Theil^{(c)} = \sum_i s_i^{(c)} ln \left(s_i^{(c)} / s_i^{(W)} \right), \quad (2)$$

where $s_i^{(c)}$ represents the share of product i in exports of country c in value terms, and $s_i^{(W)}$ stands for the share of product i in world imports in value terms. The i-th element for the case of zero trade is mechanically set to zero (since $s_i^{(c)}$=0).[8]

We prefer weighted Theil index for several reasons. Firstly, as argued by *Parteka and Tamberi* (2013, p. 124), absolute (or, in our terms, unweighted) measures of diversification isolate country-specific trade patterns from those typical for world structure of trade and do not account for relative importance of products. Secondly, *Lessmann* (2014, p. 37) shows that the lack of homogeneity in classification units[9] makes it difficult to interpret an unweighted measure. And finally, weighted Theil index in the form presented in equation (2), in fact, measures the deviation of a country's product-level export structure from the patterns of world demand.

Practically, these features of the index are important because we are not able to choose product groups according to some criteria but rather make calculations simultaneously for all standard product groups from international Harmonized System classification.

Imagine that a country has numerous zero trade flows. The standard unweighted Theil index would treat all these trade flows equally, even if some of the product groups are not traded internationally. The weighted Theil index would imply that zero trade for a product that is not traded internationally and a product heavily traded by other countries are quite different stories. The first would not have impact on the weighted trade structure, while the second would have much impact.

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[7] One may easily show that unweighted Theil index from equation (1) would be equal to weighted Theil index from equation (2) if world import values for all product lines are identical (in this case, all shares for the world imports would equal $1/n^{(W)}$, where $n^{(W)}$ stands for the number of export lines for the world).

[8] By construction, Theil index ranges from zero to infinity. Zero index value reflects full diversification, or a perfect match between export structure of a country and the whole world. For a certain country, zero trade for products that are heavily traded by other countries would *raise the trade shares for other products* compared with the world average. So, the index is able to account for these cases indirectly.

[9] In his case, unequal distribution of population by regions; in our case, unequal distribution of export value by products.

2.2 Decomposing the index

In this paper, we develop a novel decomposition of Theil index of export concentration into the two terms – concentration resulted from the differences in the structure of quantities (exports in physical terms) between a country and the world, and concentration resulted from the differences in the structure of unit values.[10]

Firstly, we present the shares from equation (2) as follows:

$$s_i^{(c)} = \frac{p_i^{(c)} q_i^{(c)}}{\sum_i p_i^{(c)} q_i^{(c)}}, \quad (3)$$

$$s_i^{(W)} = \frac{p_i^{(W)} q_i^{(W)}}{\sum_i p_i^{(W)} q_i^{(W)}}, \quad (4)$$

where p_i is the export unit value for product i, q_i is the volume of exports of product i in physical terms, while superscripts c and W indicate a country and the world, respectively.

Secondly, we apply the logarithm quotient rule to equation (2) and get:

$$Theil^{(c)} = \sum_i s_i^{(c)} ln\left(s_i^{(c)}\right) - \sum_i s_i^{(c)} ln\left(s_i^{(W)}\right). \quad (5)$$

Then we transform equation (5) by adding and subtracting the same term γ:

$$Theil^{(c)} = \left[\gamma - \sum_i s_i^{(c)} ln\left(s_i^{(W)}\right)\right] + \left[\sum_i s_i^{(c)} ln\left(s_i^{(c)}\right) - \gamma\right], \quad (6)$$

$$\text{where } \gamma = \sum_i s_i^{(c)} ln\left(s_i^{(c_w)}\right), \quad (7)$$

$$s_i^{(c_w)} = \frac{p_i^{(W)} q_i^{(c)}}{\sum_i p_i^{(W)} q_i^{(c)}}, \quad (8)$$

and $s_i^{(c_w)}$ is the "neutral" (to unit values) share of product i in exports of country c (that is, this share reflects only differences in quantities, not prices), where $p_i^{(W)}$ is the world export unit value for product i (sum of exports in USD by all countries divided by the sum of exports in kilograms by these countries[11]).

Finally, we obtain the resulting decomposition:

$$Theil^{(c)} = \left[\sum_i s_i^{(c)} ln\left(s_i^{(c_w)} / s_i^{(W)}\right)\right] + \left[\sum_i s_i^{(c)} ln\left(s_i^{(c)} / s_i^{(c_w)}\right)\right], \quad (9)$$

where the first term in square brackets represents Theil index component shaped by quantities, while the second term reflects the component shaped by unit values (quality).

