Received: 31 May 2023 | Accepted: 3 June 2023

DOI: 10.1111/twec.13456

INVITED REVIEW

The World Economy WILEY

Productivity effects of trade in natural resources—comparison with mechanisms of technological specialisation

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Funding information
Narodowe Centrum Nauki, Grant/Award Number: DEC-2020/37/B/HS4/01302

Abstract

This paper compares two alternative growth paths, assessing the effects on productivity of specialisation in natural resources (NR) and in technologically advanced products. The empirical analysis exploits product-level export data for 109 developing and 51 developed economies over the period 1996–2018. We document two distinct types of specialisation, based on exports either of natural resources or of technological products, and compare their role in labour productivity growth by GMM estimation of a conditional convergence model. In general, natural resource exports weakly slow down growth but we find that the type of resources exported is important: Metals enhance productivity catch-up and can stimulate growth in developing countries. Technological specialisation, especially in products typical of the Fourth Industrial Revolution, reinforces productivity growth but does not affect natural resources–productivity growth relationship.

KEYWORDS

natural resources, productivity growth, specialisation, technology

1 | INTRODUCTION

This paper assesses the role played by different types of export specialisation[1] in labour productivity growth. The key aim is to simultaneously compare two alternative productivity growth forces: 'traditional' mechanisms relating to natural resource endowment and 'modern' specialisation relating to the development of technological capacity. We verify the interdependence between these two growth patterns, assessing if the intensification of technologically advanced exports affects the relationship between productivity growth and natural resource dependence.

The wealth of empirical literature on economic growth tends to treat these two development paths separately. Therefore, their confrontation as two distinct mechanisms affecting productivity growth, proposed in our paper, is crucial. The role played by natural resources, commonly analysed from the perspective of the developing countries (Bond & Malik, 2009; Boos & Holm-Müller, 2013; Collier et al., 2010; Isham et al., 2005; Kim & Lin, 2017), is usually portrayed in a negative way and lacks the examples of high-income resource exporters. The main focus is either on the economic and political distortions produced by resource endowments (the 'resource curse' debate on the failure of many resource-rich countries: see, among many, Gylfason, 2001; Mehlum et al., 2006; Ross, 2015; Sachs & Warner, 2001; Torvik, 2009) or on the risky excessive concentration on a narrow basket of primary products typical for many low-income countries (the export diversification literature: Basile et al., 2018; Cadot et al., 2011; Parteka & Tamberi, 2013a, 2013b). Much attention has recently gone to the potential growth and productivity effects of the Fourth Industrial Revolution (4IR) and rapid innovations in digital technology and AI (Aghion et al., 2018, 2020; Foster-McGregor et al., 2019; Venturini, 2022) but this literature, in turn, focuses on the developed countries (mainly the discrepancy between their official productivity statistics and the expectations related to the potential of 4IR technologies—the 'modern productivity paradox': Brynjolfsson et al., 2019, 2021; Byrne et al., 2016; Crafts, 2018; Gal et al., 2019; Syverson, 2017).

There are numerous facts related to the effects of natural resource abundance that need to be addressed. First of all, some resource-rich countries have managed to avoid the resource curse, such as Norway and Botswana. Nearly 70% of Norway's exports consists of NR (mostly crude oil and gas), while Botswana relies heavily on diamonds (around 90% of exports),[2] but the two countries' per capita income is higher than the world's average ($65,000 and $16,000, respectively, in 2018).[3] At the same time, the group of countries that depend heavily on primary commodity exports includes such poor economies as Nigeria and Angola (NR export dependency of 91% and 90%, respectively, and 2018 per capita income of $5000 and $7000) or Venezuela, where dependence on oil revenue, combined with economic mismanagement and inappropriate government practices, led to one of the most severe crises in the modern history (Bull & Rosales, 2020; John, 2019; Weisbrot & Sachs, 2019). Among the fuel exporters of the Middle East, we might compare Iraq (97% of total exports consisting in fuel and per capita income of $10,500) with Kuwait (87%, $50,500). Second, the effects on growth of export concentration in natural resources and modern technologies can be intertwined. There are countries that do both (for instance,

[1]Throughout the paper, the term 'specialisation' is used to describe a country's export structure in relation to the other countries in the sample, quantified via export shares and revealed comparative advantage in two specific groups of exported products: natural resources and technologically advanced goods.

[2]Export data from CEPII (2021).

[3]Per capita income data from World Development Indicators database.

medium and high tech products make up approximately 15% of Norway's exports), meaning that technological upgrading may be possible by using resource revenues, so the two growth paths need not be mutually exclusive. The question is whether Norway is an isolated case, while most of the developing countries, including resource-rich exporters, are excluded from technology-based growth?

We address this question analysing the process of labour productivity growth in a large sample of 109 developing and 51 developed economies, from 1996 to 2018. We use product-level trade data to compare the degree of specialisation in NR and in high-tech products. Importantly, unlike other studies, in analysing the growth process, we consider the role played by different types of resources (forestry products, fuels, metals, minerals) and different types of technology (comparing broadly defined tech exports to ICT exports and 4IR exports).

The paper is structured as follows. Section 2 reviews the literature, and Section 3 presents the data and some descriptive evidence on the relationship between the two patterns of specialisation. Estimates of the productivity growth model are described in Sections 4 and 5 concludes.

2 | NATURAL RESOURCES AND TECHNOLOGY AS GROWTH DETERMINANTS—LITERATURE REVIEW

The early literature on the relationship between natural resources and economic development argued that resource-rich countries, in general, struggle with economic problems and that, almost without exception, they have stagnated since the 1970s (Sachs & Warner, 2001). The phenomenon has come to be known as the 'resource curse' or 'paradox of plenty'. Now, however, the debate has grown less one-sided. Havranek et al. (2016) show that of 33 resource-curse studies analysed, about 40% find a negative effect, 40% no effect and 20% a positive effect of natural resources on long-term economic growth. Certainly, the results of different papers depend on multiple factors: the databases used, the time period analysed, the number of developing and developed countries in the sample and so on (Badeeb et al., 2017; Van der Ploeg, 2011). Nevertheless, there are several possible explanations why natural resources may have an adverse impact on growth in some countries and beneficial effects in others.

