Structural Transformation and Quality Ladders: Evidence from the New Theil's Decomposition*

Andrey A. Gnidchenko†

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Abstract. This paper examines structural transformation along the development path by linking export concentration to economic development in a cross-country setting. I explore the role of widening product mix, export restructuring and quality upgrading for the patterns of export concentration measured by the weighted Theil index. This study contributes to the literature by developing the decomposition of this index into the extensive, quantitative and qualitative components. I find that structural transformation is primarily driven by export restructuring according to the world demand and towards the products with higher potential to improve quality. Controlling for the world demand, re-specialization is not pronounced at a high level of economic development, while the ability to upgrade quality becomes increasingly important for the higher-middle-income and high-income countries.

JEL Classification: F10, F14, L16, C43.

Keywords: export concentration, economic development, Theil index, unit value.

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† *Affiliations:* Center for Macroeconomic Analysis and Short-Term Forecasting; Institute of Economic Forecasting, Russian Academy of Sciences; National Research University Higher School of Economics – Nakhimovsky prospekt, 47, Moscow, Russia. Senior research fellow.

E-mail: agnidchenko@forecast.ru

1. Introduction

The importance of structural transformation for economic growth has been emphasized in the literature since the middle of the 20th century. *Kuznets* (1973) marked the high rate of structural transformation (the shift from agriculture to industry and then services) as one of the key features of modern economic growth. Following this concept, *Duarte and Restuccia* (2010) and *Herrendorf et al.* (2014) defined structural transformation as the reallocation of economic activity across the broad sectors of agriculture, manufacturing, and services.

In parallel, *Hidalgo and Hausmann* (2009) developed the new view on how a country's productive structure changes. They linked a set of products exported by a country to a set of its capabilities and showed that export structure evolves by spreading to "nearby" products that require a similar set of capabilities. In this concept, structural transformation is a process of the gradual accumulation of capabilities. Countries combine new capabilities with a set of existing ones, resulting in new products. Accumulation of capabilities is empirically reflected in higher export diversification, and countries with a wider set of capabilities tend to export "sophisticated" products (exported by higher-income countries).

However, this concept does not account for product quality variation among countries. *Sutton and Trefler* (2011) confirmed that countries do move into "sophisticated" products, but low-income countries tend to produce such products at low quality. *Henn et al.* (2020) stated that diversification and quality upgrading are complementary in the development process, and that diversification without quality upgrading may not lead to a boost in per capita GDP. On the other hand, as argued by *Wacker and Trenczek* (2017), quality upgrading per se is not enough for developing countries because they typically export products with less potential to improve quality (with shorter "quality ladders": *Grossman and Helpman*, 1991; *Taylor*, 1993; *Khandelwal*, 2010; *Amiti and Khandelwal*, 2013). Quality ladders reflect the scope of quality differentiation and thus quality upgrading of the exported products.

In this paper, I propose to study diversification and quality upgrading simultaneously. Following *Cadot et al.* (2011) and *Parteka and Tamberi* (2013), I link export concentration to economic development, and measure export concentration by the Theil index in the two forms. The standard Theil index implies that perfect diversification is the equality of exports for all products. According to the weighted Theil, perfect diversification is the absence of revealed comparative advantage in any product (a perfect match between the structures of exports and world demand). As the weighted Theil accounts for the world demand, it is more suitable for analyzing export concentration. In the paper, I focus on the two research questions.

First, *what is the key driver of structural transformation: restructuring export volumes, exporting new products, or quality upgrading of the exported products*? Should a country change its patterns of export specialization to achieve higher export diversification? or is it enough to export more products and improve quality? Decomposing the Theil export concentration index is a relevant tool to answer these questions. However, there is a lack of evidence of this sort in the literature. *Hummels and Klenow* (2005) studied to what extent a typical country's exports (but not export concentration) are shaped by the number of exported products (the extensive margin), export quantities, and prices (the intensive margin). *Cadot et al.* (2011) decomposed the standard Theil into the extensive and intensive margins but did not account for prices. On the other hand, the weighted Theil index advocated by *Parteka and Tamberi* (2013) has not been ever decomposed.

I develop the decomposition of the weighted Theil into the extensive, quantitative and qualitative components. The latter is based on export unit values (USD per physical unit of the product) and represents quality upgrading. I show that structural transformation is primarily driven by the quantitative component (restructuring of export volumes). Overall contribution of the qualitative component and the extensive margin is low. However, the least developed countries experience a rapid progress both in quality upgrading and exporting new products. The middle-income countries are primarily bounded by their export structure.

Second, *do countries at a high level of economic development re-concentrate their exports?* In other words, is there a U-shaped relationship between export concentration and per capita income? If so, there is no need in diversifying exports after a certain level of per capita income. If not, the need in export diversification is persistent. There is no confidence on this point in the literature. *Imbs and Wacziarg* (2003), *Klinger and Lederman* (2006), and *Cadot et al.* (2011) documented the U-shaped relationship between economic concentration and per capita GDP, but *Parteka* (2010) and *Mau* (2016) provided evidence against the re-specialization.

I test the stability of export concentration path in the flexible environment of a non-parametric approach to obtain the result that is not affected by few countries with the very high per capita income. I apply the locally estimated scatterplot smoothing (*loess*) procedure in several steps, excluding the country with a maximal value of per capita income in each step. As I show, re-specialization is not pronounced for the generalized weighted Theil index, unlike the standard Theil. This is explained by the fact that exports of many oil and gas exporting countries are much less concentrated after I control for the structure of world demand. The results speak against the re-specialization of exports.

So, the key message of the paper may be formulated as follows. Countries consistently experience export diversification, but the potential to diversify by exporting new products or quality upgrading becomes limited for the middle-income countries; their further success is primarily associated with their ability to change the export structure according to the world demand and towards the products with higher potential to improve quality.

The remainder of the paper is structured as follows. In *Section 2*, I compare the two versions of the Theil index and develop the new decomposition of the weighted Theil index. In *Section 3*, I discuss the link between export concentration and economic development in the contexts of the differences between the standard and the weighted Theil indices and the new decomposition of the weighted Theil. In *Section 4*, I explore the quality margin with the special emphasis on the quality ladders concept. *Section 5* concludes.

2. Methodology

2.1. Constructing the Theil

Economists started to use the Theil index in international trade studies after the paper by *Cadot et al.* (2011), which focused on the evolution of the intensive and extensive margins of export diversification along the development path. They measured export concentration by the unweighted (standard) Theil index formulated as follows:

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

where X_i^c is the export value for product i and country c, and n is the total number of products exported by all countries. The index range is between zero (equal distribution) and $ln(\mathrm{n})$. Higher values represent higher export concentration. The index reaches its maximum when a country exports only one product (no matter what it is).

Later, *Parteka and Tamberi* (2013) have adopted a generalized approach to measuring export concentration by the weighted Theil index:

$$WT^c = \sum_i s_i^c ln(s_i^c / s_i^W), \quad (2)$$

where $s_i^c = X_i^c / \sum_i X_i^c$ represents the share of product i in the total exports of country c, and s_i^W represents the share of product i in the total world imports. In case of zero trade for product i, the i-th term is mechanically set to zero (as s_i^c=0, the whole term also tends to 0); it is equivalent to calculating the sum only for positive values of s_i^c.

The unweighted Theil index from equation (1) is equal to the weighted Theil from equation (2) if world imports for all products are identical. In this case, s_i^W for all i are also identical, and thus s_i^W equals $1/n$ for each i, where n represents the total number of products. This confirms that the weighted Theil index is a generalization of the unweighted index.

