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EXPORT DIVERSIFICATION AND DEPENDENCE ON NATURAL RESOURCES

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Abstract

This paper models export diversification in the context of an abundance of natural resources by decomposing the relative Theil index. On a sample of 160 countries from 1996 to 2018 we document that 74% of the high export concentration typical of the initial stage of development is driven by the limited variety of products other than natural resources. Later, the component representing export reallocation between resources and non-resource products gains importance, and eventually, together with intra-resource heterogeneity, explains the entire amount of export diversification at high income levels. Our estimates show that natural resource abundance (in particular of fossil fuels) impedes overall diversification, limiting the variety of non-resource exports and hampering restructuring towards technologically advanced exports. However, once size and productivity differences across countries are taken into account, the effect of resource abundance on export diversification is weak.

JEL Classification: *F14; O13; Q3*

Keywords: *natural resources, export diversification, Theil, decomposition*

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1. Introduction

This paper analyses the process of export diversification in countries with abundant natural resources – a tricky feature that may bring economic wealth (Ross, 2019) but also excessive concentration (Bond and Malik, 2009; Bacchetta et al., 2010; Hattendorff, 2014; Bahar and Santos, 2018) and the so-called “resource curse”¹ (amongst many others: Sachs and Warner, 1995,1999,2001; Gylfason et al., 1999; Gylfason, 2001; Karl, 2005; Gylfason and Zoega, 2006; Mehlum et al., 2006; Torvik, 2009; Ross, 2015; Farhadi et al., 2015; Doraisami, 2015; Badeeb et al., 2017; Kim and Lin, 2017; Henry, 2019; Canh et al., 2020). The curse may consist not only in the focus on primary commodities per se, but in their heavy concentration (Badeeb et al., 2017; Karl 2005). Resource-rich economies, especially low income ones, face a twofold danger of volatility, because they export only a narrow range of products (Imbs and Wacziarg, 2003; Amurgo-Pacheco & Pierola, 2008; Cadot et al., 2011; Carrère & Strauss-Kahn, 2014; Parteka, 2020) and because they rely heavily on natural resources (Hausmann et al., 2007; Ross, 2019).

This paper contributes to the discussion on export diversification² and natural resources in several ways. Firstly, a new methodological approach based on the decomposition of the weighted Theil index, which identifies the share attributable to the within-resource component, is used to model export diversification in the context of resource abundance. So far, the literature on the diversification curve³ provides partially mixed evidence on changes in export variety accompanying the development process (Imbs and Wacziarg, 2003; De Benedictis et. al., 2009; Cadot et al., 2011; Parteka and Tamberi, 2013a and 2013b; Cadot et al., 2013; Mau, 2016; Basile et al., 2018; Caselli et al., 2020; Gnidchenko, 2021). High income countries are generally more diversified, but there are a significant number of exceptions: Kuwait, Norway, Oman, Qatar, Saudi Arabia and the United Arab Emirates built their wealth on extreme specialisation in fossil fuels (Ross, 2019). This pattern fits with the part of the diversification literature that postulates the possibility of subsequent respecialisation, at high income levels (Imbs and

¹ “Resource curse” (or “paradox of plenty”) describes a situation in which the economic performance of resource-rich countries is measurably worse than others, despite the presumptive benefits of resource abundance.

² Export diversification is defined as the ability to differentiate the export basket either by adjusting the shares of existing commodities or by adding new ones to the export mix (Ali et al., 1991). As such, it is the inverse of export specialisation or export concentration.

³ The diversification curve is typically obtained by linking country-year observations on export concentration and per capita income in a flexible setting such as nonparametric lowess (Gnidchenko, 2021) or the semiparametric General Additive Model (De Benedictis et. al., 2009; Parteka and Tamberi, 2013b).

Wacziarg, 2003; Cadot et al., 2011), but it could be driven by the presence of a few rich fuel exporters in the sample (Parteka and Tambari, 2013b; Mau, 2016; Gnidchenko, 2021). Secondly, we compare the role of natural resources in the diversification of overall exports (all product lines) and in that of non-resource exports (only products not related to primary commodities). The evolving role of natural resources in export diversification at various stages of development has not been thoroughly examined;⁴ in particular, little is known about their effect on the composition of the non-resource portion of the export basket (see Bahar and Santos, 2018 for an exception). Thirdly, we verify which types of resources weigh most heavily in hampering diversification. To this end we adopt alternative taxonomies of exported products, computed with HS 6-digit export data, to reveal heterogeneous effects across resource types and export basket parts. In particular, we verify whether specialisation in natural resources can be transformed into technological upgrading. We address all these issues in a very broad international context, using a sample of 160 countries (51 high income, 83 middle income and 26 low income) over the period 1996-2018.

The rest of the paper is structured as follows: Section 2 reviews the literature, Section 3 presents descriptive evidence on trade in natural resources and indicates alternative paths of resource-led development. Section 4 introduces resource-based decomposition of the relative Theil index and presents the outcomes of econometric analysis of the relationship between natural resources and diversification. Section 5 concludes.

2. The literature

Diversification patterns have been analysed at different levels, using both sectoral (Imbs and Wacziarg, 2003; Duarte and Restuccia, 2010; Herrendorf et al., 2014) and product level export data (Hummels and Klenow, 2005; Hidalgo and Hausmann, 2009; Cadot et al., 2011; Parteka and Tambari, 2013a and 2013b; Mau, 2016; Basile et al., 2018; Gnidchenko, 2021). The first studies of the stages of diversification date back to Imbs and Wacziarg (2003), who matched trends in sectoral production and employment with per capita income, finding a U-shaped pattern: poor countries tend to diversify (i.e.

⁴ Work to date tends to be focused on such determinants of overall export diversification as stage of development (De Benedictis et al., 2009; Parteka, 2010; Cadot et al., 2011; Parteka and Tambari, 2013a and 2013b; Mau, 2016), country size (Hummels and Klenow, 2005; Basile et al., 2018; Cieřlik and Parteka, 2021; Lee and Zhang, 2022), trade regulations (Regolo, 2013; Dutt et al., 2013; Feenstra and Ma, 2014) or quality of institutions (Sheng and Yang, 2016). See Section 2 for a detailed literature review.

divide economic activity equally across sectors) but then, at a relatively late stage of development, they re-specialise. Papers finding the U-shaped diversification curve (Imbs and Wacziarg, 2003; Klinger and Lederman, 2006; Cadot et al., 2011) rely on a traditional measure of diversification (i.e. such classic indices of concentration or inequality as Herfindahl-Hirschmann, Gini or Theil). However, once the structure of world demand is accounted for, the respecialisation track tends to vanish (Parteka, 2010; Parteka and Tamberi, 2013a and 2013b; Mau, 2016; Gnidchenko, 2021).

Cadot et al. (2011) sought to explain a hump-shaped relationship between export diversification and income level via the decomposition of an absolute (unweighted) Theil's index into its between- and within-group components, dividing all export lines into active and inactive to obtain extensive and intensive margins of trade.⁵ Cadot et al. (2011) finds that the action takes place mostly at the extensive margin (an increase in new export items) but this result is not confirmed when the structure of world demand is controlled for. Gnidchenko (2021) decomposes a relative (weighted) Theil index, contradicting the hump-shaped pattern of Cadot et al. (2011) or Imbs and Wacziarg (2003) and showing that movement towards more diversified export structures is driven by the intensive and not the extensive margin. Further splitting the intensive margin into quantitative and qualitative components, he shows that the restructuring of export values according to world demand dominates export diversification patterns. What is more, Gnidchenko (2021) gives evidence that respecialisation at high income levels is typical of fossil fuel exporters - in line with Parteka and Tamberi (2013b), who had shown that respecialisation is only plausible for small, rich countries with abundant oil resources.

The diversification literature is thus closely related to the stream of research on the economic role of natural resources, which focuses largely on the resource curse – the issue raised by the seminal paper of Sachs and Warner (1995). Since then, however, no consensus has been reached on whether resource abundance has a positive effect on economic growth (Lederman and Maloney, 2007; Alexeev and Conrad, 2009; Cavalcanti et al., 2011; Boyce and Emery, 2011; James, 2015) or a negative effect (Sachs and Warner, 1999&2001; Gylfason et al., 1999; Gylfason, 2001; Gylfason and Zoega, 2006; Mehлум et al., 2006; Torvik, 2009; Ross, 2015; Farhadi et al., 2015; Doraisami, 2015). In any case, the factors that

⁵ The decomposition of a country's exports into intensive and extensive margins was proposed by Hummels and Klenow (2005).

may influence the growth trajectory of resource exporters include: the quality of institutions and governing bodies (Torvik, 2009; Kim and Lin, 2017; Farhadi et al., 2015; Ben-Salha et al., 2018; Cavalcanti et al., 2011; Al Mamun et al., 2017), the type of resources exported (Cavalcanti et al., 2011; Torvik, 2009; Boschini et al., 2007; Olsson, 2006; Isham et al., 2005; Tsui, 2011), and the quality of resource extraction industries (Canh et al., 2020; Gerelmaa and Kotani, 2016).

While the export diversification literature highlights the problem of excessive concentration of low income countries and their dependence on natural resources (Imbs and Wacziarg, 2003; Hausmann et al., 2007; Bond and Malik, 2009; Bacchetta et al., 2010; Cadot et al., 2011; Hattendorff, 2014; Ross, 2019) so far little research has been addressed explicitly to the effects of natural resources on the process of export diversification. Among very few, Bahar and Santos (2018) find that countries with larger export shares of natural resources tend to have more concentrated non-resource export baskets as well, dominated by changes in the intensive margin (an increasing volume of existing exports), rather than the extensive margin (addition of new export lines).

The literature on resource-dependent countries shows that some at least have grown more diversified, but overall the picture is rather discouraging. Murshed and Serino (2011) show that unless they diversify, countries specialising in natural resources fail to grow. Case studies provide some insightful observations. Oman, Malaysia, Colombia, and New Zealand, analysed by Ross (2019), diversified their export baskets after the oil shocks of the 1970s, even though their oil revenues being steady or rising, while Saudi Arabia diversified at least partly in response to falling per capita oil revenues. Nevertheless, Albassam (2015) notes that after more than 40 years of development plans aiming to despecialise the Saudi economy (since the 1970s), oil is still the main engine driving this economy.⁶ A case study on Nigeria⁷ found that some key institutional problems for the Nigerian economy might be caused not by the dependence on oil exports but by the poor quality of institutions, so that even if Nigeria does diversify its export basket, in the absence of proper institutional reforms the result may be a fiasco (Charles et al., 2018).

⁶ The results presented in Albassam (2015) refer to 1970–2013; since then there have been some changes in the Saudi export structure (see Figure 3 in Section 3.3)

⁷ Approximately 90% of Nigeria's exports consists of crude oil and other fossil fuels.