First, the quality of institutions and governing bodies is crucial. Torvik (2009) argues that countries of poor institutional quality are more exposed to the risk of a negative impact from NR abundance. An analysis of 40 developing countries by Kim and Lin (2017) finds that natural resources tend to increase per capita income in countries with less government intervention, better protection of property rights and less corruption. Farhadi et al. (2015) contend that it is the quality of institutions that ultimately determines whether the 'curse' of natural resources can be turned into a blessing. Countries with bad institutions may actually suffer a double resource curse when worsening institutional setting reinforces the negative effect of resources (Mehlum et al., 2006). Policies that enable resource rents to be used well can spur economic growth, especially in developing countries (Ben-Salha et al., 2021). Growth- and welfare-enhancing policies can help counter the adverse effects of specialisation in natural resources (Cavalcanti et al., 2011).

Second, the relationship between primary commodities and productivity growth may differ with the particular type of resources involved. Cavalcanti et al. (2011) report that oil abundance (in the form of oil rents, production and reserves) does not have to be a curse but in fact has beneficial effects on both the level of output and its growth rate. The combination of institutional quality and type of natural resources also proves to be fundamental. According to Torvik (2009), in comparison with NR in general, oil and minerals have a more pronounced negative impact on growth when the quality of institutions is poor. Minerals (diamonds in particular) have the most detrimental effect possible when combined with poor-quality institutions (Boschini et al., 2007; Olsson, 2006).

Another major issue is how resource revenues are spent or saved. Exclusive dependence on these rents obviously carries the risk of price instability. For instance, after the price of oil plunged by almost 50% in 2015,[4] Venezuela was left with the bare minimum of savings during the subsequent economic crisis. It is crucial for countries to have reserves: According to Torvik (2009), the countries that have escaped the resource curse have higher rates of savings out of resource revenues. What is more, the accumulation of physical, human and social capital is inversely correlated with the share of natural resource capital and has a significant effect on the relationship between resources and economic growth (Gylfason & Zoega, 2006).

Another important factor is how resource exploitation combines with other economic activities. A more complex economy, as measured by the Economic Complexity Index[5] (Hausmann et al., 2007, 2014; Hidalgo et al., 2007; Hidalgo & Hausmann, 2009), can diminish the importance of NR rents (Canh et al., 2020) and drive economic development. The quality and profitability of resource extraction industries can also help to avoid the paradox of plenty. Resource abundance can spur economic growth in countries that succeed in developing strong and efficient resource production industries (Gerelmaa & Kotani, 2016).

The exploitation of natural resources relies on exogenously given endowments, but countries can also base their growth on a completely different factor—technology. Technology is a key component of the production function (Solow, 1957) and technical progress is a factor in many growth models (Aghion & Howitt, 1992; Lucas, 1988; Romer, 1986, 1990). Since the 1980s, the impact of the ICT revolution on growth has been intensively analysed (Acemoglu et al., 2014; Inklaar et al., 2005; Jorgenson et al., 2008; Oliner et al., 2007; Timmer & Van Ark, 2005). Recently, a new kind of technological specialisation, related to the advanced 4IR digital technologies, including artificial intelligence (AI), has gained more and more attention (Baruffaldi et al., 2020; Bassetti et al., 2020; Gal et al., 2019; Venturini, 2022) but its role in the growth process is ambiguous.

Aghion et al. (2018), developing the model of economic growth of Zeira (1998), argue that automation (and AI) can increase the economic growth rate either temporarily or permanently, depending on how they are implemented. The effects of AI and automation depend also on institutions and policies. AI can foster growth but it may also inhibit it if combined with improper competition policy (Aghion et al., 2020). There exists a rich literature on the problem of the recent slowdown in productivity growth in many developed countries, partly dashing the high hopes for the use of digital technologies—a phenomenon dubbed the 'modern productivity paradox' (Brynjolfsson et al., 2019). Inklaar et al. (2020) show that the productivity slowdown of the past decade began well before the 2007–2008 crisis and consequently cannot be considered a simple business cycle effect. Bloom et al. (2020) document that, in many technological fields, research productivity has been falling, and Nordhaus (2015) finds that the hypothesis of an acceleration of technology-driven growth fails a variety of tests.

Are resource-rich countries excluded from the technology race? The empirical analysis of Fagerberg and Verspagen (2021) shows the wide gap between the countries that specialise in

[4]Annual price of Brent Crude Oil (BP, 2021).

[5]The Economic Complexity Index (ECI), provided by Harvard Growth Lab, ranks countries by the diversity and complexity of their export baskets.

high-tech production and those, lagging behind in terms of technology and income, that specialise in resource-based products. The results of Foster-McGregor et al. (2019) suggest that only the inner circle of the most developed countries displays a high degree of specialisation in 4IR technologies. However, to the best of our knowledge, none of the studies evaluates simultaneously the role of resources and technology (especially the newest digital solutions) in the growth process; therefore, our analysis initiates a new research avenue on resource-dependent countries. Verifying whether introduction of technologically advanced exports affects the relationship between productivity growth and natural resource dependence seems crucial, especially now when finding solution to climate changes, inevitable resource depletion, domination of renewable energy sources and ongoing technological acceleration is more urgent than ever (BP, 2021; OPEC, 2021). The next section describes the data we use to address all those issues.

3 | DATA AND DESCRIPTIVE EVIDENCE

3.1 | Data set

The analysis covers a total of 160 countries—109 developing and 51 developed economies (listed in Appendix S1: Table A1), from 1996 to 2018.[6] The final choice of countries depends on data availability and representativeness: microstates (with population under 100,000) and countries with limited data on GDP and productivity are excluded. The disaggregated export data (HS96 6-digit)[7] used to compute indices of natural resource (NR) and tech specialisation comes from the BACI CEPII database[8] (CEPII, 2021; Gaulier & Zignago, 2010).

To gauge the importance of NR in countries' exports, we use the taxonomy of mining and forestry products based on the WTO International Trade Statistics classification (Bacchetta et al., 2010).[9] We divide products into four groups: forestry products, fuels, metals and minerals (Appendix S1: Table A4). To measure technological specialisation, we employ three alternative classifications, denoting technologically advanced products broadly defined (TECH) based on Lall (2000), ICT exports (ICT) from UNCTAD (2021) and 4IR-related products including robots, 3D printers and CAD/CAM machines (4IR) from Parteka et al. (2022)[10]—see Appendix S1: Table A5. The 4IR and ICT classifications use 6-digit HS96 product level detail. To match the SITC-based taxonomy of Lall (2000) with the HS96 scheme in BACI data, we use the SITC (Rev.3)—HS96 correspondence tables from UN Trade Statistics.