By construction, the weighted Theil index range is between zero and $ln(1/s_l^W)$, where l denotes the product with the lowest world exports. Zero values represent full diversification, or a perfect match between the product-level export structure of a country and the import

structure of the whole world. Higher values of the weighted index represent higher export concentration *relative to the world*. The weighted index reaches its maximum when a country exports only product *l*. This index may be regarded as the weighted sum of the log revealed comparative advantage indices proposed by *Balassa* (1965) that equal s_i^c / s_i^W. Then, perfect diversification is the absence of specialization in any product.

I prefer the weighted Theil index for several reasons. First, as argued by *Parteka and Tamberi* (2013, p. 124), absolute (or, in my terms, unweighted) measures of diversification isolate country-specific trade patterns from those typical for the world structure of trade and also do not account for the relative importance of products. Second, *Lessmann* (2014, p. 37) demonstrated that the lack of homogeneity in classification units makes interpretation of an unweighted measure difficult.[1] And finally, the weighted Theil index presented in equation (2) measures the deviation of a country's export structure from patterns of world demand.

Practically, these features of the weighted index are critical because I cannot choose product groups according to some criteria but instead perform calculations simultaneously for all standard product groups from an international Harmonized System classification (HS).

For a country with numerous zero trade flows, the unweighted Theil index would treat all these trade flows equally, even if some of the products are not traded internationally. The weighted Theil index implies that zero trade does not mean the same for a product not traded internationally and a product heavily traded by other countries. The first case does not lead to an increase in export concentration, unlike the second one.[2]

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[1] For the case of international trade, the distribution of exports by products is unequal by default because products differ in their characteristics. To obtain an idea about the scope of this problem, compare motor cars (HS 8703, world trade was above USD bln 700 in 2017) and photographic paper (HS 3703, world trade was lower than USD bln 1 in 2017).

[2] For a certain country, zero trade for products heavily traded internationally raises the trade shares for other products compared with the world average; this effect is pronounced only for the weighted index.

2.2. Deconstructing the Theil

The unweighted Theil index, as with every entropy measure, is decomposable into the between and the within components:

$$T^c = T^c_{(B)} + T^c_{(W)} = \sum_g \frac{X^c_g}{\sum_i X^c_i} ln\left(\frac{\frac{1}{n_g}X^c_g}{\frac{1}{n}\sum_i X^c_i}\right) + \sum_g \frac{X^c_g}{\sum_i X^c_i} T^c_g, \quad (3)$$

where X^c_g is the total export value for a group of products g and country c, n (or n_g) is the total number of potential export lines for all products (or group g specific for country c), and T^c_g is the unweighted Theil index for group g that is calculated according to (1).

Cadot et al. (2011) applied decomposition (3) to the two groups: g_1 and g_0 (active and inactive export lines for country c). Note that the group composition varies across countries. Formally, $X^c_{g_1}/\sum_i X^c_i = 1$, $X^c_{g_0}/\sum_i X^c_i = 0$. Then, decomposition (3) transforms as follows:

$$T^c = T^c_{(EM)} + T^c_{(IM)} = ln\big(1/(n_{g_1}/n)\big) + T^c_{g_1}. \quad (4)$$

The first component corresponds to the extensive margin, and the second component represents the intensive margin. Exports at the extensive margin diversify when the number of active export lines increases. The dynamics of the intensive margin reflect changes in the distribution of trade values across the existing export lines.

Decomposition (3) for the case of weighted Theil index is as follows:

$$WT^c = \sum_g s^c_g ln\big(s^c_g/s^W_g\big) + \sum_g s^c_g WT^c_g, \quad (5)$$

where s^c_g represents the share of a group of products g in the total exports of country c, and WT^c_g is the weighted Theil index for group g that is calculated according to equation (2).

Following *Cadot et al.* (2011), I also split all products into the two groups — g_1 and g_0 — with the same interpretation. Next, I decompose the weighted index into the extensive and intensive margins:

$$WT^c = WT^c_{(EM)} + WT^c_{(IM)} = ln\left(\frac{1}{s^W_{g_1}}\right) + WT^c_{g_1}. \quad (6)$$

The extensive margin accounts for the share of products exported by country *c* in the world trade. For a country that exports all products, this share equals 1 (the extensive margin adds nothing to the weighted Theil index).

In this paper, I go further and develop the novel decomposition of the weighted Theil index into the extensive ($WT^c_{(EM)}$), quantitative ($WT^c_{(QN)}$), and qualitative ($WT^c_{(QL)}$) margins. This decomposition is a convenient tool to answer the question about the drivers of structural transformation because the three margins can be further linked to economic development.

I split the intensive margin into the quantitative and qualitative components. The first one represents the differences in the product-level structure of export quantities (volumes in physical terms) between a country and the world, and the second reflects the product-level differences in export unit values (USD per kilogram) between a country and the world.[3] The details on the relation between unit values and quality are presented later (Section 4.1).

First, I present the shares from equation (2) as follows:

$$s^c_{j\in g_1} = p^c_j q^c_j / \sum_{j\in g_1} p^c_j q^c_j \,, \tag{7}$$

$$s^W_{j\in g_1} = p^W_j q^W_j / \sum_{j\in g_1} p^W_j q^W_j \,, \tag{8}$$

where p_j is the export unit value for product *j* exported by country *c*, q_j is the volume of exports of product *j* in physical terms, and superscripts *c* and *W* indicate a country and the world, respectively.

Second, I apply the logarithm quotient rule to equation (2) and obtain:

$$WT^c_{g_1} = \sum_{j\in g_1} s^c_j ln\left(s^c_j\right) - \sum_{j\in g_1} s^c_j ln\left(s^W_j\right). \tag{9}$$

Third, I transform equation (9) by adding and subtracting the same term:

$$WT^c_{g_1} = \left[\gamma - \sum_{j\in g_1} s^c_j ln\left(s^W_j\right)\right] + \left[\sum_{j\in g_1} s^c_j ln\left(s^c_j\right) - \gamma\right], \tag{10}$$

$$\text{where } \gamma = \sum_{j\in g_1} s^c_j ln\left(s^{cw}_j\right), \tag{11}$$

[3] Note that this also helps to account for the changes in world prices.

and $s_j^{cw} = \left(p_j^W q_j^c / \sum_{j \in g_1} p_j^W q_j^c\right)$ is the share of product *j* in the total exports of country *c* that are "neutral" to unit values (reflect only the differences in quantities, not prices), where p_j^W is the world export unit value for product *j* (sum of exports in USD of all countries divided by sum of exports in kilograms of these countries[4]).

Next, I obtain the decomposition of the intensive margin of the weighted Theil:

$$WT_{g_1}^c = WT_{(QL)}^c + WT_{(QN)}^c = \sum_{j \in g_1} s_j^c ln\left(s_j^c / s_j^{cw}\right) + \sum_{j \in g_1} s_j^c ln\left(s_j^{cw} / s_j^W\right), \quad (12)$$

where $WT_{(QN)}^c$ is the quantitative component, and $WT_{(QL)}^c$ is the qualitative component shaped by unit values (proxies for quality).

Applying (12) to (6), I finally decompose the weighted Theil index into the extensive, qualitative, and quantitative components (for a numerical example, see **Appendix A**):

$$WT^c = ln\left(\frac{1}{s_{g_1}^W}\right) + \sum_{j \in g_1} s_j^c ln\left(s_j^c / s_j^{cw}\right) + \sum_{j \in g_1} s_j^c ln\left(s_j^{cw} / s_j^W\right). \quad (13)$$

3. Results and discussion

3.1. Data description

The trade data for the empirical work is from the UN COMTRADE database (USD and volumes in kilograms). The data on per capita PPP GDP (constant 2011 international dollars) is from the World Economic Outlook Database, published by the IMF.

I use the trade data for 2011—2017 at the 6-digit level of the Harmonized System, rev. 2007 (HS 2007). To obtain the world aggregates for each product (the number of products is 5038), I sum up imports of all countries that reported any data. Next, I calculate the weighted and the unweighted Theil indices for all 120 countries from the sample.