Reliance on natural resources may hamper qualitative upgrading and progress towards more advanced economic structures. Diversification and upgrading are complementary in the development process (Henn et al., 2020), but the possibility of diversifying by export portfolio expansion or quality upgrading vanishes at the middle income stage (Gnidchenko, 2021). Overall, export upgrading in resource-rich countries turns out to be more complex than anticipated: it depends on the type of resources involved – natural gas and crude oil exert a particularly significant and positive effect on export sophistication (Zhu and Fu, 2013). Unfortunately, the technological upgrading of resource-based economies (and resource-intensive industries as well) has not been studied as thoroughly as one would wish. One of a relative handful of works, Figueiredo and Piana (2021), reveals that technological upgrading is extremely relevant to the catch-up process in resource-dependent economies. Nonetheless, the evidence on the transition from natural resources to technologically advanced export products is rather negative. Resource exporters lag behind the developed countries in technology (Fagerberg and Verspagen, 2021) and are generally excluded from specialisation in technological production (Foster-McGregor et al., 2019).

3. Data and descriptive evidence

3.1 Dataset

Our analysis covers 160 countries (51 high income, 83 middle income and 26 low income economies, listed in Table A.1. in the Appendix A)⁸ over the period 1996-2018. The final selection of countries was dictated by data availability and representativeness: microstates⁹ and economies with incomplete data on GDP and productivity were excluded. Disaggregated export data (6-digit HS96),¹⁰ used to calculate export diversification indices and export shares of product types (natural resources, technological products), comes from BACI CEPII¹¹ (Gaulier and Zignago, 2010). In order to decompose the relative (weighted) Theil index with respect to particular types of product (see section

⁸ The country sample is composed of five distinct groups (Table A.3. in Appendix A): Natural resource (NR) exporters experiencing rise, fall and no significant change in the NR export share, plus two types of non-resource exporters: the larger group with a minor role of NR in exports (NR export share below 15%) and the remaining countries with NR export share of 15% to 50%.

⁹ Countries with population of under 100,000.

¹⁰ The number of HS96 product codes in BACI CEPII diminishes over time, so to hold it constant (a necessary step in the calculation of the relative Theil index) we delete export lines that “disappear” between 1996 and 2018, as well as codes no longer present in subsequent revisions. As a result we consider 4895 product lines.

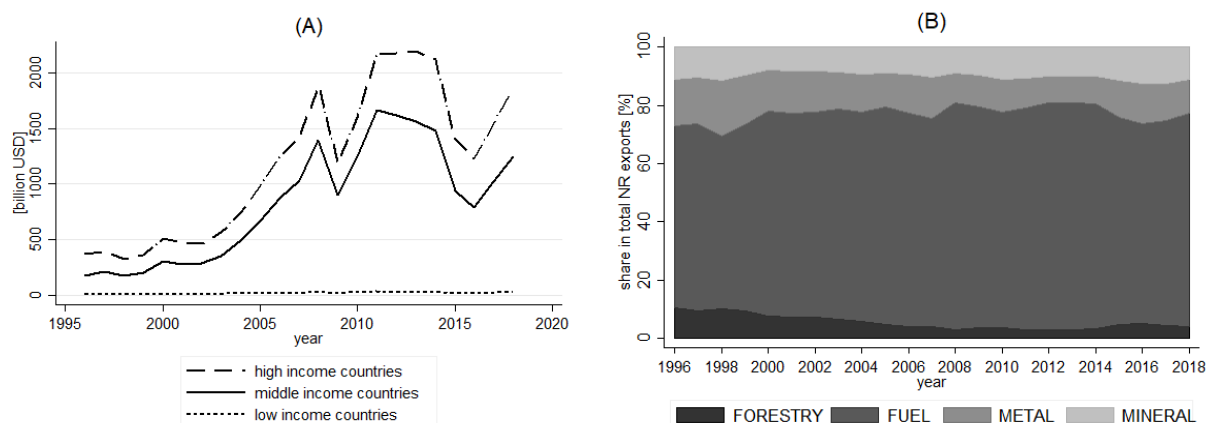
¹¹ The BACI database provides yearly product-level data on bilateral trade flows where only strictly positive exports are recorded and trade flows below 1,000 USD do not appear.

4.1), we use the taxonomy of natural resources, *NR*, based on WTO International Trade Statistics (Bacchetta et al., 2010), further divided into four subgroups: forestry, fuel, metal and mineral products¹² (see Table A.4. in Appendix A). To measure analogous technological indicators, we use UNCTAD’s classification of middle and high tech products based on Lall (2000), denoted as *TECH*. The taxonomies were converted from SITC rev.3 into HS96 nomenclature using concordance tables from UN Trade Statistics.¹³ Additional macro-level statistics (productivity records, GDP) come from Penn World Table 10.0 (Feenstra et al., 2015).

3.2 Evidence on trade in natural resources

As shown in Figure 1A, global exports of natural resources (NR) have been rising since the mid-1990s (with dips in 2008-2009 and 2013-2015). The contribution of low income countries is negligible – global NR exports come mainly from middle and high income economies, where they peaked in 2013 at 2 trillion USD. More than half the countries with NR export shares of over 50% (see Table A.2. in Appendix A) are low or middle income. Once we split resources by type (Figure 1B), it is clear that fuels (fossil fuels: coal, natural gas and petroleum; plus electric power)¹⁴ lead the way, accounting for some 65% of total NR exports and rising periodically to nearly 80%. The contribution of metal and mineral products was quite constant, around 10% of total NR exports each.

Figure 1. Natural resource exports by income group and resource type, 1996-2018



Notes: sample: 160 countries (1996-2018) listed in Table A.1. (Appendix A); types of natural resources based on the WTO natural resource classification (Table A.4. in the Appendix A); countries grouped using 2018 World Bank income classification; see Figure B.1. in Appendix B for value of resource exports by type of NR.

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

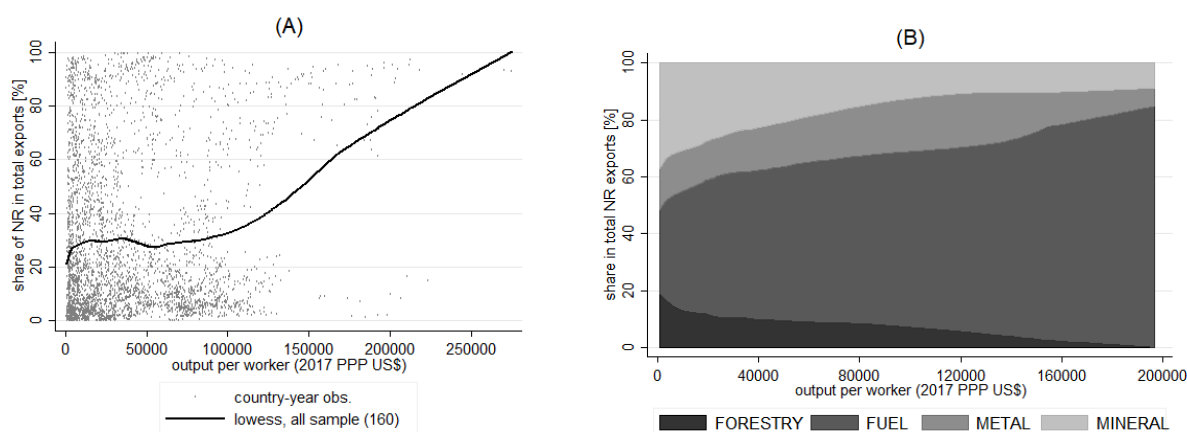
¹² We use the narrow definition of natural resources (excluding fishery products, as we do not handle agricultural resources in this work). The WTO classification of natural resources also includes raw materials and resource semi-manufactures.

¹³ Concordance tables come from the UN Trade [classifications on economic statistics](#) website.

¹⁴ See Table A.4. in Appendix A.

There is a definite positive relationship between NR exports and productivity (Figure 2A), but the general trend conceals considerable cross-country variability: the scatterplot underlying Figure 2A clearly shows that at low levels of income we find some countries with NR shares in total trade of 0 and of 100%. Figure 2B shows how the importance of particular resource types evolves along the development path: rich countries focus on fuel exports, while low productivity exporters tend to have a more varied NR export composition. As productivity increases, the contribution of mineral and forestry products decreases while fuel exports gain importance. On average, fuel products account for 44% of the exports of low income countries and 73% of those of high income economies (details in Table B.2. in Appendix B).

Figure 2. Relationship between productivity and natural resource exports (overall and by type)



Notes: sample: 160 countries (1998-2018); types of natural resources based on the WTO natural resources classification (see Table A.4. in the Appendix A).

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010) and output per worker from Penn World Table 10.0 (Feenstra et al., 2015).

The disaggregated data shows high income countries with comparative advantage in more products (Table 1). Matching this information with Figure 2B, we can see some particular features of low income countries' resource trade: it is diversified across broad resource types (forestry, fuel, metal, mineral) but at the same time quite uncompetitive within them (low income countries have comparative advantage only in a small number of NR products). Our dataset allows us to look deeper into the export baskets: resource products manufactured by economies with low productivity are mostly unprocessed or little processed.

Table 1. Comparative advantage in NR products (2018)

NR product type:	Countries:					
	High income (51)		Middle income (83)		Low income (26)	
	No.*	%**	No.*	%**	No.*	%**
ALL NR	54	17%	30	9%	15	5%
FORESTRY	9	20%	5	11%	2	5%
FUEL	7	17%	4	10%	1	3%
METAL	19	16%	8	7%	3	3%
MINERAL	19	16%	13	11%	9	8%

Notes: * mean number of product codes with $RCA > 1$ within the group, ** share of product codes with $RCA > 1$ in total number of NR products (within each resource type); types of natural resources based on WTO classification (see Table A.4. in the Appendix A).

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010) and 2018 World Bank's income classification.

3.3. Country-specific evidence

Our sample of 160 countries allows us to trace cross-country heterogeneity in development paths and the role of natural resources in it. Natural resource abundance is a relatively stable but not always permanent feature (see the detailed country grouping in Table A.3. in Appendix A). The resource exporting countries that maintained relatively stable NR exports throughout the period include both low or medium-low income countries like Nigeria, Bolivia and Zambia and developed economies like Norway, Qatar and Kuwait. However, a few NR exporters have recorded significant declines¹⁵ in the contribution of resource products to their export baskets. Out of 13 such economies, 10 specialise in fossil fuel exports (including four high income Middle Eastern countries). Next, some countries have shifted from non-resource to resource exports, either from agricultural products and/or textiles to natural resources (e.g. Chad, Gambia, Mongolia, Mozambique, Togo) or from other manufactured goods to natural resources (e.g. Australia, Malta, Panama, Sierra Leone). The economies that sustain average NR export shares of between 15% and 50% embrace such countries as Canada and Finland (both petroleum and wood) and Peru (copper ore). Finally, in the largest group – 67 countries with the lowest NR export share (under 15%) – we find a whole array of development and specialisation patterns: from low income economies specialising in agricultural products to strongly diversified high income countries.