[6]For comparison, the related studies analyse lower number of countries: Farhadi et al. (2015) analyse 99 countries over the period 1970–2010 (5-year differences); Badeeb et al. (2016) use only time series data over the period 1970–2013; Cavalcanti et al. (2011) revise resource curse hypothesis for 53 countries over 27 years (1980–2006); Canh et al. (2020) investigate sample of 90 economies over the period 2002–2017; Kim and Lin (2017) use panel data covering 40 countries and 23 years (1990–2012).

[7]The number of HS96 product codes in BACI CEPII diminishes over time, so to hold it constant we delete the product codes that 'disappear' between 1996 and 2018 and those that are no longer present in subsequent revisions. The final product-level export database used here contains 4895 product codes.

[8]The BACI database has yearly product-level data on bilateral trade flows; only strictly positive exports are recorded and trade flows below 1000 USD do not appear. We aggregate bilateral trade data to the reporter-world dimension.

[9]The WTO classification also comprises fish, raw materials and other semi-manufactures as product groups.

[10]The taxonomy builds upon Domini et al. (2021) and Foster-McGregor et al. (2019).

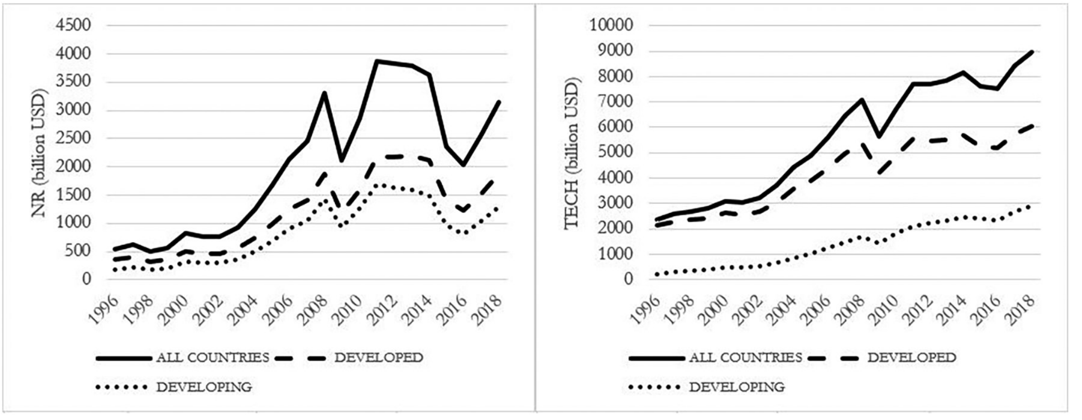

FIGURE 1 Value of natural resources (NR) exports versus technological exports (sample: 160 countries, 1996–2018). *Note*: Countries split into developing and developed in Appendix S1: Table A1. The scales in two above graphs differ: 0–4500 billion USD for NR exports and 0–10,000 USD for TECH exports. Values of NR and TECH exports expressed in nominal terms. *Source*: Author's elaboration based on 6-digit HS export data from BACI CEPII (Gaulier & Zignago, 2010), NR product taxonomy from Bacchetta et al. (2010) and TECH export taxonomy from Lall (2000).

3.2 | Trends in resources' trade and technological trade

Figure 1 illustrates the growth in the value of NR and TECH exports between 1996 and 2018. Developed countries contribute the greater part of TECH exports, whose total value tripled. The value of developing countries' TECH exports also tripled over these years, but their share of total exports is smaller than in the developed countries. For almost 15 years (1996–2010), the value of NR exports was practically equal in developed and developing countries. Afterwards, it soared in the developed countries while declining steadily in the developing countries. As of 2018, values of natural resources exports were on an uptrend again.

Figure 2 shows the relative importance of specific NR types in overall NR exports of all the countries in our sample. Unsurprisingly, fuels account for some 70% of all NR exports, and this proportion has basically increased over the years (from 63% in 1996 to a peak of 78% in 2013 before slipping to 73% in 2018).[11] The export shares of minerals and metals have remained more or less at their original levels, suggesting the persistence of relatively constant demand in various production processes (e.g. lithium, cobalt and nickel needed to make batteries, or iron for steel production). Given the non-renewable character of these resources, careful and deliberate action in this field is indispensable. The share of forestry in total NR exports has shrunk (from 10% in 1996 to 5% in 2018).

Division of the sample into developed and developing countries shows that the dominance of fuel products is more prominent in low- and middle-income countries (Appendix S1: Figure A1). The average share of oil, gas and coal in total resource exports amounts to 80% in developing economies and 65% in high-income countries. Natural resource exports of developed countries are also more diversified, including around 15% of mineral and metal

[11]Countries that specialise in the fuels category generally focus on crude and refined petroleum and distillation products (e.g. Qatar, Iraq, Iran, Venezuela and Saudi Arabia). Of course there are also some countries that in addition to petroleum also export natural gas (Russia, Norway) or coal (Indonesia).