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[4] To exclude the impact of outliers on the world export unit value, I estimate exports in kilograms. For each product *j*, I recalculate exports in kilograms for countries whose export unit value is higher than the 95th or lower than the 5th percentile. I fix such unit values at these bounds and estimate exports in kilograms by dividing exports in USD by the fixed unit values.

3.2. Export concentration along the development path

To study the link between export concentration and economic development, I first apply a non-parametric *loess* procedure that smooths the raw data averaged over 2011–2017 by performing a set of regressions for localized subsets of the data.[5] To test the stability of the smoothed curve for countries with the highest per capita income, I perform six iterations. In the first iteration, I use the full sample; next, I exclude one country with the highest per capita income in each step (Qatar, Macao, Luxembourg, Singapore, and Brunei). Notably, the range of per capita PPP GDP between USD 70,000 and USD 140,000 is populated by only five countries, and the range between USD 60,000 and USD 65,000 is populated by three countries. This is why I stop iterating just after excluding Brunei (at USD 70,000). I apply the procedure to the unweighted and the weighted Theil (**Fig. 1**).

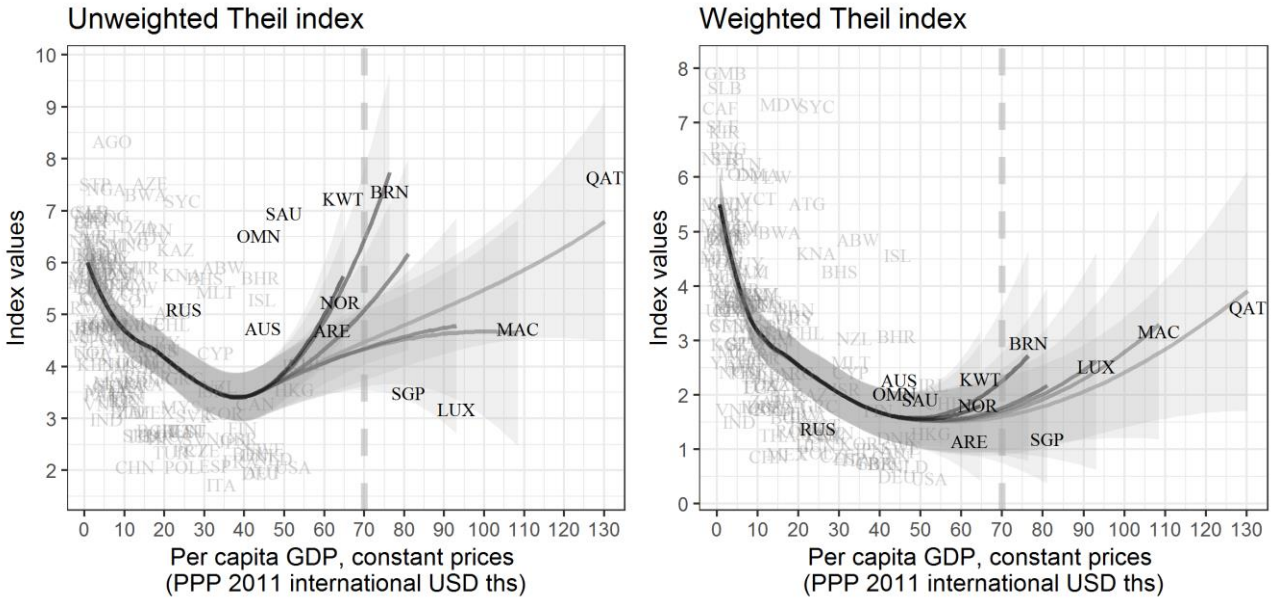


***Fig. 1**. Theil vs per capita PPP GDP, averaged over 2011–2017*

I find four important differences in the behavior of the indices. First, the weighted Theil's relationship with high income levels is more stable in terms of variance (**Table 1**). For the weighted index, the smoothed curve does not change dramatically during the exclusion of the highest-income countries (that is not the case for the unweighted index).

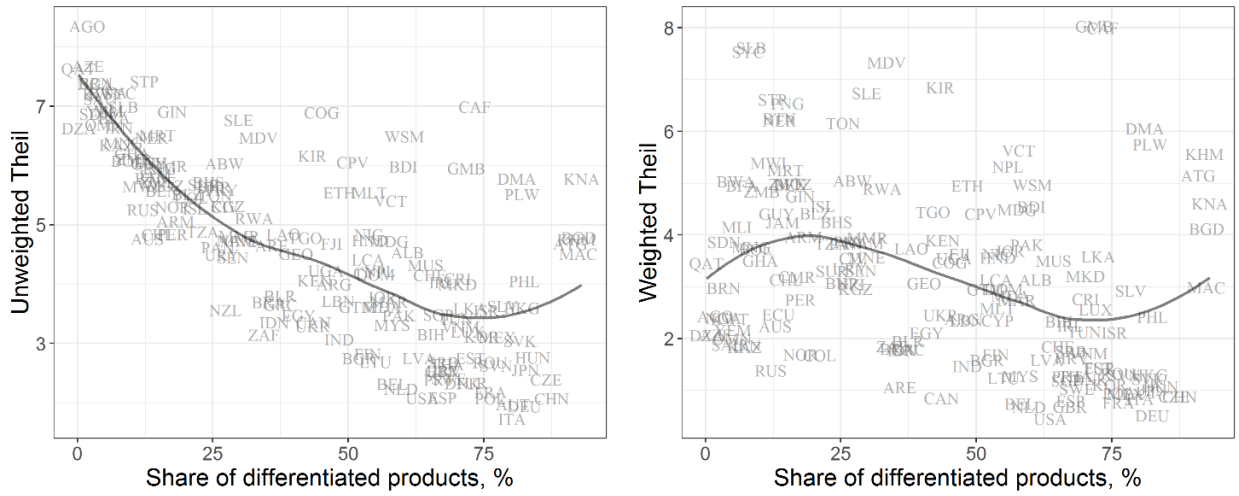
[5] Technically, I use the *"geom_smooth"* function from the R *"ggplot2"* package.

***Table 1**. Variance of the weighted and the unweighted Theil, averaged over 2011–2017*

Per capita PPP GDP, USD ths.	Variance, weighted Theil	Variance, unweighted Theil
> 0	3.0	2.4
> 10 000	2.2	2.5
> 20 000	1.9	2.8
> 30 000	1.4	3.1
> 40 000	1.1	3.5
> 50 000	0.9	3.2
> 60 000	0.8	3.1
> 70 000	0.9	4.5

Note: the range of per capita PPP GDP between USD 70,000 and USD 140,000 is populated by only five countries

Second, the concentration of exports for a set of oil and gas exporting countries is much lower if measured with the weighted Theil index (**Table 2**). The intuition is quite simple: such countries are specializing in "core" products that are in a great demand on the world market. The unweighted index is unable to distinguish between products according to this criterion. Rather, the unweighted Theil assigns high export concentration level to all countries with low export share of differentiated products[6] (**Fig. 2**). Contrarily, the weighted Theil varies even for countries that predominantly specialize on homogeneous products. Interestingly, the largest export shares of differentiated products do not imply high export diversification as measured by both unweighted and weighted Theil.



Note: the export share of differentiated products is calculated according to the Rauch's (1999) classification

***Fig. 2**. Share of differentiated products and Theil indices, averaged over 2011–2017*

[6] Products heterogeneous in prices according to the *Rauch*'s (1999) classification.