[10] Note that the effect of changes in world prices is eliminated because a country's structure is compared with the world average.

[11] To exclude the impact of outliers on the world price, we use an estimated export in kilograms for this calculation. For each product group, we recalculate export in kilograms for countries whose export unit value is higher than 95th or lower than 5th percentile. We fix such unit values at these bounds and estimate export in kilograms by dividing export value in USD on the fixed unit values (since the outliers are rarely registered for export value data, unlike export volume data).

Note that the term associated with unit values, in fact, reflects both quality and prices. So, this term can be interpreted as the upper bound estimation for export concentration due to the differences in quality: to some extent, unit values are higher due to higher quality, and the rest is explained by higher prices that may reflect markups, scale effects and costs.

Quality estimations are usually extracted from unit value data by combining it with other indicators.[12] Conditional on unit values, *Khandelwal* (2010) assigns higher quality to product groups with higher market shares, while *Hallak and Schott* (2011) use international trade balances for this purpose. Other studies obtain estimations for quality as a residual, eliminating the effect of unit values and country-year / product fixed effects: according to this approach, a higher quality variety is the one with a higher quantity, conditional on unit value (*Khandelwal et al.*, 2013; *Fan et al.*, 2013; *Manova and Yu*, 2017). Note that *all these studies* use unit value as the key variable that should be controlled for to account for quality. So, quality is primarily reflected in unit values, while there is no any consensus about other indicators that reflect quality. Thus, at this stage of our research, we prefer to interpret the second term from (9) associated with unit values as the *upper bound* estimation for export concentration due to the differences in quality.

3. Empirics

3.1. Key cross-country patterns

The data for our empirical work comes from the UN COMTRADE database (USD and volumes in kilograms). We use the data for 2017 at the 6-digit level of Harmonized System classification (further, HS).[13] To obtain the world aggregates for every product group (the total number of product groups is 5038), we sum up the imports by all countries that reported any data. Then we calculate Theil index for every country from our sample (120 countries).[14]

Even the first look at the kernel density distribution functions for Theil index and its quantity-driven component shows almost no difference (**Fig. 1**). Countries are more likely to experience export concentration different from the world average due to the different mix of products exported. The role of quality dimension for the differences in export concentration is small: for most reporters, the share of the quality-driven component of Theil index does not exceed 20 per cent (**Fig. 2**). One explanation for such a low share of the quality-driven

[12] *Schott* (2004), *Hummels and Klenow* (2005) use unit value as proxy for quality, but later studies argue that unit value may reflect other factors as well.

[13] Such detalization is necessary to divide trade flows into differentiated and homogeneous products.

[14] Unit values that do not fall into the range between the 5-th and 95-th percentiles are set to these limits in order to eliminate the outliers (the general results do not change much if we do not apply these procedure).

component boils down to the fact that only 65 per cent of world imports consists of products that are heterogeneous in quality and thus prices – that is, differentiated products in *Rauch*'s (1999) classification.[15] Just as should be expected, countries that trade differentiated products more actively have the higher share of the quality-driven component of Theil index (**Fig. 3**).