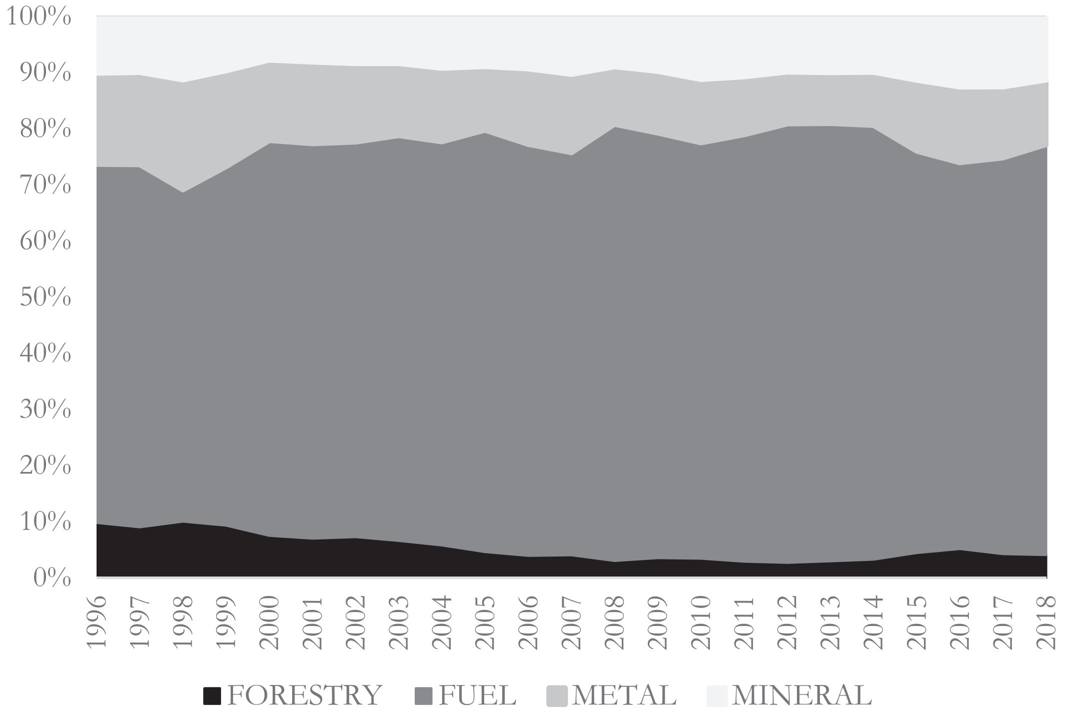

FIGURE 2 The importance of types of natural resources (share in total natural resources exports), sample: 160 countries, 1996–2018. *Source*: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010) and natural resources products taxonomy from Bacchetta et al. (2010).

exports each and around 5% of forestry products (Appendix S1: Figure A2). At the same time, in developing countries, natural resources other than fuels account for only 20% of total exports.

Figures 3 and 4 display the relative importance of NR and technologically advanced goods in countries' exports (in 2018 and in 1996, accordingly). Independently of the type of tech exports (broadly defined TECH; narrow ICT or 4IR), the relationship between NR and technology shares in 2018 (Figure 3, left plots) is negative (see also Appendix S1: Table A8). This also holds for the Balassa index of revealed comparative advantage (RCA) computed for product groups (Figure 3, right plots). The RCA in natural resources is calculated here as the ratio of the share of natural resources (product lines classified as NR in WTO's natural resources classification—Bacchetta et al., 2010) in the country's total exports to the same ratio at the world level. Similarly, RCA in technology is calculated as the ratio of the share of technological products (broadly defined TECH exports and by fields: ICT or 4IR—see Appendix S1: Table A5) in the country's total exports to the same ratio at the world level. RCA in technology corresponds to RTA (Revelled Technological Advantage—Foster-McGregor et al., 2019). The confrontation of Figures 3 and 4 clearly shows the evolution of the relationship between natural resource abundance and technologically advanced exports (in particular visible in the case of ICT and 4IR tech products). The relationship between 4IR exports and NR used to be flat in 1996, moving to negative in 2018.

The division of the sample into developed and developing countries (Appendix S1: Tables A3–A6) gives more insight into the relationship between natural resources and technological exports.