Importantly, some of the resource-abundant countries managed to diversify their export baskets towards technologically advanced products. Figure 3 shows that high income fuel exporters like Oman,

¹⁵ Defined as a fall of at least 15 percentage points between 1996 and 2018.

Saudi Arabia and the UAE display definite signs of diversifying away from natural resource towards technological exports.¹⁶

Figure 3. NR exports share versus the share of technologically advanced exports* – selected countries



Notes: countries selected from group of NR exporters (see: Table A.2. in Appendix A); exception here is Latvia - included because of notable change in export basket (from 60% share of FORESTRY and FUEL products in 1996 to nearly 40% share of TECH products in 2018);

*Technologically advanced products (TECH) comprise a group of products based on the UNCTAD middle- and high-tech classification (Lall, 2000).

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

¹⁶ The reason could be their wealth in “petrodollars”, which helped them to catch up with the developed countries in technologically advanced production. A strong motivation is the worldwide trend to renewable energy sources, which will clearly necessitate finding a substitute source of income once fossil fuels are abandoned, together with the awareness that their resources will eventually be depleted (according to the BP Statistical Review of World Energy (2021), if oil production continues at the current rate, reserves will last for only a little more than 50 years).

The descriptive evidence in Section 3 raises some important questions. How do natural resources affect the export diversification process? Are there any differences between exporters of natural resources in different income groups? What type of resource has the strongest impact on export diversification? Finally, what are the consequences of resource abundance on the variety of the non-resource part of export basket (technological products, in particular)? The next section seeks to answer these questions.

4. The role of natural resources in export diversification

4.1 Relative Theil index decomposition

To gauge the importance of natural resource trade in the process of export diversification, we decompose the overall diversification index with respect to the groups of products that make up the export portfolio.¹⁷ The decomposition of a relative (weighted) Theil index,¹⁸ RT , builds on Gnidchenko (2021) and splits the index into between and within components as follows (time subscripts omitted):

$$RT^c = RT_{(B)}^c + RT_{(W)}^c = \sum_g S_g^c * \ln\left(\frac{S_g^c}{S_g^w}\right) + \sum_g S_g^c * RT_g^c \quad (1)$$

where: $g = \{g_o, g_i\}$ denotes product group, S_g^c is the share of g in country c 's total exports, S_g^w is the share of g in world (w) exports and $RT_g^c = \sum_{i \in g} S_i^c * \ln\left(\frac{S_i^c}{S_i^w}\right)$ is a relative Theil index calculated using product-level data on exports belonging only to group g . Theil is an entropy measure, so higher values of RT correspond to less diversification, relative to the structure of world trade. The lower bound of the RT index is zero when the country's exports are fully diversified.

To explain the export diversification process in the context of natural resource dependence, we divide all exported products (i.e. 4895 export lines within the HS6 classification scheme) into resource and non-resource products ($g_i=res$, $g_o=non-res$). Following (1), the overall RT index of every country c can be obtained as:

¹⁷ In the export diversification literature, a similar method was first applied by Cadot et. al (2011), who decomposed an unweighted (absolute) Theil index into the intensive margin (i.e. action within existing product lines) and the extensive margin (addition of new products to the export portfolio).

¹⁸ The degree of export concentration has traditionally been measured by absolute indices such as: Theil, Gini or Herfindahl (Imbs and Wacziarg, 2003; Klinger and Lederman, 2006; Cadot et al., 2011). Following Gnidchenko (2021), Parteka and Tamberi (2013b) and Mau (2016), we choose a relative measurement (relative Theil index) because it accounts for the world demand and is more suitable for analysing export diversification in a cross-country perspective. In Table B.4. we report additional results obtained with the unweighted (absolute) Theil index.

$$RT^c = S_{g_1}^c * \ln\left(\frac{S_{g_1}^c}{S_{g_1}^w}\right) + S_{g_1}^c * RT_{g_1}^c + S_{g_0}^c * \ln\left(\frac{S_{g_0}^c}{S_{g_0}^w}\right) + S_{g_0}^c * RT_{g_0}^c \quad (2)$$

which can be rewritten as a combination of three components, corresponding to the between, within-resource and within-non-resource margins:

$$RT^c = \underbrace{S_{g_1}^c \ln\left(\frac{S_{g_1}^c}{S_{g_1}^w}\right) + S_{g_0}^c \ln\left(\frac{S_{g_0}^c}{S_{g_0}^w}\right)}_{\text{between}^c} + \underbrace{S_{g_1}^c RT_{g_1}^c}_{\text{within}_{res}^c} + \underbrace{S_{g_0}^c RT_{g_0}^c}_{\text{within}_{non-res}^c} \quad (3)$$

Table 2 shows the results of the decomposition (3). High income countries are, on average, characterised by lower overall RT (a sign of greater export diversity) than medium or low income countries. The within-non-resource component accounts for 72.4 percent of the overall degree of diversification typical of high income economies, 71.1 percent in middle income and 73.7 percent in low income countries.

Table 2. Results of RT decomposition with respect to natural resources (eq. 3) – by income group

	Full sample (160 countries)		High income (51 countries)		Middle income (83 countries)		Low income (26 countries)	
	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>
RT	2.89	100.0%	1.69	100.0%	3.12	100.0%	4.50	100.0%
within non-resource	2.09	71.9%	1.15	72.4%	2.26	71.1%	3.39	73.7%
within resource	0.53	17.4%	0.32	16.7%	0.55	17.4%	0.85	18.9%
between	0.27	10.7%	0.22	10.9%	0.31	11.5%	0.26	7.4%

Note: see eq.(3) for details on RT decomposition; here: decomposition with respect to products split into resources (NR) and non-resources (taxonomy in Table A.4. in the Appendix A). The table reports average values over the sample period (160 countries, 1996-2018), countries divided into income groups according to the World Bank's classification (see Table A.1. in the Appendix).

Source: own calculations.

Figure 3 depicts the general diversification curve (showing a link between output per worker and export diversification, plotted across country-year data points (as in De Benedictis et. al., 2009; Cadot et al., 2011, Parteka and Tamberi, 2013b or Gnidchenko, 2021) and the results of the decomposition (eq. 3). The graphical pattern of the RT decomposition is mirrored in parametric estimates (reported in Table 3) of a model:

$$\ln y_{ct} = \alpha + \beta \ln PROD_{ct} + \delta_t + \delta_c + \varepsilon_{ct} \quad (4)$$

where c denotes country ($c = 1, \dots, 160$), t - time ($t = 1996, \dots, 2018$) and the dependent variable $y = \{RT, RT_{\text{within res}}, RT_{\text{within non-res}}, RT_{\text{between}}\}$ while $PROD$ (output per worker)¹⁹ traces stages of diversification due to

¹⁹ To address the possible problem of reverse causality and endogeneity between productivity and relative Theil index components, we use a two-step GMM estimator with a one-year lag of the potentially endogenous variable as instrument.

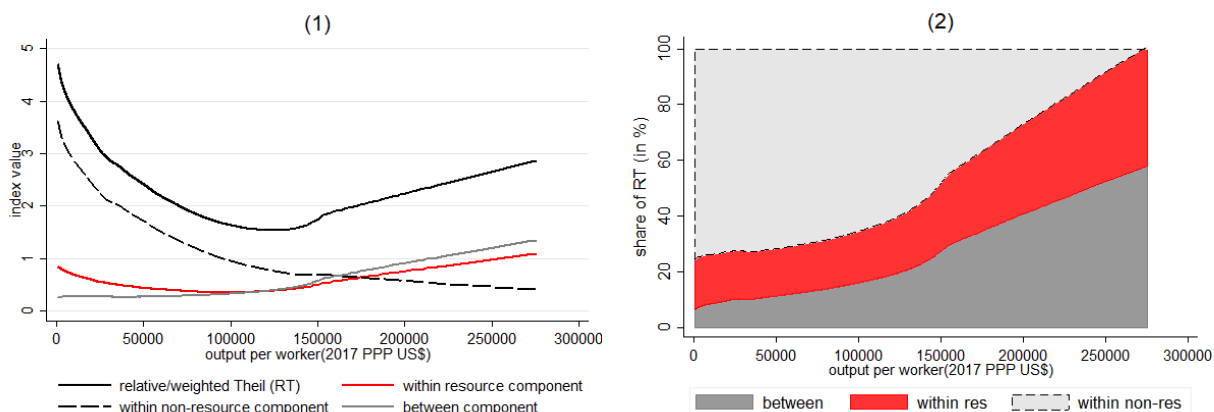
development (Imbs and Wacziarg, 2003; Cadot et al., 2011). RT is an inverse measure of diversification, so the downward line in Figure 4 (or negative β coefficient in eq. 4 and Table 3) corresponds to the ongoing diversification process.

Overall, RT tends to decrease as productivity increases (Figure 4A.1, Table 3): as countries develop they despecialise, which is in line with a well-established finding in the diversification literature (De Benedictis et al., 2009; Cadot et al., 2013, Caselli et al., 2020; Parteka and Tamberi, 2013a and 2013b; Mau, 2016). Respecialisation is plausible at high levels of income (Cadot et al., 2011) but Gnidchenko (2021) and Parteka and Tamberi (2013b) demonstrate that this pattern is actually due to outliers, in particular rich fuel exporters (in our case: Kuwait, Qatar, Saudi Arabia, UAE), which cannot be excluded from the analysis in the present context because we focus on resource trade. Importantly, what dominates is the within-non-resource component (heterogeneity of export lines not related to natural resources), and it is steadily decreasing along the development path. The within-resource component, in turn, starts to increase when output per worker surpasses \$10,000 (2017PPP); that is, the diversification of the resource portion of export baskets comes rather late in the development process.