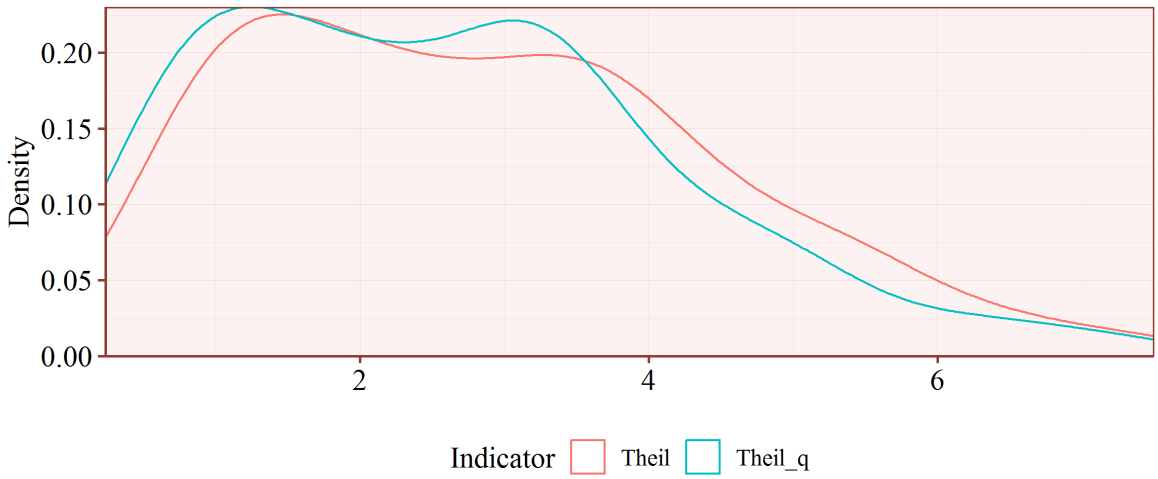

***Fig. 1**. Theil index and its quantity-driven component, kernel density distribution by countries*

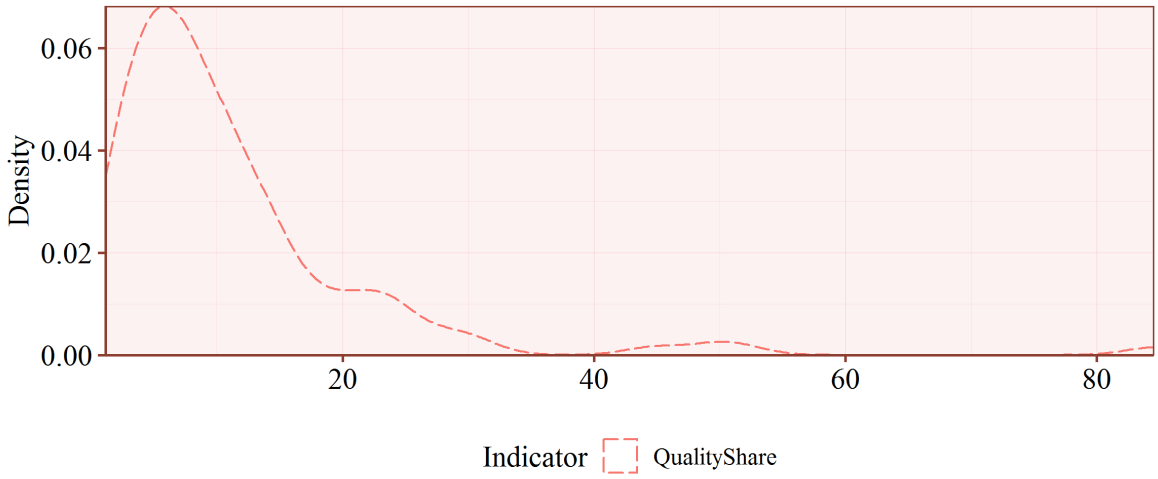

***Fig. 2**. Share of the quality-driven component, kernel density distribution by countries*

[15] To calculate these shares, we first marked all HS 6-digit product groups as differentiated, reference priced or traded on an organized exchange, relying on the *"proddiff"* function from the R *"concordance"* package. If the match was not found, we used the most common type for the corresponding HS 2-digit product group.