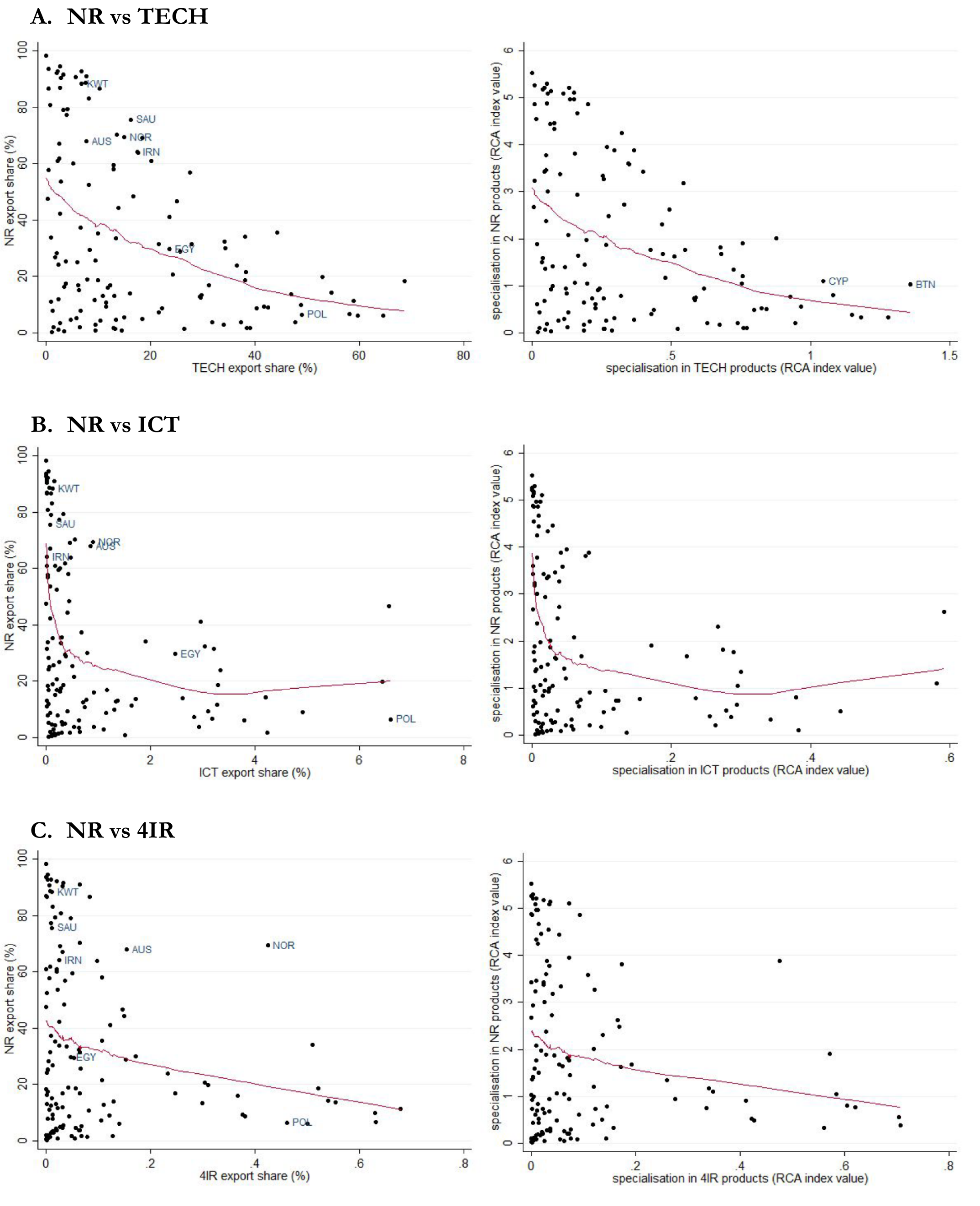

FIGURE 3 Relationship between specialisation in natural resources and technological specialisation—2018 (left plots: export share; right plots: RCA index). *Note*: Sample of 160 countries; year 2018. The scales in the two graphs differ and have various units. For the list of countries, see Appendix S1: Table A1 Product classifications in Appendix S1: Tables A4 and A5. Outliers (e.g. points located outside the upper adjacent line for every variable used here) were removed. All charts were plotted as two-way scatter plots (black points) with the lowess approximation of the relationship between the variables, span 0.8 (red line). RCA—revealed comparative advantage index. *Source*: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010). [Colour figure can be viewed at wileyonlinelibrary.com]

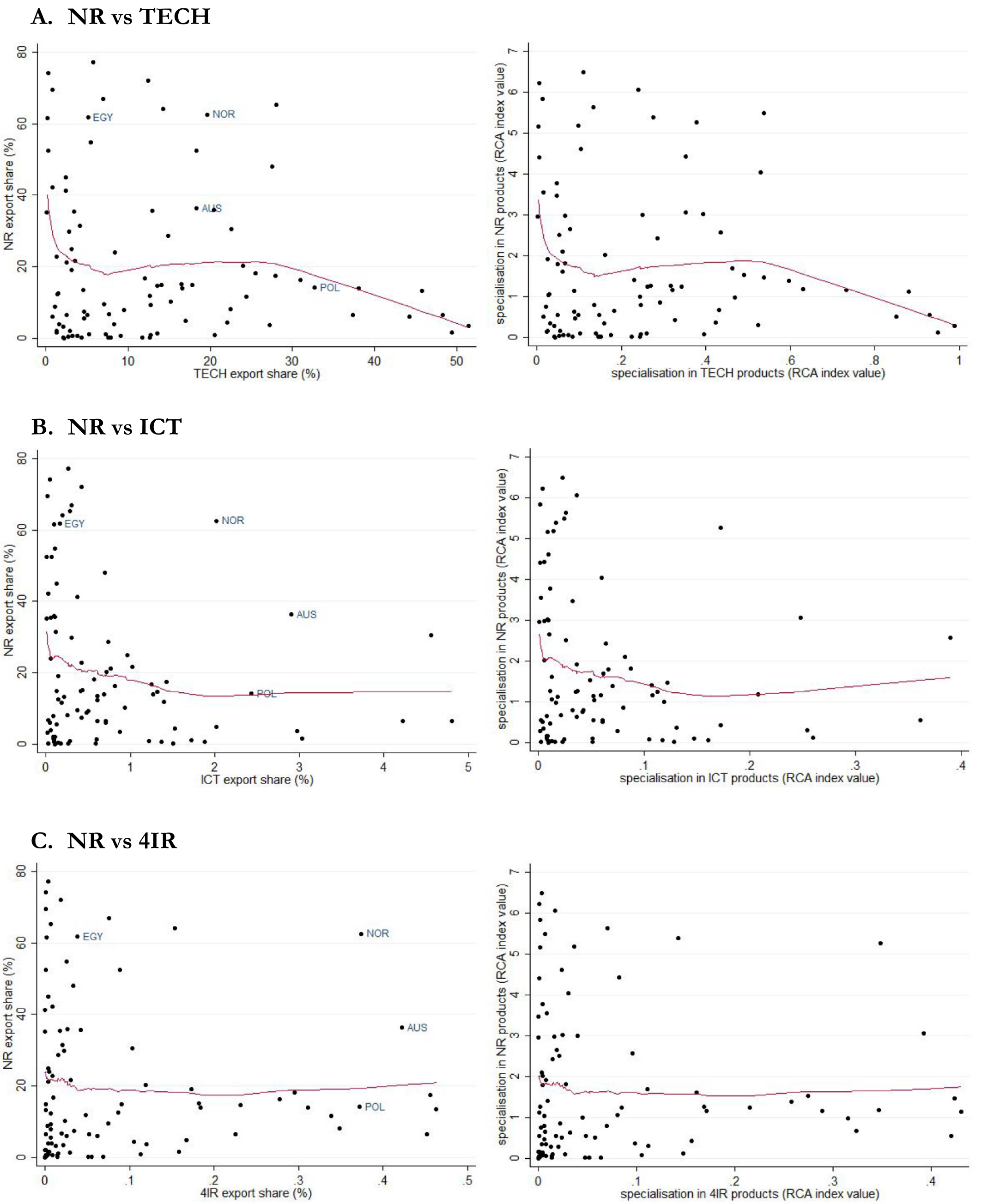

FIGURE 4 Relationship between specialisation in natural resources and technological specialisation—1996 (left plots: export share; right plots: revealed comparative advantage index). *Note*: Sample of 160 countries; year 1996. The scales in the two graphs differ and have various units. For the list of countries, see Appendix S1: Table A1 Product classifications in Appendix S1: Tables A4 and A5. Outliers (e.g. points located outside the upper adjacent line for every variable used here) were removed. All charts were plotted as two-way scatter plots (black points) with lowess approximation of relationship between variables (red line). *Source*: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010). [Colour figure can be viewed at wileyonlinelibrary.com]

The negative relationship is more prominent in the sample of developed countries (Appendix S1: Table A8) and becomes stronger over the course of years. In the group of high-income economies, we can find both countries combining high share of technological exports with natural resources (e.g. Finland, USA) and countries that abandon technological specialisation in favour of expanding NR sector (e.g. Australia). Finally, some high-income NR exporters (such as Saudi Arabia, Norway and Kuwait) continuously supplement their NR exports with middle-tech products within the broad TECH taxonomy (around 20% of total exports). The changes are not as rapid in the case of low- and middle-income economies, many of them still concentrate exports in NR. However, in the course of 23 years, countries like Iran or Egypt were able to mix NR specialisation with growing TECH exports.