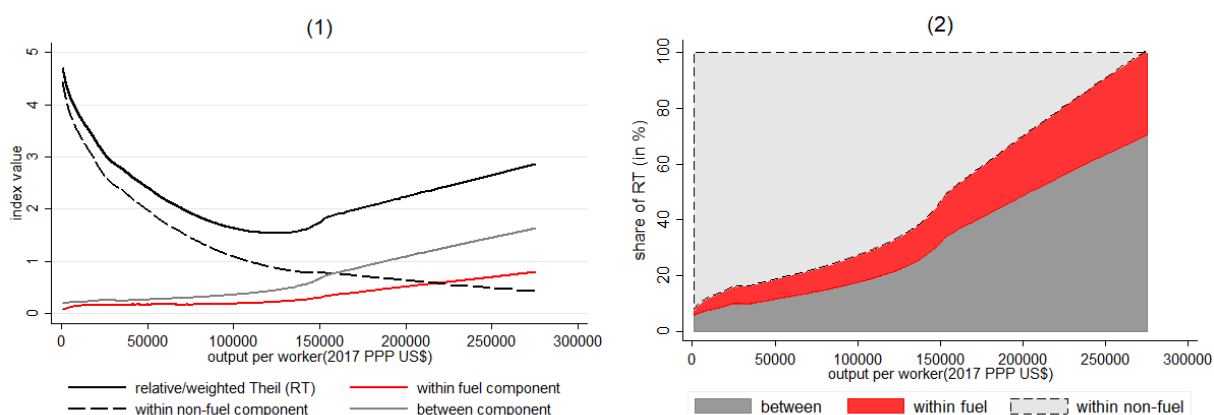
Figure 4A.2 shows the relative contribution of the components to overall export diversification typical of given levels of development. At low levels, diversification is led by increasing heterogeneity in non-resource exports (the light grey part dominates Figure 4A.2). Moving towards higher stages of development, however, the within-non-resource component loses relative importance. The other two components gain, i.e. export reallocation between resource and non-resource products (the between component – dark grey part in Figure 4A.2) and heterogeneity within resource products (within-resource component - red part in Figure 4A.2), and at very high levels of productivity they account, combined, for nearly all of RT . Figure 4B and Table 4 indicate that this pattern is driven by fuel exports. The decompositions obtained by splitting products into resources and non-resources (Figure 4A) and into fuel and non-fuel commodities (Figure 4B) are practically identical. The additional RT decomposition with respect to forestry, metal and mineral products shows that their heterogeneity contributes practically nothing to overall diversification (see Figure B.3. in Appendix B).

Figure 4. Resource-based decomposition of the export diversification curve: RT and its components (eq.3)

A. products split into NR (g_r) and non-NR (g_o)



B. products split into fuel (g_f) and non-fuel (g_o)



Note: (1) index value (2) – contribution of RT components to total RT .

Sample: 160 countries (1998-2018), list of countries in Table A.1 in Appendix A; RT – relative (weighted) Theil index of export specialisation); RT decomposition obtained with taxonomies based on the WTO natural resources classification (see Table A.4. in the Appendix A) of all NR products and FUEL products; analogous figures created with three other resources in Appendix B (Figure B.3.).

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010), and output per worker from PWT 10.0 (Feenstra et al., 2015).

Table 3. RT and its components by development level (estimates of eq. 4)

Dep. var.: $\ln y_{ct}$	OLS				GMM [#]			
	$y=RT$ (1)	$y=RT_{\text{within res}}$ (2)	$y=RT_{\text{within non-res}}$ (3)	$y=RT_{\text{between}}$ (4)	$y=RT$ (5)	$y=RT_{\text{within res}}$ (6)	$y=RT_{\text{within non-res}}$ (7)	$y=RT_{\text{between}}$ (8)
$\ln PROD_{ct}$	-0.103*** [0.0104]	-0.137 [0.0915]	-0.051** [0.0240]	-0.241*** [0.0336]	-0.095*** [0.0110]	-0.234** [0.1034]	-0.052** [0.0251]	-0.199*** [0.0334]
No.	3680	3680	3680	3680	3520	3520	3520	3520
No. countries	160	160	160	160	160	160	160	160
R^2	0.964	0.660	0.800	0.896	0.966	0.670	0.810	0.903

Notes: ***, **, * denote significance at the 1%, 5%, and 10% levels respectively; robust standard errors in parentheses; all specifications contain country and time fixed effects, constant included – not reported. [#]Instrumented variable: $\ln PROD_{ct}$. Source: based on data from BACI CEPII (Gaulier & Zignago, 2010) and PWT 10.0 (Feenstra et al., 2015).

Table 4. RT and its components – decomposition by type of NR

Sample: 160 countries	g_j =ALL NR		g_j =FORESTRY		g_j =FUEL		g_j =METAL		g_j =MINERAL	
	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>
RT	2.89	100.0%	2.89	100.0%	2.89	100.0%	2.89	100.0%	2.89	100.0%
within non-resources	2.09	71.9%	2.82	97.9%	2.48	83.1%	2.77	96.4%	2.70	94.8%
within resources	0.53	17.4%	0.04	1.1%	0.16	6.4%	0.06	2.0%	0.12	3.2%
between	0.27	10.7%	0.03	1.0%	0.26	10.5%	0.06	1.6%	0.08	2.0%

Notes: g_j denotes a group of natural resource products used to run the RT decomposition (eq. 3), obtained with taxonomies based on the WTO classification (see Table A.4. in the Appendix A); table reports average values over the sample period (160 countries, 1996-2018).

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

Table 5 further shows the decomposition (eq. 3) within the group of countries characterized by high dependence of exports on natural resources (above 50%), designated “NR exporters” (see Table A.2. in Appendix A).²⁰ If we consider the most general division of products into resources and non-resources (Table 5, panel A, g_j =all NR), the three components of RT have more or less equal impact. Low income NR exporters have concentrated exports (high RT value) and 40% of their degree of export diversification can be explained by the heterogeneity of NR products (the equivalent figure for high income resource exporters is 30.7%). Dividing exports into fuel and non-fuel products (Table 5, panel B, g_j =FUEL), the variety of non-fuel products accounts for 51% of overall diversification in resource exporters (but as much as 75% in low income ones).

Table 5. RT and its components (by income group) – subsample of NR exporters*

Sample: NR exporters only	All (36 countries)		High income (11 countries)		Middle income (19 countries)		Low income (6 countries)	
	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>	<i>value</i>	<i>structure</i>
	A. g_j =ALL NR							
RT	2.99	100.0%	2.40	100.0%	2.97	100.0%	4.14	100.0%
within non-resources	0.95	29.6%	0.73	30.7%	0.84	26.5%	1.69	37.3%
within resources	1.11	34.5%	0.81	32.7%	1.08	33.6%	1.72	40.6%
between	0.94	35.9%	0.85	36.6%	1.05	39.9%	0.73	22.0%
B. g_j =FUEL								
RT	2.99	100.0%	2.40	100.0%	2.97	100.0%	4.14	100.0%
within non-FUEL	1.76	51.1%	1.11	45.3%	1.58	46.7%	3.47	75.5%
within FUEL	0.37	13.7%	0.40	16.5%	0.40	14.1%	0.22	7.2%
between	0.86	35.2%	0.88	38.2%	0.98	39.2%	0.45	17.3%

Notes: g_j is a group of natural resource products used to run the RT decomposition (eq. 3) obtained with taxonomies based on the WTO natural resource classification (see Table A.4. in the Appendix A); the table reports average values over the sample period (36 countries, 1996-2018).

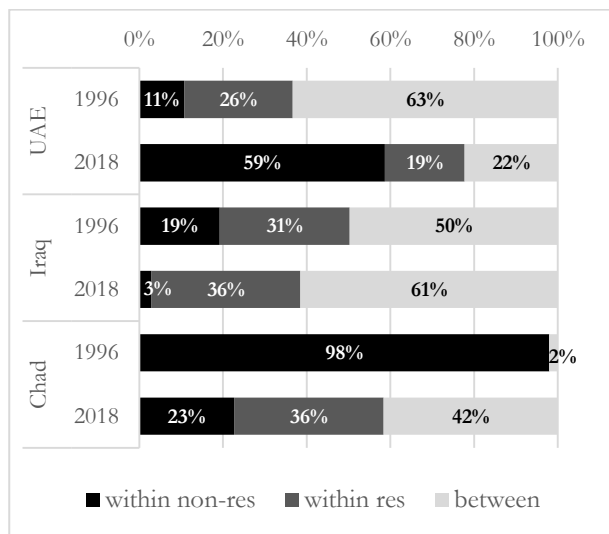
*Countries with the share of resource exports (products belonging to all NR classification) of at least 50% (1996-2018 average) - see Table A.2. in Appendix A for detailed list.

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

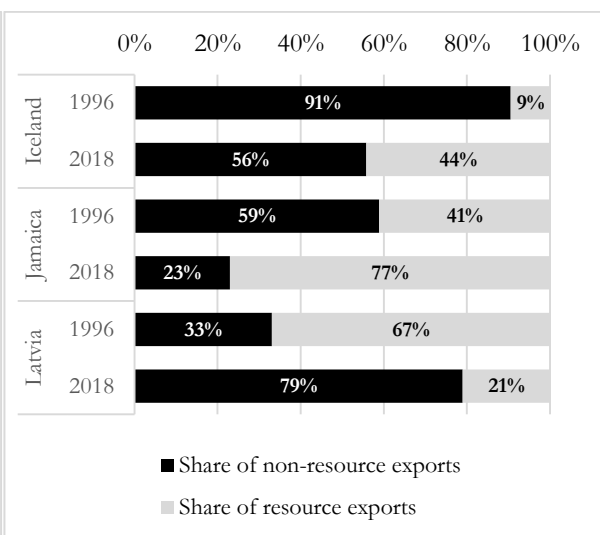
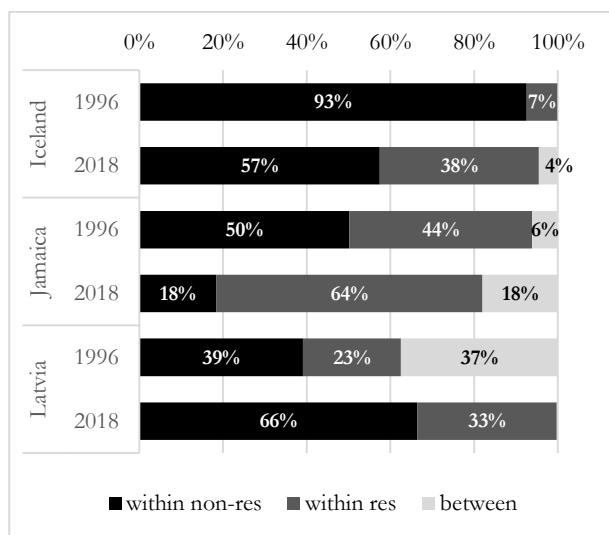
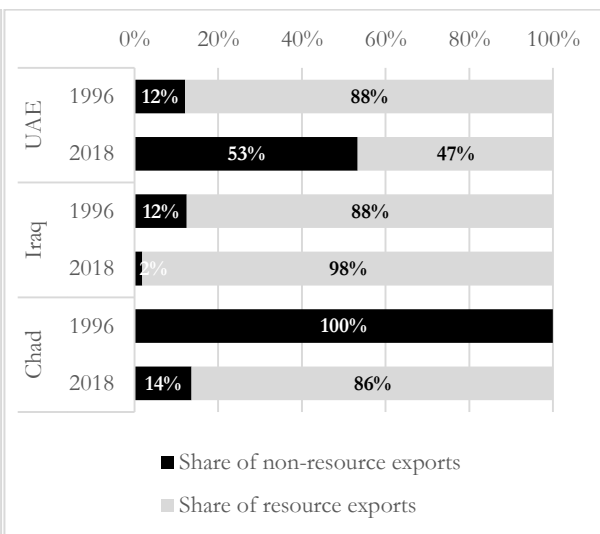
²⁰ See Table A.5. in Appendix A for the results of the decomposition (eq. 3) within the group of non-resource exporters - countries with share of resource exports <50% (1996-2018 average).