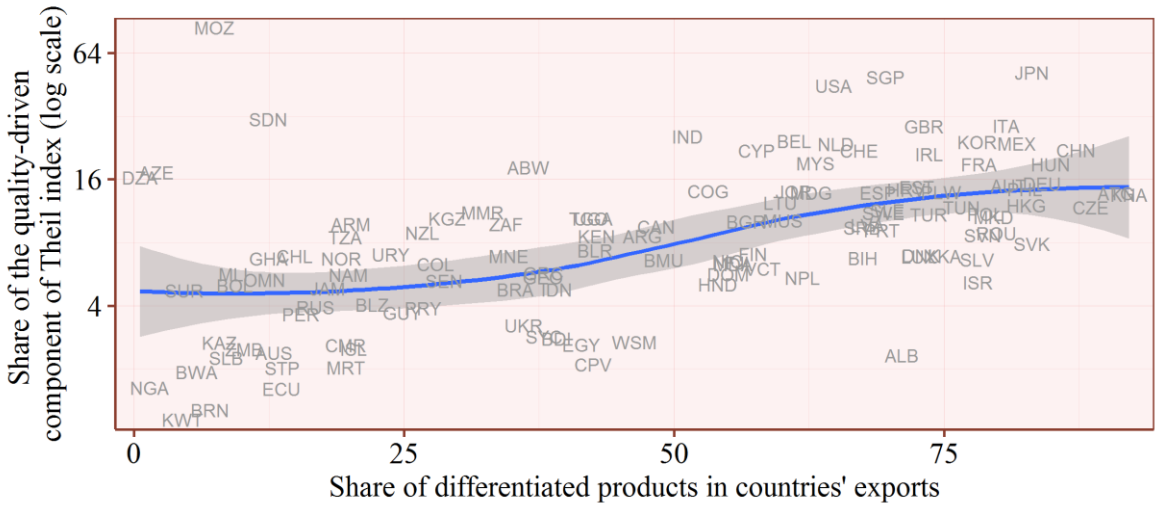

***Fig. 3**. Share of the quality-driven component and share of differentiated products defined in Rauch (1999), by countries*

And what about decomposing Theil index for differentiated products only? This choice is not an artificial one, since homogeneous products should be not differentiated in quality by definition. This is also confirmed by the data: one may see that the median length of quality ladders[16] for differentiated products is definitely higher, while the lengths for homogeneous and reference priced products are very close to each other (**Fig. 4**).

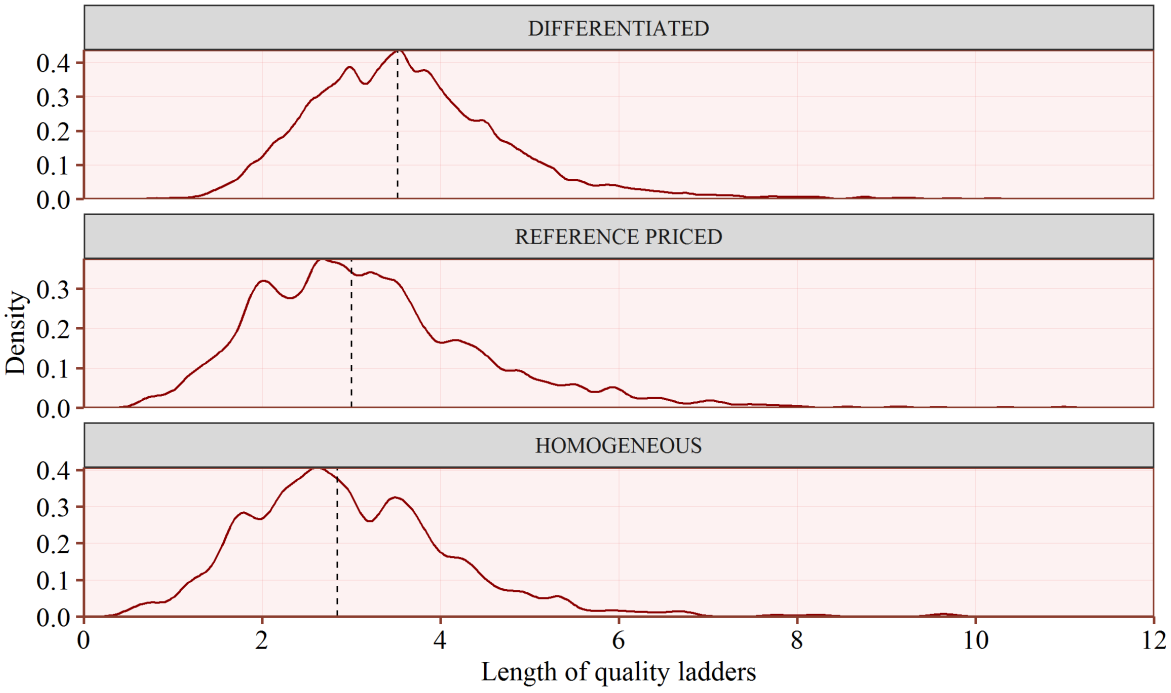

***Fig. 4**. Length of quality ladders by product groups defined in Rauch (1999), kernel density distribution by countries*

[16] We define the length of a quality ladder for each product as the ratio of the 95th and 5th percentile of the unit values across countries, to ignore the outliers. Longer quality ladders mean higher potential to improve quality and raise export prices. The **Appendix** clarifies the concept of a quality ladder and presents an example of a graphical representation of quality ladders for two goods – locomotives and unwrought nickel.

Following this logics, we skip the homogenous products from the analysis, and then repeat our exercise.[17] Not surprisingly, the kernel density distribution for the share of the quality-driven component shifts to the right, but the shift is moderate (**Fig. 5**). So, even for differentiated products only, countries are still more likely to experience export concentration patterns different from the world average primarily due to the different mix of products, not quality upgrading *within* the actually exported products.