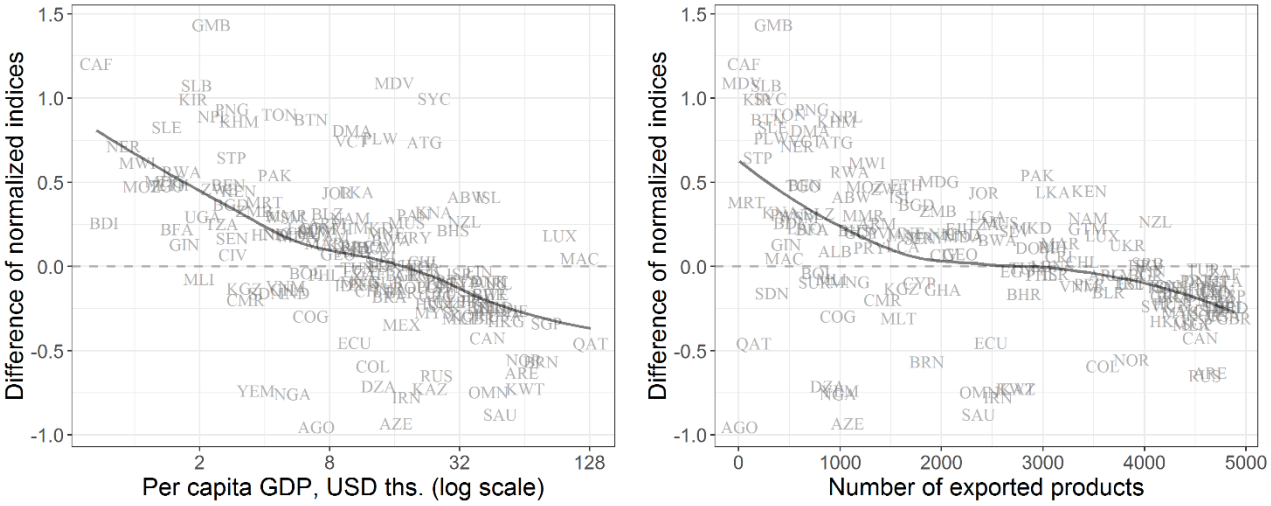
***Table 2**. Top-10 countries with overestimated and underestimated export concentration, averaged over 2011–2017*

Country name	Code	GDP per capita, USD ths.	Number of exported products	Export share, differentiated products, %	Weighted Theil index	Standard Theil index	Difference of normalized indices
Concentration overestimated by the standard Theil							
Angola	AGO	6 945	6	1.8	2.4	8.4	-1.0
Azerbaijan	AZE	16 219	1 074	1.9	2.1	7.7	-0.9
Saudi Arabia	SAU	49 472	2 365	4.2	1.9	7.1	-0.9
Iran	IRN	18 184	2 556	7.6	1.9	6.6	-0.8
Nigeria	NGA	5 389	979	3.3	2.4	7.4	-0.8
Oman	OMN	43 556	2 372	5.0	2.0	6.7	-0.7
Yemen	YEM	3 651	1 002	5.1	2.2	6.9	-0.7
Kuwait	KWT	64 429	2 734	4.5	2.4	7.2	-0.7
Kazakhstan	KAZ	23 285	2 752	7.3	1.8	6.3	-0.7
Algeria	DZA	13 491	879	0.3	2.1	6.6	-0.7
Concentration underestimated by the standard Theil							
Bhutan	BTN	6 553	288	13.7	6.2	5.8	0.9
Nepal	NPL	2 318	1 066	55.8	5.3	4.2	0.9
Tonga	TON	4 670	493	25.4	6.2	5.5	0.9
Papua	PNG	2 820	722	15.1	6.5	6.0	0.9
Kiribati	KIR	1 863	184	43.3	6.8	6.2	1.0
Seychelles	SYC	24 390	312	7.9	7.5	7.2	1.0
Solomon Isles	SLB	1 940	273	8.5	7.6	7.0	1.1
Maldives	MDV	15 942	33	33.5	7.3	6.5	1.1
Central Afr.	CAF	663	53	73.4	8.0	7.0	1.2
Gambia	GMB	2 261	346	71.8	8.0	6.0	1.4

Notes: indices are normalized by relating them to their median; the export share of differentiated products (products that are heterogeneous in prices) is calculated according to the Rauch's (1999) classification

Third, export concentration patterns along the development path differ between the two indices. The unweighted index shows that countries start to re-specialize after per capita income exceeds USD 40,000. The weighted Theil, after applying the iterated *loess* procedure, is ignorant of re-specialization in general or a turning point of per capita income in particular. Active re-specialization in terms of the unweighted Theil is largely explained by high export concentration of oil and gas exporting countries (to observe this, compare the positions of Brunei, Kuwait, Oman, and other oil and gas exporting countries for the two panels in **Fig. 1**). So, while controlling for the structure of world demand, I find that re-specialization is not pronounced at a high level of economic development.

Finally, the unweighted Theil index systematically overestimates export concentration for the high-income countries and underestimates export concentration for the low-income countries, as compared with the weighted Theil (**Fig. 3**). Since these indices differ only in the weighting scheme, the result implies that a country's export structure comes more and more close to the structure of the world demand along the development path. In other words, most low-income countries export "peripheral" products (low-traded, not in a great demand on the world market) but are not able to export highly-traded "core" products.