Tables 1 and 2 report the top countries specialising (by Balassa's definition) in technological exports and in NR (by type), in 1996 and in 2018. The position of technological forerunners (countries whose comparative advantage in tech products was already substantial in 1996) has remained more or less unaltered through the years. Japan, South Korea and various European countries still dominate, particularly in 4IR manufacturing. Specialisation in ICT is typical of some Asian countries (Singapore, Malaysia, Philippines, China, Thailand).

When it comes to specialisation in NR, we find many developing countries, both in the past and more recently. However, there have been changes in the RCA indices. Comparing bottom lines of Tables 1 and 2, the increase in the number of fuel exporters (from 50 in 1996 to 1958 in 2018) might be the reason for the generally lower values of RCA (FUEL) at the end of the period. Year by year, new oil exporters emerge, while the leading petroleum exporters slowly but steadily shift away from NR and seek alternatives. For forestry products, the situation is quite different. The number of countries specialising in lumber exports holds unchanged at 46, but the average magnitude of RCA (FORESTRY) doubles. This may be explained by restrictions on lumbering of exotic trees and their reduced availability.

The data confirm the coexistence of different specialisation paths and income-related patterns of specialisation. Low- and middle-income countries specialise in NR exports—in line with the concept of being geographically favoured[12] (Acemoglu et al., 2002; Sachs, 2000) matched with the debate on 'prisoners of geography' (Hausmann, 2001) while high-income countries—in technology. However, specialisation patterns can change (see Figure 5). Egypt, Georgia, Iran, Latvia, Oman and Saudi Arabia show signs of diversifying away from natural resources towards technological production. Petroleum-dependent countries (Egypt, Saudi Arabia, Oman, Iran) increased their technology export shares. The changes did not come overnight and are not always spectacular, but they are nevertheless significant. Latvia, for instance, was once highly specialised in NR exports (wood, crude oil, various metals) but managed to diversify substantially. Latvia's RCA in NR fell from 5.5 in 1996 to around 1 in 2018, as the country turned to electrical machinery and vehicle manufacturing. As a result, we observe a scissors-pattern curve, with the tech export share surpassing NR. The same pattern characterises Georgia, where exports of fuels (mostly petroleum) and metals fell while tech exports gained.

[12]Favourable geography refers to the abundance of natural resources that is dependent only on the nature factor; states with proven resource deposits are 'privileged' with respect in comparison to those that are obliged to develop other forms of specialisation.

TABLE 1 Technological and natural resources specialisation (revealed comparative advantage [RCA] index values)—top 10 countries with RCA >1 (1996).

	Technological specialisation						Specialisation in natural resources									
	4IR		**ICT**		**TECH**		**FUEL**		**METAL**		**MINERAL**		**FORESTRY**		**TOTAL NR**	
	CHE	2.80	SGP	5.36	JPN	1.61	KWT	12.70	ZMB	43.04	GIN	56.81	GNQ	32.33	GAB	8.24
	JPN	2.68	MYS	4.34	SGP	1.49	YEM	12.58	KAZ	18.96	SUR	49.01	CMR	18.75	KWT	8.16
	ITA	2.18	MLT	4.10	MLT	1.29	NGA	12.42	BHR	17.18	MRT	35.09	MMR	17.73	YEM	8.09
	DEU	1.55	PHL	3.77	DEU	1.28	DZA	12.16	CHL	14.37	JAM	34.48	BTN	17.54	NGA	7.99
	USA	1.39	IRL	2.30	USA	1.23	AGO	12.11	PER	11.98	MNG	28.77	LAO	16.64	DZA	7.83
	AUT	1.39	THA	2.08	MYS	1.23	SAU	11.91	KGZ	11.28	GEO	17.12	GAB	13.52	AGO	7.75
	SWE	1.09	JPN	1.97	KOR	1.19	OMN	11.83	TJK	10.92	BOL	14.86	LVA	12.80	SAU	7.66
	CZE	1.07	KOR	1.85	MEX	1.18	QAT	11.71	RUS	8.63	GUY	14.82	CHL	9.00	OMN	7.63
			HKG	1.79	SWE	1.16	IRQ	11.32	COD	8.28	CHL	13.78	BOL	7.99	GNQ	7.56
			USA	1.43	CHE	1.14	IRN	11.30	BOL	6.69	PER	11.77	GHA	7.88	QAT	7.52
Number of countries with RCA >1	8		15		15		50		41		65		46		78	

Source: Based on export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010) and product taxonomies (Appendix S1: Tables A4 and A5). Analysed sample: 160 countries (Appendix S1: Table A1).

TABLE 2 Technological and natural resources specialisation (revealed comparative advantage [RCA] index values)—top 10 countries with RCA >1 (2018).

	Technological specialisation						Specialisation in natural resources									
	4IR		**ICT**		**TECH**		**FUEL**		**METAL**		**MINERAL**		**FORESTRY**		**TOTAL NR**	
	JPN	4.30	PHL	5.04	JPN	1.55	IRQ	7.52	ZMB	37.06	JAM	31.70	CAF	75.35	IRQ	5.51
	KOR	2.89	MYS	3.31	PHL	1.51	DZA	7.23	COD	33.52	GIN	22.72	URY	33.53	DZA	5.30
	ITA	2.16	VNM	3.18	KOR	1.44	TKM	7.04	ISL	20.44	SLE	21.01	CMR	25.28	COD	5.25
	DEU	1.97	CHN	2.63	MEX	1.42	AZE	6.97	MOZ	15.74	MNG	18.88	SLE	20.38	TKM	5.20
	AUT	1.92	KOR	2.58	DEU	1.39	BRN	6.93	CHL	11.39	TJK	18.69	GMB	19.66	GNQ	5.20
	SGP	1.85	HKG	2.52	HUN	1.39	AGO	6.88	BHR	9.87	PER	18.62	LVA	15.06	AZE	5.16
	CHE	1.58	SGP	2.42	BTN	1.36	NGA	6.87	MDG	8.82	MRT	16.66	FJI	14.49	NGA	5.14
	CZE	1.50	MAC	2.16	SVK	1.34	KWT	6.73	COG	8.53	CHL	14.57	NZL	13.95	BRN	5.10
	SWE	1.20	THA	1.59	CZE	1.34	GNQ	6.67	TJK	8.49	BOL	13.73	FIN	10.25	GAB	5.08
	USA	1.15	MLT	1.57	MKD	1.28	TCD	6.62	BGR	5.51	AUS	13.64	LAO	10.18	AGO	5.08
Number of countries with RCA >1	16		14		27		58		48		64		46		79	

Source: Based on export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010) and product taxonomies (Appendix S1: Tables A4 and A5). Analysed sample: 160 countries (Appendix S1: Table A1).