The role of the quality dimension may become more important, but typically only after widening the product mix – that is, for countries with highly diversified export basket (**Fig. 6**). So, the results of our empirical exercise do not support the idea that climbing quality ladders (quality upgrading *within* the actually exported products) is the best way to proceed with structural transformation; rather, they favor the network approach by Hausmann et al.

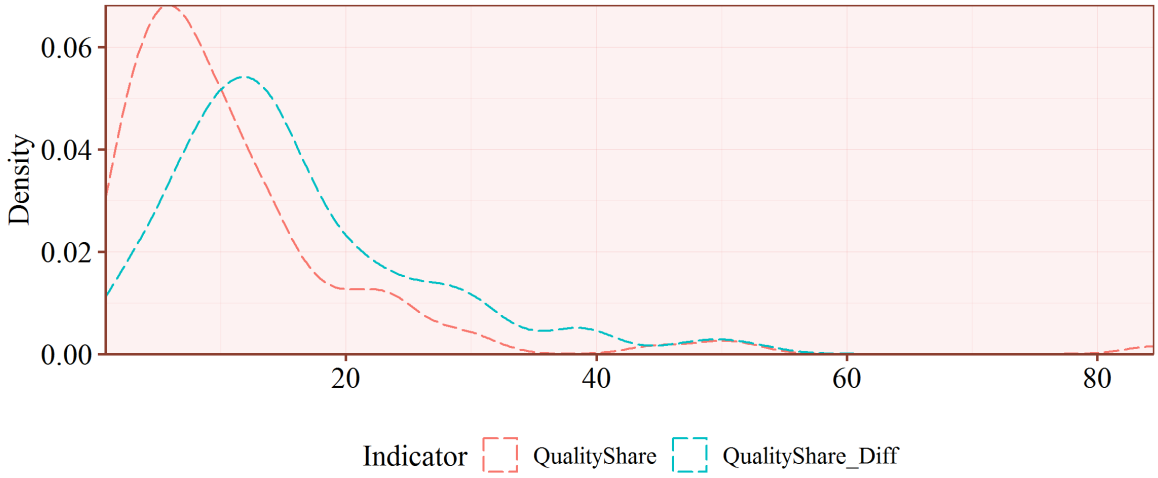

***Fig. 5**. Share of the quality-driven component for all products and differentiated products, kernel density distribution by countries*

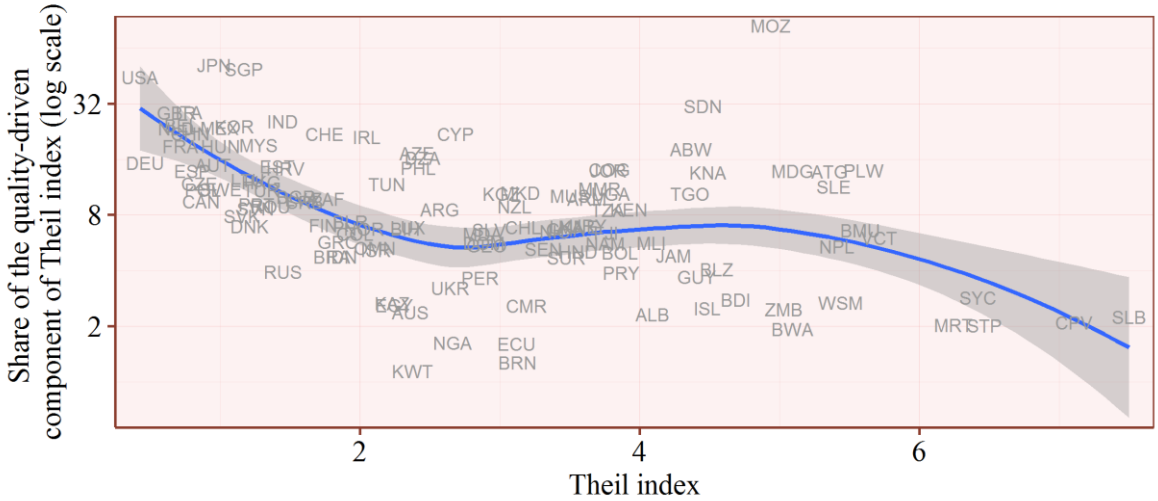

***Fig. 6**. Theil index and the share of the quality-driven component, by countries*

[17] Trade shares in this case are recalculated, relative to total trade in differentiated products only.