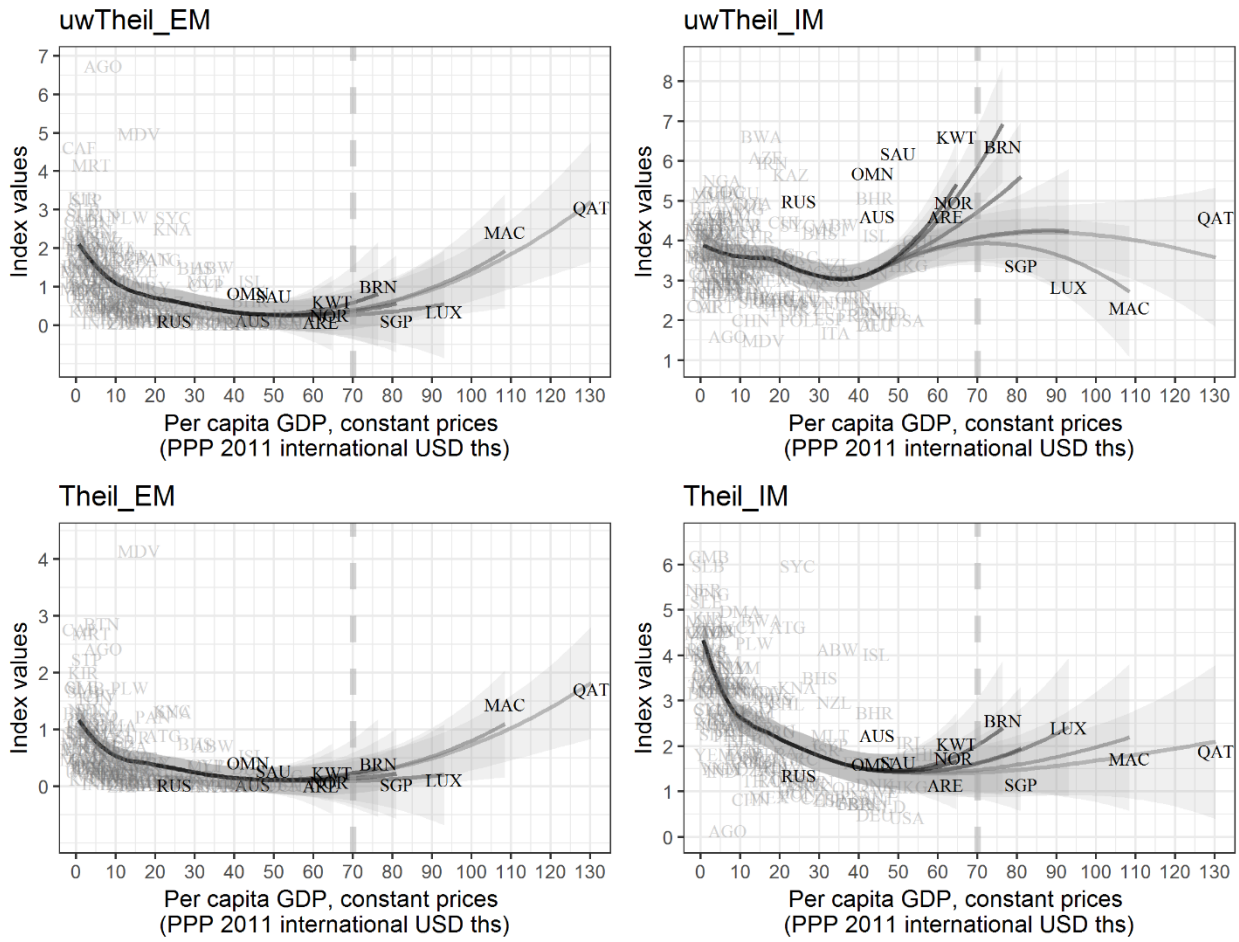


Note: indices are normalized by relating them to their median; the upper (lower) part of each graph represents countries with export concentration underestimated (overestimated) by the standard Theil

***Fig. 3**. Difference between the weighted and the unweighted Theil, averaged over 2011–2017*

3.3. Structural transformation: what's behind the Theil?

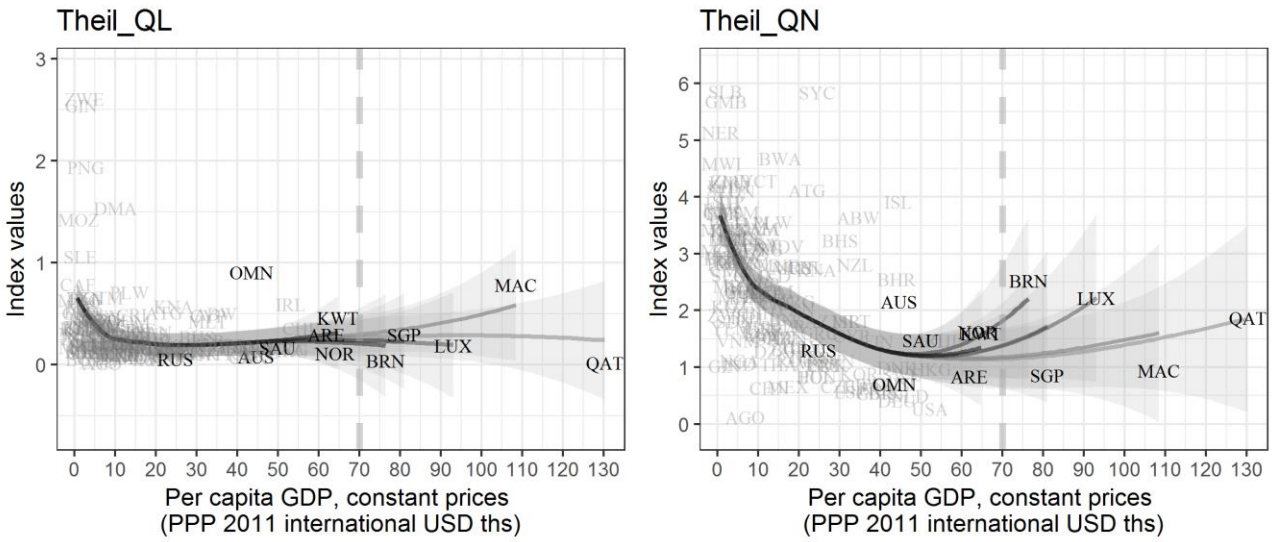
To examine the factors driving structural transformation along the development path, I first apply the same iterated *loess* procedure to the extensive and intensive margins of the standard and the weighted Theil indices (**Fig. 4**). The results demonstrate that the differences outlined are primarily related to the differences in the intensive margin, and the paths of the extensive margin of the unweighted and the weighted Theil are nearly identical, although the absolute value of the extensive margin is higher for the unweighted index. The evolution of the weighted Theil is primarily driven by the intensive margin, unlike what was previously documented for the standard Theil (*Cadot et al.*, 2011, p. 596).



Note: "uwTheil" is the unweighted Theil index, and "Theil" is the weighted one; "EM" and "IM" are the extensive and intensive margins of the indices, respectively

***Fig. 4**. Theil's margins vs per capita PPP GDP, averaged over 2011–2017*

Then, I apply the same procedure to the qualitative and quantitative components of the weighted Theil index (**Fig. 5**). The results show that the weighted Theil is certainly dominated by the quantitative component: structural transformation is primarily driven by restructuring export values according to the world demand. Exporting new products and quality upgrading of the exported products are also important, but their influence is limited to the lower-income countries (**Fig. 6**). At the first stage of the development path, countries expand their narrow export basket and avoid low quality of products that is inconsistent with the export status. At the middle-income stage, quality upgrading means rather adopting higher technologies than avoiding low quality; the former is obviously more difficult to implement. The unconditional expansion of the export basket also becomes less efficient, and countries have to add more and more heavily traded "core" products to their export basket.



Note: "Theil" is the weighted Theil; "QL" and "QN" are the qualitative and quantitative components, respectively

***Fig. 5**. Theil's components vs per capita PPP GDP, averaged over 2011–2017*

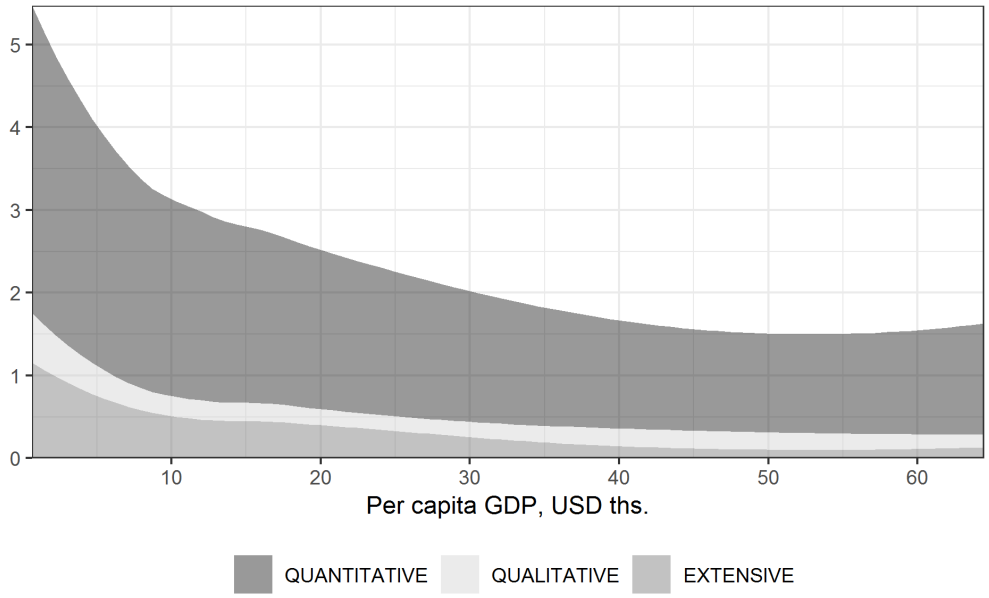
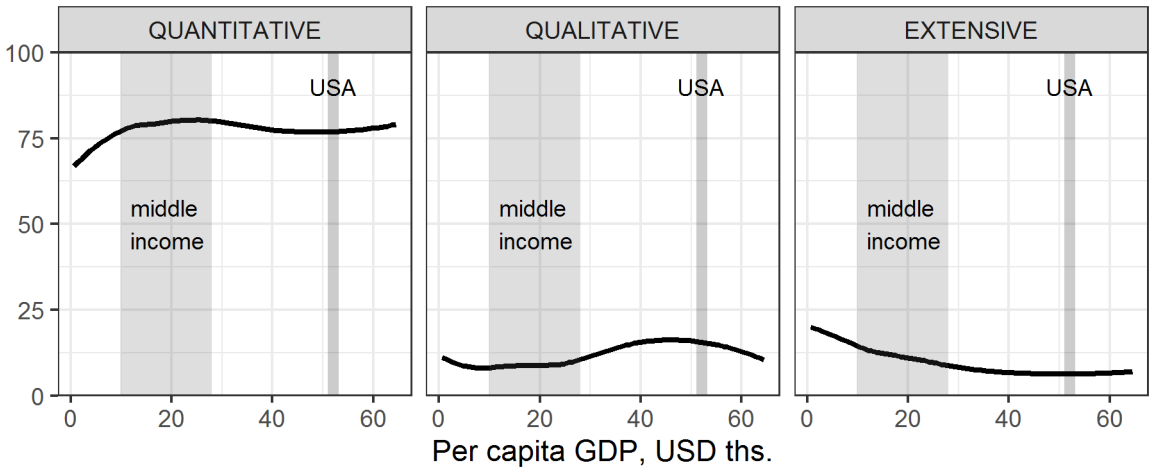