Figure 5. Alternative diversification trajectories – case studies

A. Relative contribution of RT components



B. Share of NR in total exports



Notes: the graphs in A show the relative importance of the single components in the overall RT value (RT decomposition from eq. 3);
 NR taxonomy based on the WTO natural resource classification (see Table A.4. in the Appendix A).
 Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

By way of example, Figure 5²¹ presents the results of decomposition (3) for six countries: three fuel exporters at different levels of income (UAE, Iraq and Chad), one country rich in minerals (Jamaica), one metal exporter (Iceland) and a former forestry product exporter (Latvia). In 1996, the UAE began diversifying away from natural resources towards technological production. This can be seen in the notable increase in the importance of the within-non-resource component of RT, which in 1996 accounted for only 11% and in 2018 for almost 60% of the country's overall export diversification (Figure 5A). This was accompanied by a significant increase in the share of non-resource products in

²¹ For more detailed data see Table A.6. and Table A.7. in Appendix A.

total exports (Figure 5B), from 12% in 1996 to 53% in 2018. A small European economy, Latvia, is another, comparable example: it had once concentrated exports in forestry products and crude oil, but over time managed to achieve export diversification mostly through heterogeneity of non-resource products. Iceland, Jamaica and Chad demonstrated a different pattern, shifting from export diversification dominated by the within-non-resource component to diversification based on the within-resource component (accompanied by a strong increase in the resource share of exports).

4.2 The role of natural resources in export diversification – econometric analysis

To determine whether natural resources affect the diversification of exports in a statistically significant way, we estimate the model:

$$\ln RT_{ct} = \alpha + \beta_1 NR_{ct} + \beta_2 \ln GDP_{ct} + \beta_3 \ln PROD_{ct-1} + \delta_t + \varepsilon_{ct} \quad (5)$$

where the dependent variable is RT calculated across all product lines, but we also check if (and how) NR affects the composition of the rest of the export basket, i.e. the variety of products not related to resources (non-res) and a particular subset of these, namely technologically advanced goods:

$RT_g^c = \sum_{i \in g} S_i^c * \ln \left(\frac{S_i^c}{S_i^w} \right)$, $g = \{all\ NR, nonNR, TECH\}$. We use information on the NR share of total exports – overall (all resources) and by type, so that $NR = \{ALL\ NR, FORESTRY, FUEL, METAL, MINERAL\}$.²² Apart from international differences in productivity ($PROD$),²³ we control for country size, which is a major determinant of export concentration/diversification (Parteka and Tamberi, 2013b; Basile et al., 2018; Cieřlik and Parteka, 2021; Lee and Zhang, 2022), using data on GDP (in constant 2017 USD, from PWT 10.0).

We further consider a model with fuel exports only (which is likely to dominate the diversification pattern – see Figure 4B), estimated within three income groups:

$$\ln RT_{ct} = \alpha + \beta_1 FUEL_{ct} + \beta_2 \ln GDP_{ct} + \delta_t + \varepsilon_{ct}, \quad c \in \{low, middle, high\} \quad (6)$$

Tables 5, 6 and 7 report the estimation results for eq.(5), Table 8 for eq. (6).²⁴ As expected, GDP and productivity are inversely correlated with RT : other things equal, larger and more productive

²² Here, ALL NR combines forestry, fuel, metal and mineral – see Table A.4. in Appendix A.

²³ The effects of productivity on export diversification are not immediate, so the variable $PROD$ is lagged. To deal with the possible problem of reverse causality and endogeneity between productivity and export diversification, we use a two-step GMM estimator with a one-year lag of the potentially endogenous variable as instrument.

²⁴ Natural resource exporters tend to have highly persistent levels of resource production, which results in stable resource exports (see Table A.8. in Appendix A), so in models (5) and (6) we omit country fixed effects that would wipe out cross-

economies have less specialised (more diversified) export structures. A stronger focus on natural resources affects diversification negatively (but weakly). Controlling for size and productivity differences between countries, a 1-percentage-point increase in the share of natural resources in total exports corresponds to a 0.003% rise in the value of RT index, *ceteris paribus* (Table 5, column 1). What is more, natural resources affect not only the overall diversity of export baskets but also that of non-resource exports as such, limiting their diversification (Table 6). This result holds for all types of NR except for forestry products.²⁵ Still, even taking the highest coefficient (typical for fuel exports - Table 6, column 3), the relationship is not strong. This result holds also after quantifying the interplay between natural resource exports and the diversity observed within technologically advanced products (Table 7). Resources can hamper technological upgrading (overall resource abundance and intense fuel exporting are positively related to $\ln RT_{TECH_{ct}}$), but the downward pressure of resource abundance on technological product heterogeneity is not particularly strong.

Table 8 reveals some differences in the relationship between fuel abundance and diversification specific to stages of development (eq. 6). A positive and statistically significant relationship between fuel exports and the overall RT index is typical for high income countries (that is, fuel abundance is accompanied by greater export specialisation). As to the magnitude of the effect, other things being equal a 1-p.p. increase in the share of fuel exports corresponds to an increase of 0.005 % in the RT index in the high income group (Table 8, column 1). The opposite result characterises low income countries. Fuel abundance reinforces the concentration of non-resource products and of technological exports (especially in high and middle income economies).²⁶ Here too, however, it is clear that export diversity is determined primarily by factors other than resources, such as country size.

country variability but we include time fixed effects to account for cyclical and global fluctuations in commodity prices (Bahar and Santos, 2018).

²⁵ Forestry product exporters comprise both high income countries (e.g. Finland, Latvia, New Zealand, Estonia) and low income countries (e.g. Central African Republic, Cameroon, Gambia, Gabon). The positive correlation between the share of forestry products and the RT index persists even when outliers are excluded – the Central African Republic, say, whose average share of forestry products in total exports in 1996-2018 was 32% (and 55% in 2018 alone).

²⁶ This result is confirmed also using the classic (absolute) Theil index – Table B.4. in the Appendix B.

Table 5. Correlation between natural resources and diversity of exported products (eq. 5)

Dependent variable: <i>lnRT_{ct}</i>	OLS					GMM#				
	Type of NR:					Type of NR:				
	ALL NR	FORESTRY	FUEL	METAL	MINERAL	ALL NR	FORESTRY	FUEL	METAL	MINERAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>NR_{ct}</i>	0.003*** [0.0002]	-0.004*** [0.0008]	0.002*** [0.0002]	0.005*** [0.0004]	0.006*** [0.0004]	0.003*** [0.0002]	-0.003*** [0.0008]	0.002*** [0.0002]	0.005*** [0.0004]	0.006*** [0.0004]
<i>lnGDP_{ct}</i>	-0.195*** [0.0030]	-0.197*** [0.0032]	-0.197*** [0.0031]	-0.197*** [0.0031]	-0.193*** [0.0032]	-0.195*** [0.0031]	-0.197*** [0.0033]	-0.197*** [0.0032]	-0.196*** [0.0032]	-0.192*** [0.0032]
<i>lnPROD_{ct-1}</i>	-0.191*** [0.0051]	-0.189*** [0.0051]	-0.195*** [0.0053]	-0.184*** [0.0051]	-0.181*** [0.0051]	-0.192*** [0.0051]	-0.191*** [0.0052]	-0.196*** [0.0053]	-0.185*** [0.0051]	-0.182*** [0.0052]
<i>No.</i>	3520	3520	3520	3520	3520	3360	3360	3360	3360	3360
<i>No. countries</i>	160	160	160	160	160	160	160	160	160	160
<i>R²</i>	0.751	0.733	0.740	0.739	0.742	0.751	0.732	0.740	0.738	0.741

Notes: ***, **, * denote significance at the 1%, 5%, and 10% levels respectively; robust standard errors in parentheses; all specifications contain time fixed effects.

Constant included – not reported. #Instrumented variable *lnPROD_{ct-1}*.

Source: based on data from BACI CEPII (Gaulier & Zignago, 2010) and PWT 10.0 (Feenstra et al., 2015).

Table 6. Correlation between natural resources and diversity of non-NR exported products (eq. 5, cont.)

Dependent variable: <i>lnRT_{non-NR_{ct}}</i>	OLS Type of NR:					GMM# Type of NR:				
	ALL NR (1)	FORESTRY (2)	FUEL (3)	METAL (4)	MINERAL (5)	ALL NR (6)	FORESTRY (7)	FUEL (8)	METAL (9)	MINERAL (10)
<i>NR_{ct}</i>	0.007*** [0.0002]	-0.006*** [0.0009]	0.008*** [0.0002]	0.004*** [0.0005]	0.003*** [0.0005]	0.008*** [0.0002]	-0.006*** [0.0010]	0.008*** [0.0002]	0.004*** [0.0005]	0.003*** [0.0005]
<i>lnGDP_{ct}</i>	-0.200*** [0.0032]	-0.198*** [0.0032]	-0.206*** [0.0032]	-0.196*** [0.0031]	-0.194*** [0.0032]	-0.199*** [0.0033]	-0.197*** [0.0033]	-0.206*** [0.0033]	-0.196*** [0.0032]	-0.194*** [0.0033]
<i>lnPROD_{ct-1}</i>	-0.196*** [0.0054]	-0.191*** [0.0052]	-0.216*** [0.0054]	-0.184*** [0.0051]	-0.181*** [0.0051]	-0.197*** [0.0054]	-0.192*** [0.0052]	-0.218*** [0.0054]	-0.185*** [0.0052]	-0.182*** [0.0052]
<i>No.</i>	3520	3520	3520	3520	3520	3360	3360	3360	3360	3360
<i>No. countries</i>	160	160	160	160	160	160	160	160	160	160
<i>R²</i>	0.758	0.730	0.769	0.734	0.730	0.759	0.729	0.770	0.733	0.730

Notes: See notes to Table 5. Source: own calculations based on data from BACI CEPII (Gaulier & Zignago, 2010) and PWT 10.0 (Feenstra et al., 2015).