Note that our results do not mean that quality upgrading is not important. Country may upgrade its export quality by moving to more complex products such as pharmaceuticals or machinery. Our results demonstrate that quality upgrading *within* the actually exported products may be powerless without the changes in the product mix.

3.2. Stability of the results

To demonstrate the stability of our conclusion about the dominance of the quantity-driven component, we construct the boxplot by years across all countries. It shows that the median share of the quality-driven component is rather stable (**Fig. 7**); this share is only a bit higher for differentiated products.

However, the boxplot by selected countries across all years shows that countries differ much in the median share of the quality-driven component and the share's dispersion (**Fig. 8**). Moreover, outliers occur quite often, due to sharp changes in unit values for major products. For example, the outlier for Japanese exports in 2017 is associated with the reporting error for silver powder. Such errors are usually found in physical volumes data.

So, the results are definitely stable in time for an average country, but may vary from year to year for a specific country. This fact limits our ability to construct and analyze cross-country panel data for the components of the weighted Theil index, at least until the data is cleaned from "outliers."

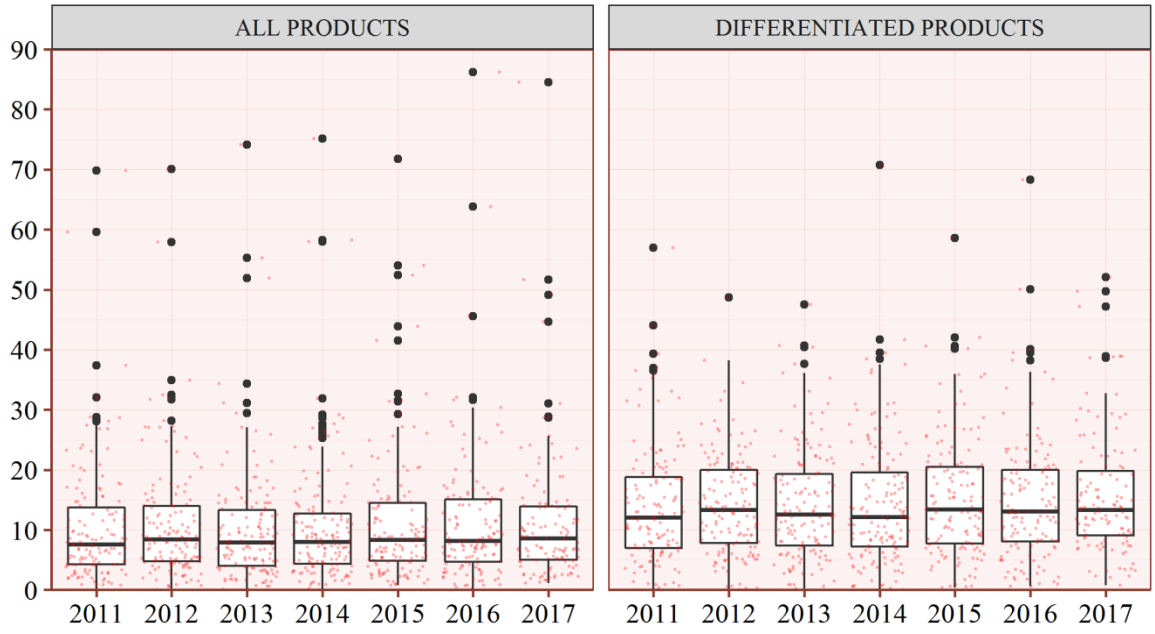

***Fig. 7**. Share of the quality-driven component of Theil index by years across all countries*

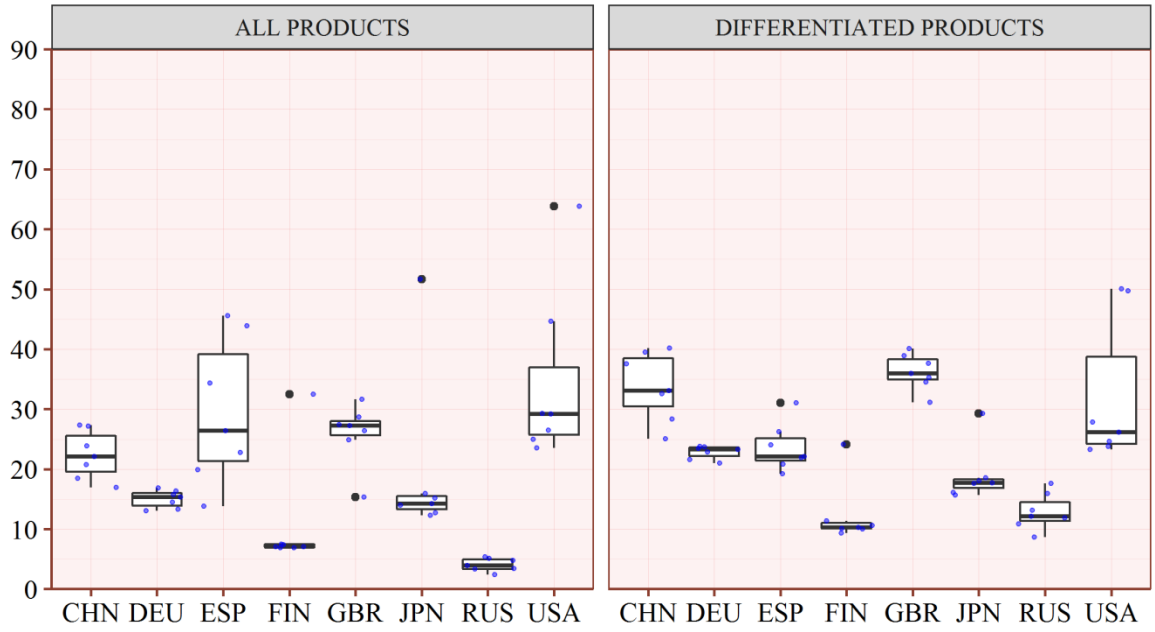

Fig. 8*. Share of the quality-driven component of Theil index by selected countries across all years*

4. Conclusion

In this paper, we develop the novel decomposition of the weighted Theil index into the two terms that reflect differences between countries in the structure of exported quantities (quantity-driven component) and unit values (quality-driven component). We show that bulk of the differences in export concentration boils down to the product mix, not the differences in quality *within* the actually exported products. The best strategy to proceed with structural transformation is: jumping to longer ladders first (or moving to nearby complex products) and then climbing up (raising quality). The results are quite stable on average, but should be treated with caution at the individual country level due to "outliers."

Future research may move in several directions. First, after the intensive data cleaning, it would be useful to trace the link between economic development and export diversification shaped by quality differences. Second, it is highly important to study the timing of structural transformation along quantity and quality dimensions: is it necessary to make progress along both dimensions simultaneously for a successful structural transformation?

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Appendix

Technically, we construct each quality ladder as an empirical cumulative distribution function of unit values across all countries for a particular product. Depending on the research purpose, one may construct unweighted or weighted quality ladders (high stairs for weighted quality ladders indicate large exporters; they are difficult to climb, especially at the top).

Longer quality ladders mean much higher potential to improve quality and raise export prices. For example, Russia may increase the revenue from exporting railway locomotives 10 times only by improving their quality to the German level (see **Fig. A1**).