***Fig. 6**. The contribution of the weighted Theil components, averaged over 2011–2017*

Importantly, export diversification becomes increasingly difficult at the middle-income stage, as the weighted Theil starts to decrease much slower. This applies to all components of the Theil index. However, as shown in **Fig. 7**, the share of the quantitative component of the weighted Theil index is maximized at about USD 25,000. This means that the middle-income countries, on average, remain primarily bounded by their export structure, not narrow export basket or low product quality.



Note: the middle-income countries are defined according to Woo et al. (2012)

Fig. 7*. The shares of the weighted Theil components, averaged over 2011–2017*

Notably, the share of the qualitative component becomes higher as countries approach the higher-income development level. This means that developed countries may experience a slight re-concentration of their exports along the quality margin. As I show further, the higher share of the qualitative component for the developed countries is associated with the larger export share of differentiated products and the longer quality ladders.

4. Exploring quality ladders

4.1. Quality and unit values

Traditionally, a product's quality in trade studies is proxied by its export unit value (USD per kilogram or another unit). The literature has demonstrated that such unit values are higher for countries with higher relative capital abundance and per capita income (*Aiginger*, 1997, p. 581; *Schott*, 2004, p. 647-648).

Many recent papers have estimated product quality from unit values combined with other indicators. Conditional on unit values, *Khandelwal* (2010) assigned a higher quality to product groups with higher market shares, and *Hallak and Schott* (2011) used international trade balances for this purpose. Other studies obtained estimations for quality as a residual, eliminating the effect of unit values and country-year or product fixed effects: according to

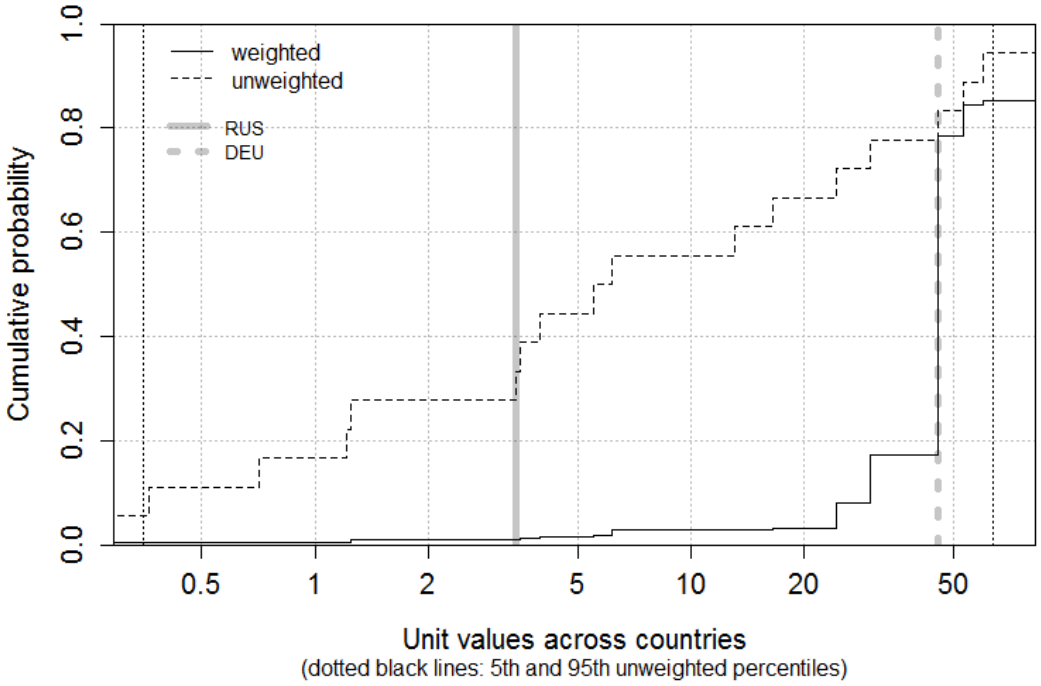
this approach, a higher quality variety is the one with a higher quantity, conditional on unit value (*Khandelwal et al.*, 2013; *Fan et al.*, 2013; *Manova and Yu*, 2017).

Notably, *all these studies* used unit value as the key variable that should be controlled to account for quality. Thus, quality is *primarily reflected* in unit values, but no consensus has been reached on other indicators that should also be accounted for. Particularly, *Feenstra and Romalis* (2014, p. 522) compared the export quality estimates by *Khandelwal* (2010) and *Hallak and Schott* (2011) and concluded that "estimates for quality are very sensitive to proxies chosen for important model variables, whether it be population as the proxy for the number of firms or the manufacturing trade balance as a measure of demand." In addition, the regression model approach that has been implemented in these papers is hardly applicable to the direct decomposition of the Theil index that I conduct. Thus, in this stage of the research, I interpret unit values as proxies for quality.