FIGURE 5 Share of natural resources and TECH products in total exports (%) over time—selected countries. *Source*: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010). [Colour figure can be viewed at wileyonlinelibrary.com]

4 | THE ROLE OF NR AND TECH EXPORTS IN PRODUCTIVITY GROWTH—EMPIRICAL ANALYSIS

4.1 | The models

Given the two distinct types of specialisation—either in natural resources or in technological exports—we now compare their roles in productivity growth. We are particularly interested in countries' relative positions and accordingly apply the empirical model of conditional convergence (based on the catching-up theory[13]). The first step is to assess the role of natural resources in the productivity growth process by estimating a baseline model:

$$g(y)_{it} = \alpha + \beta_1 y_{i,t-1} + \beta_2 NR_{i,t-1} + \delta_t + \varepsilon_{it} \tag{1a}$$

where i denotes country ($i=1, \ldots, 160$), t time ($t=1996, \ldots, 2018$) and $g(y)$ the annual rate of growth in labour productivity (in %). *NR* is the share of natural resources in total exports. We then extend model (1a), adding a set of control variables (X), described below, that could potentially affect productivity growth–*NR* relationship:

$$g(y)_{it} = \alpha + \beta_1 y_{i,t-1} + \beta_2 NR_{i,t-1} + \beta_3 X_{i,t-1} + \delta_t + \varepsilon_{it} \tag{1b}$$

Specifically, the extension of model (1a) adds a particular control variable: the share of technologically advanced products in total exports (T), used to check whether technological specialisation affects the relationship between *NR* and productivity growth process:

$$g(y)_{it} = \alpha + \beta_1 y_{i,t-1} + \beta_2 NR_{i,t-1} + \beta_3 T_{i,t-1} + \delta_t + \varepsilon_{it} \tag{2}$$

In all the models, labour productivity[14] (y) is measured as output per worker (real GDP in constant 2017 USD divided by the number of workers from PWT 10.0; Feenstra et al., 2015) and is expressed in thousands USD.[15] Both *NR* and T are computed using 6-digit HS96 product-level trade data from BACI CEPII (Gaulier & Zignago, 2010), matched with product-level taxonomies (*NR* in Table A3 and T in Table A4). We consider different types of *NR* and tech products: *NR*={*FORESTRY*, *FUEL*, *METAL*, *MINERAL*} and T={*TECH*, *ICT*, *4IR*} which measures technological exports broadly defined (*TECH*) or ICT and 4IR products. The effects of activities in these fields are not immediate, so *NR* and T are lagged. The set of control variables X (investment ratio, *INV*,[16] i.e. the share of gross fixed capital formation in GDP, the human capital index, *HCI*,[17] and

[13]Convergence theory posits the catch-up effect, whereby poor countries tend to grow faster than rich (Barro & Sala-i-Martin, 1992; Solow, 1957).

[14]The justification for the choice of labour productivity instead of TFP is threefold: (1) we focus on how NR dependence affects changes in productivity of workforce (and not other factors of production); (2) the data available for TFP are much more limited (e.g. in PWT TFP is available only for 110 countries while we analyse 160 economies); (3) TFP data are missing for many developing countries (so its use could distort the analysis of the issues crucial for the developing world, such as the dependence on natural resources).

[15]Dependent variable (labour productivity) is expressed in thousands 2017 USD to avoid the scale problems.

[16]Following the World Bank's definition of gross fixed capital formation, this consists in land improvements, plant, machinery and equipment purchases, construction of roads, railways, schools, offices, hospitals, private residential dwellings and commercial and industrial buildings (World Bank, 2022). Straub (2008) argues that investment in public infrastructure can enhance productivity; good infrastructure allows time and capital to be invested in more efficient activities, improving productivity.

[17]HCI (range 0–1) proxies for the productivity of future generations of workers and assesses the amount of capital lost due to poor education and health. It is measured by reference to the quality and quantity of education, state of health and children's survival. The knowledge and skills of the population are crucial to generating new technologies, hence to productivity gains (Kim & Loayza, 2019).

R&D expenditures as percentage of GDP, *RD*[18]) comes from the World Bank's World Development Indicators (WDI) database. These too are lagged.

As to primary commodities, there may be problems of simultaneity: the relationship between *NR* and productivity growth is potentially open to reverse causality and endogeneity (Farhadi et al., 2015), so we use a two-step GMM estimator with a 1-year lag of the potentially endogenous variable as an instrument. The same applies to the technological variables. What's more, NR exports tend to be highly persistent[19] (Appendix S1: Table A6), so in models (1a), (1b) and (2), we do not take into consideration country fixed effects to avoid wiping out all cross-country variability. This approach is also in compliance with the thought of Barro (2015) on country fixed effects in panel regressions. Nevertheless, we include time fixed effects to account for common business cycle effects and volatility in prices of resources.

4.2 | The results

Table 3 reports the basic estimation results of model 1. Separate columns refer to estimates obtained with NR export share measured as a total (column 1) or by type (columns 2–5). In keeping with the convergence theory, the correlation between productivity growth and past productivity level is negative and significant. Natural resources tend to inhibit, weakly, the process of catching up. Ceteris paribus, a 1-percentage-point (p.p.) increase in the NR export share is related to a 0.007-p.p. decrease in the productivity growth rate. As the NR share is relatively fixed, this implies weak but constant negative pressure on productivity growth. Importantly, the subdivision of *NR* into types reveals that not all natural resource endowments act in the same way. While the correlation between fuel exports and productivity growth is negative and significant (column 2), metal exports instead are a positive factor in labour productivity growth (column 5). In terms of magnitude, all these effects are weak. This result holds also after adding control variables (*INV*, *RD*, *HCI*)—Table 4.

Turning to the importance of technological specialisation (model 2), all three types of tech exports are positively related to productivity growth, but not always in a statistically significant way. Sticking to the statistically significant results of the model estimated with a general measure of resource abundance, TOTAL NR (column 1 in Tables 6 and 7), other things being equal, a 1--p.p. increase in the export share of ICT, and TECH products is related to an increment of 0.02 and 0.01 point in the productivity growth rate, respectively. This effect is weak, but the magnitude and the significance of the *T* coefficients vary with the type of NR considered as explanatory variable in the productivity growth equation. More importantly, the inclusion of *T* variables does not alter the benchmark result (reported in Table 3), namely the adverse but weak relationship between fuel exports and productivity growth and the positive relationship with metal exports.