Table 7. Correlation between natural resources and diversity of technologically advanced exported products (eq. 5, cont.)

Dependent variable: <i>lnRT_{TECH_{ct}}</i>	OLS Type of NR:					GMM# Type of NR:				
	ALL NR (1)	FORESTRY (2)	FUEL (3)	METAL (4)	MINERAL (5)	ALL NR (6)	FORESTRY (7)	FUEL (8)	METAL (9)	MINERAL (10)
<i>NR_{ct}</i>	0.007*** [0.0002]	-0.010*** [0.0015]	0.009*** [0.0003]	0.002*** [0.0005]	0.000 [0.0005]	0.008*** [0.0002]	-0.010*** [0.0016]	0.009*** [0.0003]	0.002*** [0.0005]	0.000 [0.0005]
<i>lnGDP_{ct}</i>	-0.199*** [0.0038]	-0.204*** [0.0046]	-0.205*** [0.0039]	-0.202*** [0.0045]	-0.201*** [0.0046]	-0.198*** [0.0039]	-0.203*** [0.0047]	-0.204*** [0.0040]	-0.201*** [0.0047]	-0.200*** [0.0047]
<i>lnPROD_{ct-1}</i>	-0.179*** [0.0062]	-0.174*** [0.0069]	-0.200*** [0.0062]	-0.168*** [0.0069]	-0.169*** [0.0069]	-0.180*** [0.0063]	-0.176*** [0.0071]	-0.202*** [0.0063]	-0.170*** [0.0071]	-0.172*** [0.0071]
<i>No.</i>	3520	3520	3520	3520	3520	3360	3360	3360	3360	3360
<i>No. countries</i>	160	160	160	160	160	160	160	160	160	160
<i>R²</i>	0.678	0.579	0.692	0.576	0.575	0.678	0.575	0.692	0.572	0.571

Notes: see notes to Table 5. Source: based on data from BACI CEPII (Gaulier & Zignago, 2010) and PWT 10.0 (Feenstra et al., 2015).

Classification of TECH products from UNCTAD (Lall, 2000).

Table 8. Relationship between fuel exports and product diversity - by income group (estimates of eq. 6)

Sample - income group:	Dependent variable: $\ln RT_{ct}$			Dependent variable: $\ln RT_{nonFUEL_{ct}}$			Dependent variable: $\ln RT_{TECH_{ct}}$		
	HIGH	MIDDLE	LOW	HIGH	MIDDLE	LOW	HIGH	MIDDLE	LOW
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$FUEL_{ct}$	0.005*** [0.0003]	-0.000 [0.0002]	-0.007*** [0.0002]	0.009*** [0.0004]	0.006*** [0.0002]	0.000 [0.0003]	0.010*** [0.0004]	0.006*** [0.0002]	0.000 [0.0004]
$\ln GDP_{ct}$	-0.257*** [0.0057]	-0.172*** [0.0036]	-0.099*** [0.0094]	-0.279*** [0.0058]	-0.180*** [0.0037]	-0.107*** [0.0095]	-0.308*** [0.0060]	-0.165*** [0.0045]	-0.089*** [0.0108]
No.	1173	1909	598	1173	1909	598	1173	1909	598
No. countries	51	83	26	51	83	26	51	83	26
R^2	0.678	0.643	0.610	0.729	0.664	0.311	0.787	0.519	0.128

Notes: ***, **, * denote significance at the 1%, 5%, and 10% levels respectively; robust standard errors in parentheses; all specifications contain time and country fixed effects; division into income groups according to Table A.1. in Appendix A. Classification of tech products from UNCTAD (Lall, 2000).

Source: based on data from BACI CEPII (Gaulier & Zignago, 2010) and PWT 10.0 (Feenstra et al., 2015).

5. Conclusions

We contribute to the literature by relating the strand of inquiry into export diversification (Imbs and Wacziarg, 2003; Hummels and Klenow, 2005; Cadot et al., 2011; Cadot et al., 2013, Caselli et al., 2020; Parteka and Tambari, 2013a and 2013b; Gnidchenko, 2021) to that on the economic effects of natural resource abundance (Sachs and Warner, 1995,1999,2001; Gylfason et al., 1999; Gylfason, 2001; Torvik, 2009; Ross, 2015, 2019; Farhadi et al., 2015; Canh et al., 2020). We started from the observation that there is no unique pattern of diversification typifying all natural resource exporters. A high share of natural resources in total exports can be found in countries at all income levels but, contrary to the received view, at low stages of development countries may be either totally specialised or not at all specialised in natural resources. Moreover, low income countries tend to focus on various types of resources (a mix of forestry, fuel, metal and mineral products) but at the same time they export only a small fraction of products within these groups (out of all that could potentially be traded) – that is, diversification is low.

Decomposition using the relative Theil index quantifies the contribution of resource abundance to the export diversification that tends to accompany economic development. A large-scale empirical analysis (160 countries over the period 1996-2018) reveals that high export concentration, typical of the initial stage of development, is driven chiefly by the relative lack of heterogeneity in non-resource products. Later, the between component (i.e. export reallocation between resource and non-resource products) gains in importance and at high income levels, together with the intra-resource component, accounts for almost all export diversification. We show that intensive exports of natural resource slow overall diversification and affect the composition of the non-resource part of the export basket, reinforcing their concentration; these effects are weak, however.

Considering that oil exporting countries were successful in initiating diversification towards technological production, a possible extension for our work should include the subdivision of fuel exporters into three groups – those specialising in coal, natural gas and oil (in the FUEL group as a whole, the concentration of non-resource and technological exports is greater). This further breakdown would allow verification of the exact relationship between oil exports as such and trade concentration.

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Appendix A

Table A.1. List of countries and their income classification

Group of countries (number of countries)	Countries
High income (51)	Australia, Austria, Bahamas, Bahrain, Barbados, Belgium and Luxembourg, Brunei, Canada, Chile, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kuwait, Latvia, Lithuania, Macao, Malta, Netherlands, New Zealand, Norway, Oman, Panama, Poland, Portugal, Qatar, Saudi Arabia, Singapore, Slovakia, Slovenia, Spain, South Korea, Sweden, Switzerland, Trinidad and Tobago, USA, United Arab Emirates, United Kingdom, Uruguay
Middle income* (83)	Albania, Algeria, Angola, Argentina, Armenia, Azerbaijan, Bangladesh, Belarus, Belize, Bhutan, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Cabo Verde, Cambodia, Cameroon, China, Colombia, Comoros, Congo, Costa Rica, Côte d'Ivoire, Djibouti, Dominican Rep., Ecuador, Egypt, El Salvador, Equatorial Guinea, Fiji, Gabon, Georgia, Ghana, Grenada, Guatemala, Guyana, Honduras, India, Indonesia, Iran, Iraq, Jamaica, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Laos, Lebanon, Macedonia, Malaysia, Maldives, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Peru, Philippines, Rep. of Moldova, Romania, Russian Federation, Saint Lucia, Saint Vincent and the Grenadines, Sao Tome and Principe, Senegal, Sri Lanka, Sudan, Suriname, Thailand, Tunisia, Turkey, Turkmenistan, Ukraine, Uzbekistan, Venezuela, Vietnam, Zambia, Zimbabwe
Low income (26)	Benin, Burkina Faso, Burundi, Central African Republic, Chad, Dem. Rep. of the Congo, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Liberia, Madagascar, Malawi, Mali, Mozambique, Nepal, Niger, Rwanda, Sierra Leone, Syria, Tajikistan, Togo, Tanzania, Uganda, Yemen

Notes: Belgium and Luxembourg (BELX) stand for joint data for Belgium (BEL) and Luxemburg (LUX); division into high middle and low income countries in line with 2018 World Bank income classification (*low-middle income and upper-middle income categories merged into the middle income group).

Table A.2. List of natural resources (NR) exporters*

Income class (number of countries)	Countries
High income (11)	Australia, Bahrain, Brunei Darussalam, Chile, Kuwait, Norway, Oman, Qatar, Saudi Arabia, Trinidad and Tobago, United Arab Emirates
Middle income (19)	Algeria, Angola, Azerbaijan, Bolivia, Cameroon, Congo, Equatorial Guinea, Gabon, Iran, Iraq, Jamaica, Kazakhstan, Mongolia, Nigeria, Russian Federation, Sudan, Turkmenistan, Venezuela, Zambia
Low income (6)	Chad, Dem. Rep. of the Congo, Guinea, Mozambique, Tajikistan, Yemen

Notes: division into high middle and low income countries in line with 2018 World Bank income classification; * countries with share of resource exports $\geq 50\%$ (1996-2018 average).

Table A.3. Countries' groups according to changes in natural resources exports' share

subsample	group of countries (number of countries)	countries
NR exporters*	NR exporters with decrease** in NR exports share (13)	Djibouti, Egypt, Georgia, Guinea, Iran, Latvia, Niger, Oman, Saudi Arabia, Suriname, Syria, United Arab Emirates, Yemen
	NR exporters without distinct change** in NR exports share (18)	Algeria, Angola, Bahrain, Bolivia, Brunei Darussalam, Cameroon, Chile, Colombia, Equatorial Guinea, Gabon, Iraq, Kuwait, Nigeria, Norway, Qatar, Russian Federation, Venezuela, Zambia
	Countries with increase** in NR exports share (30)	Australia, Azerbaijan, Central African Rep., Chad, Congo, Cyprus, Dem. Rep. of the Congo, Gambia, Greece, Iceland, Jamaica, Kazakhstan, Laos, Liberia, Maldives, Malta, Mongolia, Mozambique, Panama, Rwanda, Saint Lucia, Saint Vincent and the Grenadines, Sierra Leone, Sudan, Tajikistan, Togo, Trinidad and Tobago, Turkmenistan, Uruguay, Uzbekistan
Non NR exporters	Countries with avg. share*** of NR exports >15% and <50% (32)	Albania, Armenia, Bahamas, Barbados, Belarus, Benin, Bhutan, Bosnia Herzegovina, Brazil, Bulgaria, Canada, Croatia, Côte d'Ivoire, Ecuador, Estonia, Finland, Ghana, Guinea-Bissau, Guyana, Indonesia, Lithuania, Malaysia, Mauritania, Myanmar, Netherlands, New Zealand, Paraguay, Peru, Singapore, Ukraine, Vietnam, Zimbabwe
	Countries with avg. share*** of NR exports <15% (67)	Argentina, Austria, Bangladesh, Belgium and Luxembourg, Belize, Burkina Faso, Burundi, Cabo Verde, Cambodia, China, Comoros, Costa Rica, Czechia, Denmark, Dominican Rep., El Salvador, Ethiopia, Fiji, France, Germany, Grenada, Guatemala, Haiti, Honduras, Hong Kong, Hungary, India, Ireland, Israel, Italy, Japan, Jordan, Kenya, Kyrgyzstan, Lebanon, Macao, Macedonia, Madagascar, Malawi, Mali, Mauritius, Mexico, Morocco, Nepal, Nicaragua, Pakistan, Philippines, Poland, Portugal, Rep. of Moldova, Romania, Sao Tome and Principe, Senegal, Slovakia, Slovenia, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Tanzania, Thailand, Tunisia, Turkey, USA, Uganda, United Kingdom

Notes: Belgium and Luxembourg (BELX) stands for joint data for Belgium (BEL) and Luxemburg (LUX).