4.2. Visualizing quality ladders

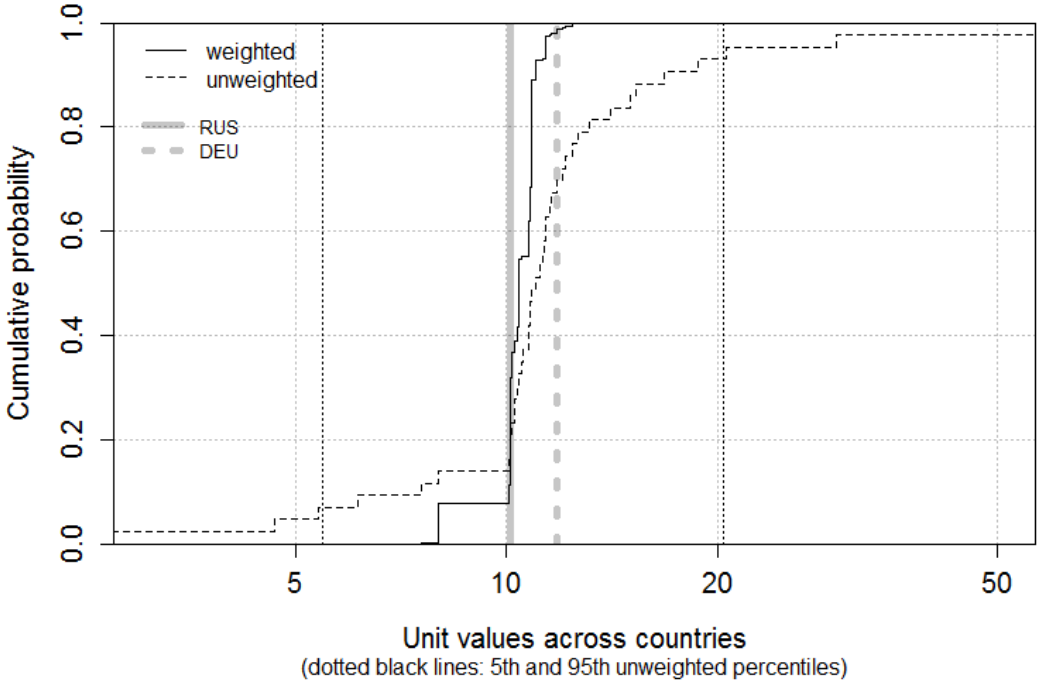
A "quality ladder" can be constructed as an empirical cumulative distribution function (ECDF) of unit values across all countries for a particular product. Depending on the research purpose, unweighted or weighted quality ladders (high "stairs" for weighted quality ladders indicate large exporters; they are difficult to climb, especially at the top) can be constructed. Longer quality ladders mean a much higher potential to improve quality (raise export unit values). Shorter quality ladders mean a much lower potential to improve quality, due to the standardized nature of products. I estimate the length of the quality ladder for each product as the ratio of the 95th and 5th percentiles of the unit value distribution across countries.

For example, the quality ladder for railway locomotives is rather long; thus, Russia may increase the revenue from exporting this product ten times by improving its export unit value to the German level (**Fig. 8**). However, the ladder for unwrought nickel is short; thus, Russia is unable to increase exports much even after climbing to the very top of the ladder (**Fig. 9**).



Note: percentile is the unit value below which a given percentage of the number of countries falls; weighted percentile is the unit value below which a given percentage of exports of countries falls; cumulative probability is the step function (ECDF) that increases by the inverse number of countries at each data point; weighted cumulative probability is the step function (ECDF) that increases by the share of exports of a country at each data point

***Fig. 8**. Weighted and unweighted quality ladders for railway locomotives (HS 860110), 2017*

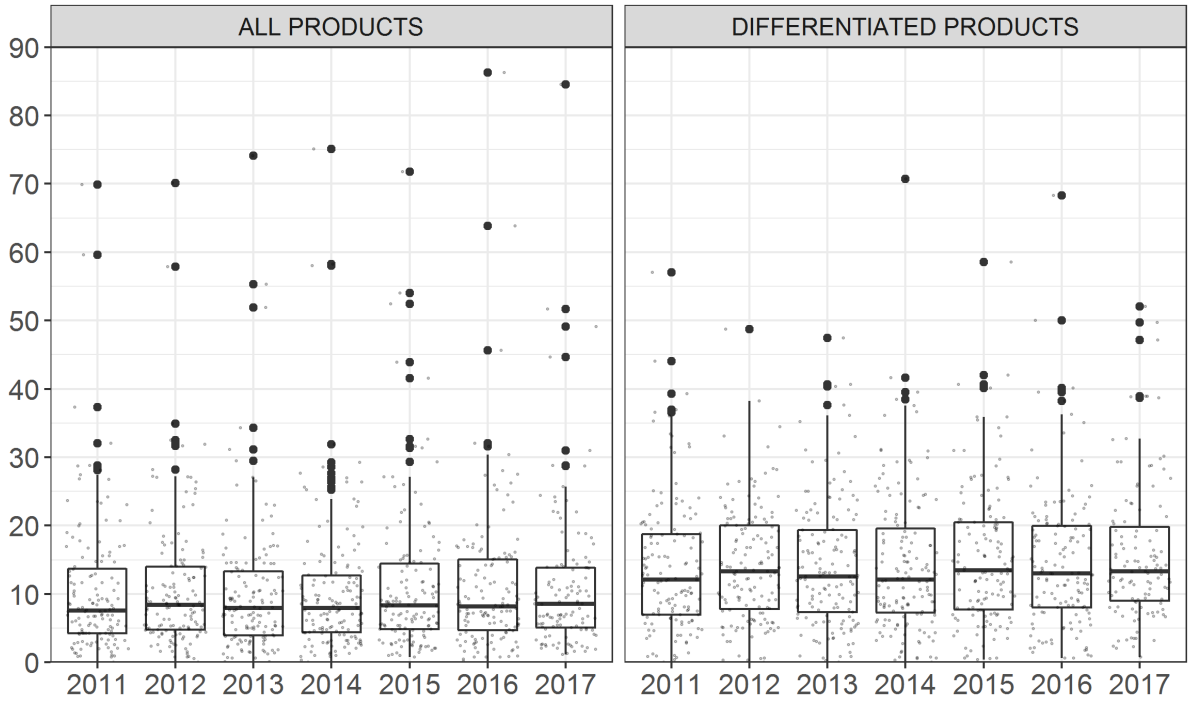


Note: percentile is the unit value below which a given percentage of the number of countries falls; weighted percentile is the unit value below which a given percentage of exports of countries falls; cumulative probability is the step function (ECDF) that increases by the inverse number of countries at each data point; weighted cumulative probability is the step function (ECDF) that increases by the share of exports of a country at each data point

***Fig. 9**. Weighted and unweighted quality ladders for unwrought nickel (HS 750210), 2017*

4.3. The role of the quality margin

The role of the quality dimension of export concentration is small: for most countries, the share of the qualitative component of the weighted Theil index does not exceed 20%, even after focusing on those products that are differentiated in prices according to *Rauch's* (1999) classification[7] (**Fig. 11**). The median share of the qualitative component of the weighted Theil index is stable across time.



Note: data points represent countries, bold data points indicate outliers, bold lines represent the median, and the threshold of the boxes are the 25th and 75th percentiles of the distribution across countries

***Fig. 11**. Share of the qualitative component of the weighted Theil index, 2011–2017*

At the same time, the share of the qualitative component is far from being stable across countries. This share is positively related with the export share of differentiated products and the weighted length of quality ladders for the subset of the differentiated products[8] (**Fig. 12**). Note that the latter is much more important: countries that export more products with longer quality ladders (higher potential to improve quality) are mostly high-income countries.