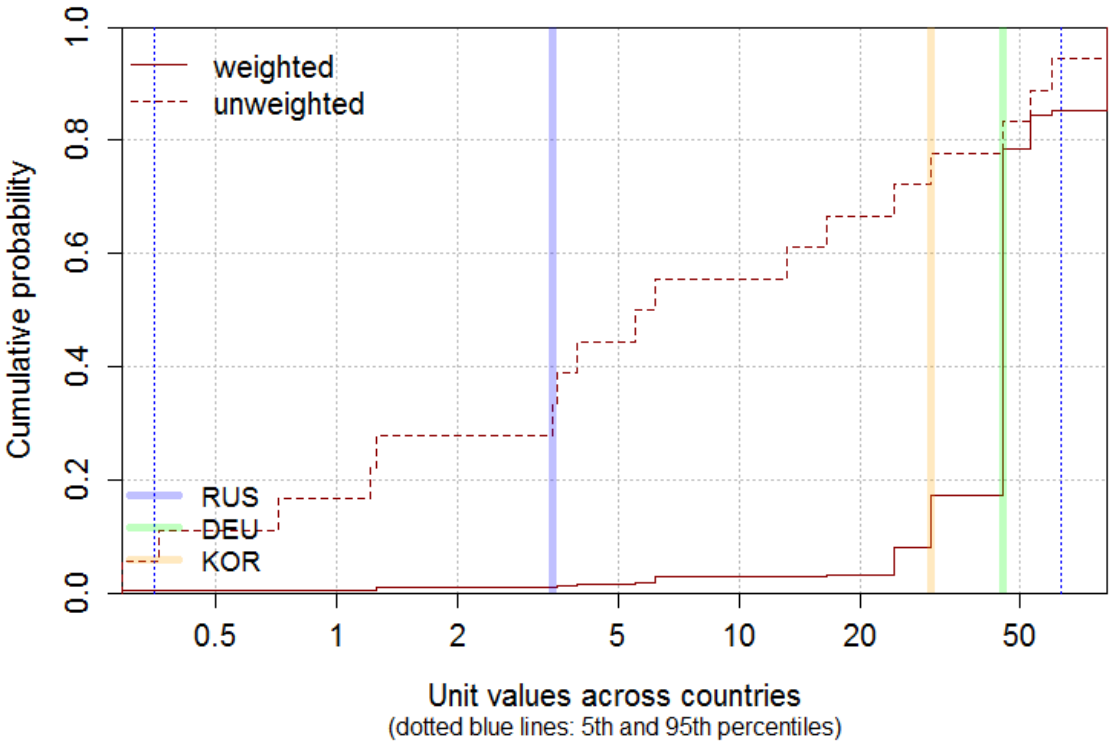

***Fig. A1**. Weighted and unweighted quality ladders for railway locomotives (HS 860110)*

Shorter quality ladders mean much lower potential to improve quality and raise export prices, due to the "standardized" nature of the product. A good example is unwrought nickel (see **Fig. A2**). For this product, Russia is unable to increase exports much even after climbing at the very top of the quality ladder. Rather, the country should move to nearby products that are more complex (nickel tubes, pipes, etc.).

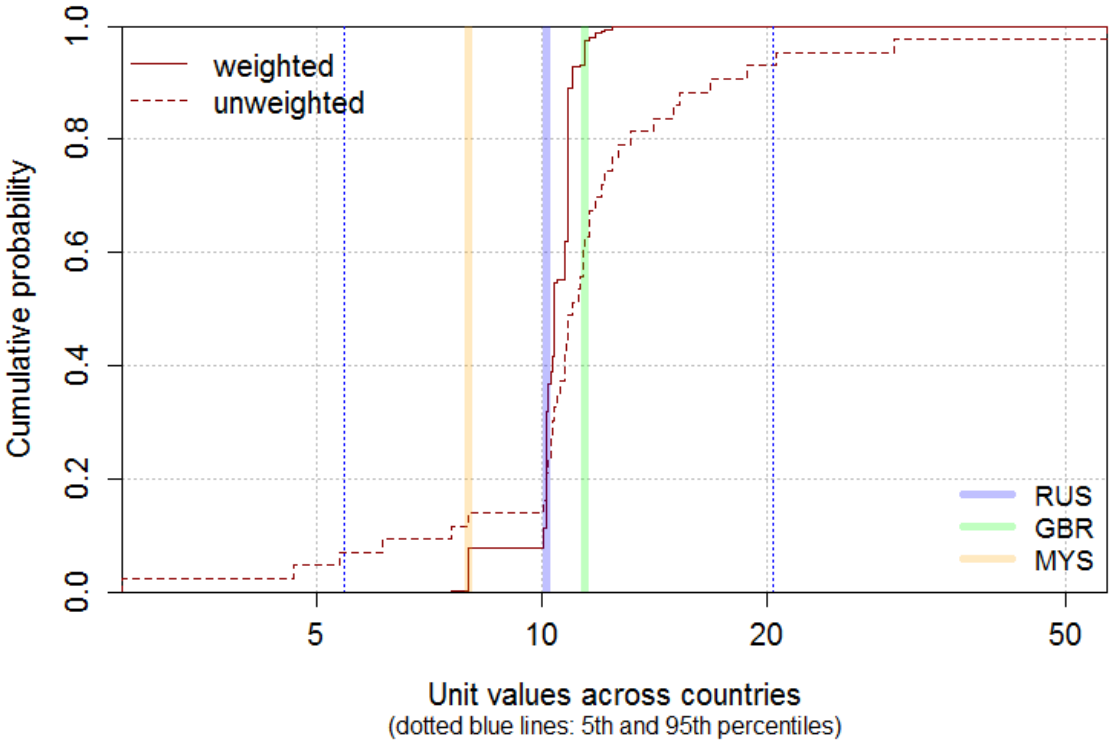

***Fig. A2**. Weighted and unweighted quality ladders for unwrought nickel (HS 750210)*

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