* countries with share of resource exports (ALL NR classification) $\geq 50\%$ (1996-2018 average).

** at least 15 p.p. difference between 1996 and 2018 shares.

*** 1996-2018 average.

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

Table A.4. Natural resources taxonomy

Segment (WTO classification)	Division number	Division description	NR group (used in this paper)
FORESTRY PRODUCTS	24	Cork and wood	FORESTRY
	25	Pulp and waste paper	FORESTRY
FUELS AND MINING PRODUCTS	27	Crude fertilizers and crude minerals	MINERAL
	28	Metalliferous ores and metal scrap	MINERAL
	32	Coal, coke and briquettes	FUEL
	33	Petroleum, petroleum products and related materials	FUEL
	34	Gas, natural and manufactured	FUEL
	35	Electric current	FUEL
	68	Non-ferrous metals	METAL

Source: Based on the WTO natural resources classification (Bacchetta, 2010).

Notes: Main natural resource segments from the WTO classification divided into four groups (forestry, mineral, fuel, metal) and converted from SITC Rev.3 into HS96 nomenclature.

Detailed information about resource classifications and used product codes in file **classification-resources.xlsx**.

Table A.5. RT and its components – non-resource exporters* (by income group)

Sample: non-NR exporters	All (124 countries)		High income (40 countries)		Middle income (64 countries)		Low income (20 countries)	
	Value	Structure	Value	Structure	Value	Structure	Value	Structure
g_1 =ALL NR								
RT	2.86	100.0%	1.50	100.0%	3.17	100.0%	4.61	100.0%
within non-ALL NR	2.42	84.2%	1.26	83.8%	2.68	84.3%	3.90	84.6%
within ALL NR	0.36	12.5%	0.19	12.3%	0.40	12.6%	0.59	12.4%
between	0.08	3.3%	0.05	3.9%	0.09	3.1%	0.12	3.0%
g_1 =FUEL								
RT	2.86	100.0%	1.50	100.0%	3.17	100.0%	4.61	100.0%
within non-FUEL	2.69	92.4%	1.37	90.4%	2.96	92.8%	4.42	95.1%
within FUEL	0.10	4.2%	0.07	5.5%	0.12	4.3%	0.06	1.6%
between	0.08	3.4%	0.05	4.1%	0.08	3.0%	0.13	3.3%

Notes: g_i is a group of natural resources products used to run decomposition (eq. 3); decomposition obtained with taxonomies based on WTO natural resources classification (see Table A.4. in the Appendix A); table reports average values over the sample period (124 countries, 1996-2018).

*countries with share of resource exports <50% (1996-2018 average)

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

Table A.6. RT and its components – case studies

	High income FUEL exporter				Middle income FUEL exporter			
	UAE* - 1996		UAE* - 2018		Iraq - 1996		Iraq - 2018	
	Value	Structure	Value	Structure	Value	Structure	Value	Structure
g_1 =ALL NR								
RT	2.40	100%	0.98	100%	3.02	100%	2.61	100%
within non-ALL NR	0.26	11%	0.58	59%	0.58	19%	0.08	3%
within ALL NR	0.62	26%	0.19	19%	0.94	31%	0.93	36%
between	1.52	63%	0.22	22%	1.50	50%	1.60	61%
	Low income FUEL exporter				METAL exporter			
	Chad - 1996		Chad - 1996		Iceland - 1996		Iceland - 2018	
	Value	Structure	Value	Structure	Value	Structure	Value	Structure
g_1 =ALL NR								
RT	6.00	100%	2.69	100%	4.57	100%	4.14	100%
within non-ALL NR	5.87	98%	0.61	23%	4.23	93%	2.38	57%
within ALL NR	0.00	0%	0.96	36%	0.34	7%	1.58	38%
between	0.12	2%	1.12	42%	0.00	0%	0.19	4%
	MINERAL exporter				FORESTRY exporter			
	Jamaica - 1996		Jamaica - 2018		Latvia - 1996		Latvia - 2018	
	Value	Structure	Value	Structure	Value	Structure	Value	Structure
g_1 =ALL NR								
RT	4.43	100%	4.65	100%	2.22	100%	1.40	100%
within non-ALL NR	2.22	50%	0.85	18%	0.87	39%	0.93	66%
within ALL NR	1.93	44%	2.96	64%	0.52	23%	0.47	33%
between	0.27	6%	0.84	18%	0.83	37%	0.00	0%

Notes: g_t is a group of natural resources products used to run decomposition (eq. 3); decomposition obtained with taxonomies based on WTO natural resources classification (see Table A.4. in the Appendix A).

* UAE – United Arab Emirates

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

Table A.7. Share of resource and non-resource exports – case studies

	United Arab Emirates		Iraq		Chad	
	1996	2018	1996	2018	1996	2018
Share of resource exports	87.9%	46.7%	87.5%	98.1%	0.1%	86.4%
Share of non-resource exports	12.1%	53.3%	12.5%	1.9%	99.9%	13.6%
	Iceland		Jamaica		Latvia	
	1996	2018	1996	2018	1996	2018
Share of resource exports	9.5%	44.2%	41.1%	77.1%	66.9%	21.0%
Share of non-resource exports	90.5%	55.8%	58.9%	22.9%	33.1%	79.0%

Note: percentage share of resource and non-resource exports based on ALL NR classification from WTO natural resources taxonomies (see Table A.4. in the Appendix A).

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

Table A.8. NR persistence over time

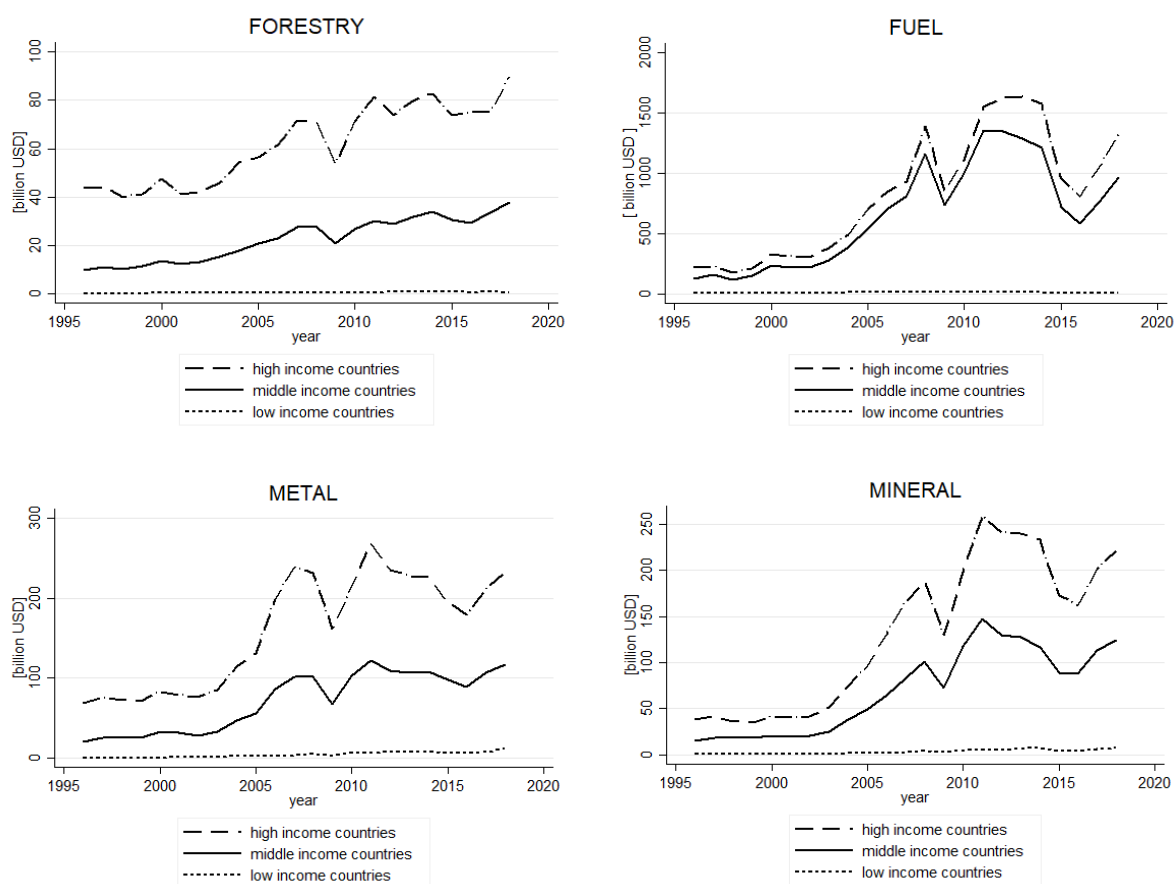
a.		$(NR_{ct} = \alpha + \beta NR_{c,t-1} + \delta_t + \varepsilon_{ct})$ where the dep. var. (NR) is:				
	<i>All NR</i>	<i>FORESTRY</i>	<i>FUEL</i>	<i>METAL</i>	<i>MINERAL</i>	
$NR_{c,t-1}$	0.974*** [0.0033]	0.938*** [0.0338]	0.973*** [0.0039]	0.981*** [0.0125]	0.958*** [0.0155]	
α	-0.005 [0.0069]	0.002 [0.0023]	-0.000 [0.0061]	0.001 [0.0009]	0.004** [0.0018]	
R^2	0.950	0.872	0.947	0.954	0.914	
N	3520	3520	3520	3520	3520	
b.		$(NR_{ct} = \alpha + \beta NR_{c,t-1} + \delta_t + \delta_c + \varepsilon_{ct})$ where the dep. var. (NR) is:				
	<i>All NR</i>	<i>FORESTRY</i>	<i>FUEL</i>	<i>METAL</i>	<i>MINERAL</i>	
$NR_{c,t-1}$	0.736*** [0.0229]	0.739*** [0.0587]	0.685*** [0.0304]	0.840*** [0.0395]	0.772*** [0.0391]	
α	0.242*** [0.0232]	0.001 [0.0022]	0.293*** [0.0295]	0.001 [0.0011]	0.005 [0.0029]	
R^2	0.958	0.890	0.957	0.959	0.923	