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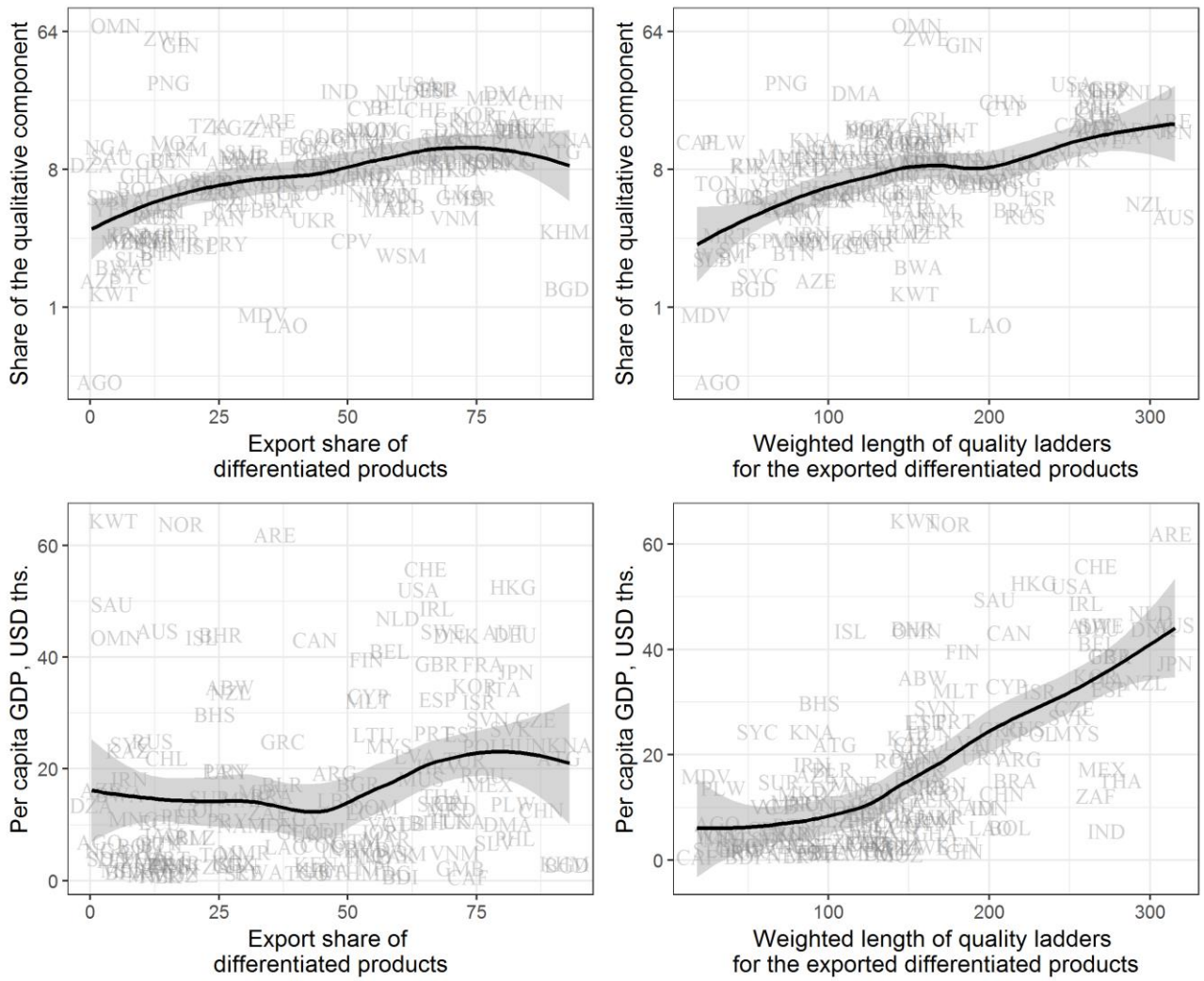
[7] In this case, trade shares are recalculated relative to trade in differentiated products.

[8] I exclude homogeneous and reference priced products to ensure that the unit values are related mostly to quality. Lengths of quality ladders are weighted by world trade values.



Note: for each country, the product-specific lengths of quality ladders are weighted by world trade values

***Fig. 12**. Share of the qualitative component and related indicators, averaged over 2011–2017*

These results complement the findings presented in Section 3. In that section, I stopped at the middle-income stage of the development path and stated that middle-income countries have to export more heavily traded "core" products to lower export concentration. Now, I can add that middle-income countries should also export more products with longer quality ladders to enter the developed countries' club. Thus, middle-income countries face a complex challenge: they should progress both along the quantitative and qualitative margins. Interestingly, the complex nature of this task may be the very thing that keeps some countries in the middle-income trap. At least, the recent paper by *Hartmann et al.* (2020) indicates that the gravitation towards simple products may lead to a failure to achieve the high level of per capita GDP. I hope that my results may be useful for future studies of this sort.

5. Conclusion

In this paper, I develop the new decomposition of the weighted Theil into the three parts: the extensive margin, and the quantitative and qualitative components of the intensive margin. I discuss the differences in export concentration (as captured by the unweighted and the weighted Theil) along the development path and show that the weighted Theil index (a) demonstrates a more stable relationship with high income levels, (b) distinguishes between products with high and low world demand, and (c) does not imply a re-specialization at a high level of economic development. I also show that the unweighted Theil index systematically overestimates export concentration for the high-income countries and underestimates export concentration for the low-income countries.

I demonstrate that the weighted Theil index and its dynamics are mainly formed by the quantitative component, or restructuring export values according to the world demand. For the low-income countries, exporting new products and avoiding low product quality are also important. The middle-income countries are primarily bounded by their suboptimal export structure: to enter the developed countries' club, they should export more heavily traded "core" products and more products with longer quality ladders (higher potential to improve quality).

This paper has limitations that provide topics for further research. The decomposition presented in the paper does not distinguish the cases of up- and downgraded quality, which may be essential for some research purposes. The timing of structural transformation along the quantity and quality dimensions could be investigated: is simultaneous progress along both dimensions necessary for successful structural transformation? Finally, the results may be related with the middle-income trap problem. This link requires a more thorough research, with potential policy implications. What the key that unlocks the trap should look like? Is it a smart structural transformation (*Lin*, 2012), or defying comparative advantage (*Lectard and Rougier*, 2018), or higher technologies adoption (*Arezki et al.*, 2019), or something else?

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Appendix A

In **Table A1**, I present a numerical example on the differences between the weighted and the unweighted Theil, and the Theil's decomposition. In this example, I assume the world of two countries and three products. Both countries export only two products out of three. Country 1 exports products A and C in the proportion 4:1. Country 2 exports products A and B in the proportion 1:4.

***Table A1**. A numerical example on the Theil's components*

Product	*Country 1 (exports)*			*Country 2 (exports)*			*World (exports)*		
	Unit value	Volume, kg	Value, usd	Unit value	Volume, kg	Value, usd	Unit value	Volume, kg	Value, usd
A	1	80	*80*	2	10	*20*	1.1	90	*100*
B	-	-	-	2	40	*80*	2.0	40	*80*
C	2	10	*20*	-	-	-	2.0	10	*20*
Sum			***100***			***100***			***200***

Theil index	*Country 1 (concentration)* Value	Structure	*Country 2 (concentration)* Value	Structure	*Comments*
Standard	**0.598**	**100%**	**0.598**	**100%**	$\sum_i s_i^c * ln(s_i^c/(1/3))$
Extensive	0.405	68%	0.405	68%	$ln(1/(2/3))$
Intensive	0.193	32%	0.193	32%	$\sum_j s_j^c * ln(s_j^c/(1/2))$
Weighted	**0.515**	**100%**	**0.371**	**100%**	$\sum_i s_i^c ln(s_i^c/s_i^W)$
Extensive	0.511	99%	0.105	28%	$ln(1/(VAL_{g_1}^W/200))$
Intensive	0.004	0.7%	0.266	72%	$\sum_j s_j^c ln(s_j^c/s_j^W)$
Quantity	*0.003*	*0.6%*	*0.241*	*65.0%*	$\sum_j s_j^c ln(s_j^{cw}/s_j^W)$
Quality	*0.001*	*0.2%*	*0.024*	*6.6%*	$\sum_j s_j^c ln(s_j^c/s_j^{cw})$

Notes: for the details on notations, see Section 2; some numbers:
$s_i^c = \{0.8, 0.2, 0\}$, $s_i^W = \{0.5, 0.4, 0.1\}$, $s_j^c = \{0.8, 0.2\}$, $VAL_{g_1}^W = \{120, 180\}$

The standard Theil index does not differentiate between the two situations, while the weighted Theil assigns lower export concentration to country 2. In this example, the extensive margin plays a crucial role. This margin is higher for country 1 (which doesn't export a "core" product B that accounts for as much as 40% of world export) and lower for country 2 (which doesn't export a "peripheral" product C that accounts for 10% of world export). The intensive margin for country 1 is very close to zero, because this country's export structure is similar to the world export structure. For country 2, the intensive margin is higher due to a substantial deviation of its export structure from the world structure. This deviation is primarily related to export volumes, though unit values also play a certain role.