Note: a - estimates with time fixed effects, b - estimates with time and country fixed effects

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

Appendix B. Extensions and robustness checks

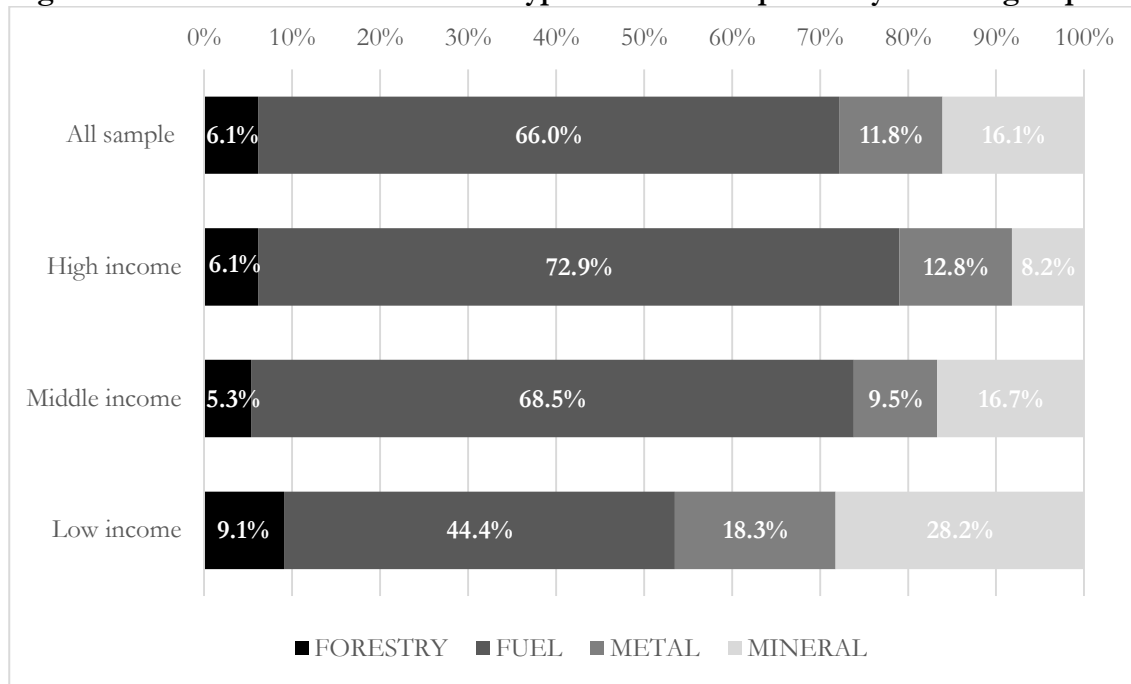
Figure B.1. Value of resource exports (by income group) – by types of NR



Notes: sample: 160 countries (1998-2018) listed in Table A.1. (Appendix A); types of natural resources based on WTO natural resources classification (Table A.4. in the Appendix A); countries grouped using 2018 World Bank income classification.

Source: own elaboration using product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

Figure B.2. Contribution of resource types to all NR exports - by income group

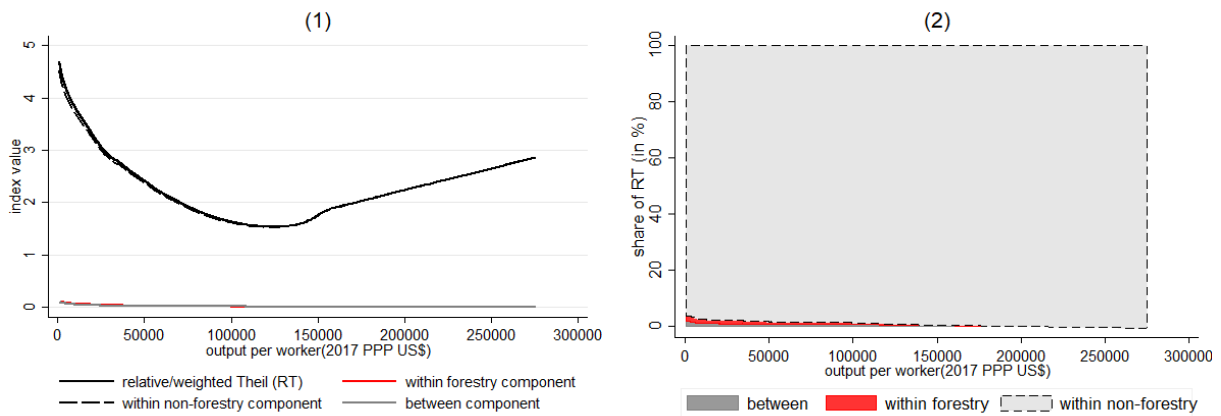


Notes: sample: 160 countries (1996-2018) listed in Table A.1. (Appendix A); types of natural resources based on WTO natural resources classification (Table A.4. in the Appendix A); countries grouped using 2018 World Bank's income classification.

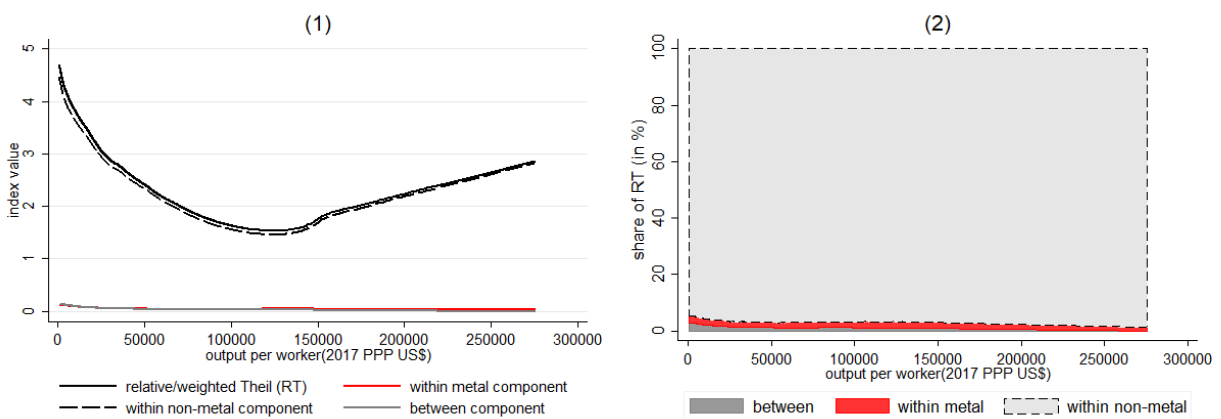
Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010).

Figure B.3. Resource-based decomposition of export diversification curve: RT and its components (eq.3) - other resource classifications

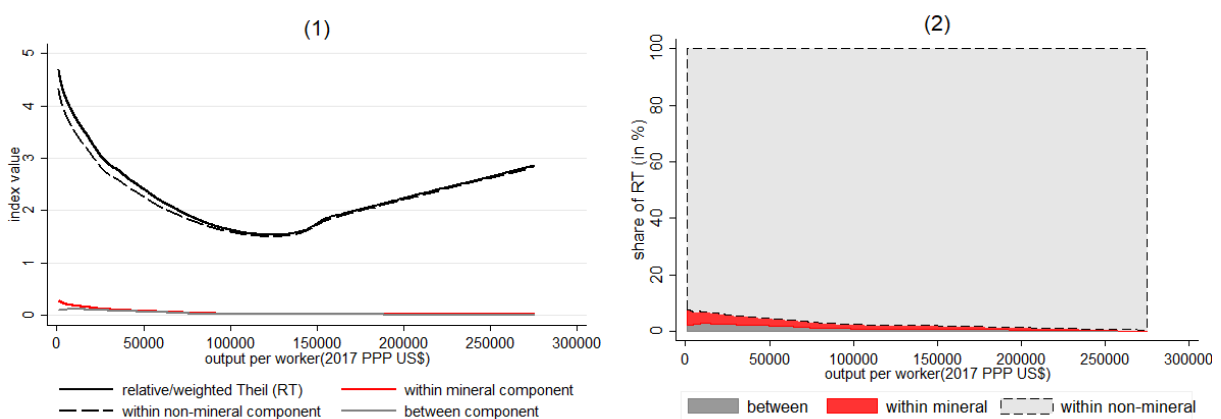
A. products split into forestry (g_f) and non-forestry (g_o)



B. products split into metal (g_m) and non-metal (g_o)



C. products split into mineral (g_m) and non-mineral (g_o)



Note: (1) index value (2) – contribution of RT components to total RT.

Sample: 160 countries (1998-2018), list of countries in Table A.1. (see Appendix A); RT – relative (weighted) Theil measure of export specialisation ($\sim 1/\text{export diversification}$); RT decomposition obtained with taxonomies based on WTO natural resources classification (see Table A.4. in the Appendix A) of FORESTRY, METAL and MINERAL products.

Source: based on product level export data (HS-6 digit) from BACI CEPII (Gaulier & Zignago, 2010), and output per worker from Penn World Table 10.0 (Feenstra et al., 2015).

Figure B.4. Relationship between natural resources' exports and diversification of tech exports

- results obtained with absolute (unweighted) Theil index (estimates of eq. 5 and 6)

Dependent variable: <i>lnTheil_{TECH}_{ct}</i>	Type of NR:		Income group (FUEL):		
	ALL NR	FUEL	HIGH	MIDDLE	LOW
	1	2	3	4	5
<i>NR_{ct}</i>	0.002*** [0.0002]	0.003*** [0.0002]	0.004*** [0.0003]	0.001*** [0.0002]	0.001 [0.0005]
<i>GDP_{ct}</i>	-0.025*** [0.0028]	-0.027*** [0.0027]	-0.080*** [0.0035]	-0.004 [0.0035]	0.031* [0.0163]
<i>PROD_{ct-1}</i>	0.010** [0.0049]	0.002 [0.0049]	x x	x x	x x
<i>N</i>	3520	3520	1173	1909	598
<i>N of countries</i>	160	160	51	83	26
<i>R²</i>	0.118	0.147	0.439	0.149	0.190

Notes: *, **, *** denote significance at the 10%, 5%, and 1% levels respectively; robust standard errors in parentheses; all specifications contain time fixed effects; classification of tech products from UNCTAD (Lall, 2000); division into income groups (for FUEL type of NR) according to Table A.1. in Appendix A. Constant included – not reported.

Source: based on data from BACI CEPII (Gaulier & Zignago, 2010) and PWT 10.0 (Feenstra et al., 2015).

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