[18]*RD* gauges spending on basic and applied research and experimental development. This expenditure is divided into four main sectors: business enterprise, government, higher education and private non-profit. Innovation spending has an enormous impact on productivity and leads to the development of more sophisticated activities, products and processes (Kim & Loayza, 2019).

[19]Countries with proven reserves of natural resources usually maintain a constant level of extraction, which tends to result in a relatively constant share of NR in total export value. Situations that can alter such conjunctures are rare and may involve new resource discoveries (increasing the share of NR in total exports), resource depletion (decreasing the NR share) or efforts at export diversification.

TABLE 3 The relationship between NR exports and productivity growth (estimates of Equation 1a).

Dependent variable: $g(y)_{it}$	1 TOTAL NR	2 FUEL	3 FORESTRY	4 MINERAL	5 METAL
$y_{i,t-1}$	−0.021***	−0.020***	−0.020***	−0.022***	−0.022***
	[0.0022]	[0.0023]	[0.0022]	[0.0022]	[0.0022]
$NR_{i,t-1}$	−0.007*	−0.011**	0.046	−0.011	0.022***
	[0.0038]	[0.0045]	[0.0287]	[0.0096]	[0.0061]
No.of obs.	3358	3264	3257	3333	3240
No. of countries	160	160	160	160	160
K–P rk Wald *F*	76986.240	48571.050	1008.039	3568.880	5792.576
K–P rk LM	1219.286	730.347	86.066	178.083	101.453
K–P rk LM (*p*-value)	.000	.000	.000	.000	.000

Note: Robust standard errors in parentheses; all specifications contain time fixed effects; K–P refers to Kleibergen–Paap test statistics. Instrumented variable: *NR*. Constant included—not reported.

*, **, ***Significance at the 1%, 5% and 10% levels respectively.

Source: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010).

TABLE 4 The relationship between NR exports and productivity growth (estimates of Equation 1b, with control variables).

Dependent variable: $g(y)_{it}$	1 TOTAL NR	2 FUEL	3 FORESTRY	4 MINERAL	5 METAL
$y_{i,t-1}$	−0.024***	−0.023***	−0.024***	−0.026***	−0.027***
	[0.0029]	[0.0031]	[0.0028]	[0.0027]	[0.0027]
$NR_{i,t-1}$	−0.005	−0.008*	0.049*	−0.011	0.022***
	[0.0042]	[0.0049]	[0.0287]	[0.0096]	[0.0061]
INV	0.039***	0.040***	0.042***	0.035***	0.047***
	[0.0119]	[0.0126]	[0.0121]	[0.0117]	[0.0118]
RD	0.237**	0.194*	0.306***	0.298***	0.333***
	[0.0977]	[0.0993]	[0.0860]	[0.0859]	[0.0845]
HCI	0.632	0.605	0.814	0.687	0.787
	[0.7370]	[0.7380]	[0.7703]	[0.7480]	[0.7440]
No. of obs.	3358	3264	3257	3333	3240
No. of countries	160	160	160	160	160
K–P rk Wald *F*	63238.359	40326.759	1012.407	3504.070	5781.898
K–P rk LM	1172.695	695.607	86.409	177.908	101.204
K–P rk LM (*p*-value)	.000	.000	.000	.000	.000

Note: As under Table 3.

Source: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010).

TABLE 5 The relationship between NR exports, 4IR exports and productivity growth (estimates of Equation 2).

	1	2	3	4	5
Dependent variable: $g(y)_{it}$	**TOTAL NR**	**FUEL**	**FORESTRY**	**MINERAL**	**METAL**
$y_{i,t-1}$	−0.021***	−0.020***	−0.023***	−0.024***	−0.024***
	[0.0028]	[0.0030]	[0.0027]	[0.0026]	[0.0026]
$NR_{i,t-1}$	−0.010***	−0.014***	0.021	−0.009	0.022***
	[0.0035]	[0.0042]	[0.0262]	[0.0100]	[0.0060]
$T_{i,t-1}$	0.036	−0.021	0.374**	0.331*	0.422**
	[0.1959]	[0.1954]	[0.1693]	[0.1704]	[0.1686]
No. of obs.	3239	3184	3159	3227	3173
No. of countries	160	160	160	160	160
K–P rk Wald F	306.191	307.495	367.245	368.833	368.811
K–P rk LM	163.662	164.382	164.283	164.736	164.428
K–P rk LM (p-value)	.000	.000	.000	.000	.000

Note: Robust standard errors in parentheses; all specifications contain time fixed effects; K–P refers to Kleibergen–Paap test statistics. Instrumented variables: *NR*, *T*. Constant included—not reported.

*, **, ***Significance at the 1%, 5% and 10% levels, respectively.

Source: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010).

4.3 | Extensions and robustness checks

As a first robustness check, we run a regression with alternative measures of natural resource endowment (Appendix S2: Tables B1 and B2), replacing the NR export share with the share of NR rents in GDP. This variable comes from the World Development Indicators database and can be described as the difference between the value (at world prices) of the natural resources extracted and their total production cost. The types of commodities (coal, forestry products, oil, gas and minerals) and their total value are largely in line with the NR taxonomy presented in Appendix S1: Table A4. The only discrepancy is the lack of metal rents and the division of fuels into three separate groups (coal, gas and oil). The results show that total NR rents correlate negatively—but not in a significant way with the catching up. There is a positive and statistically significant correlation between coal, gas and mineral rents and productivity growth. Other things being equal, a 1-p.p. increase in the GDP share of coal/gas/mineral rents results in an increase of 0.573/0.067/0.12 points, respectively, in the productivity growth rate. The addition of control variables (Appendix S2: Table B2) confirms the previous results.

To adjust for the possible heterogeneity between developing and developed countries, we split the sample of 160 countries into two groups: 51 developed and 109 developing countries (see Appendix S1: Table A1). The estimation results are reported in Appendix S2: Tables B3–B12. In the developed countries (with and without control variables), all types of NR demonstrate a statistically significant relationship with productivity growth, but it is positive only for forestry products. Ceteris paribus, a 1-p.p. increase in the share of forestry exports corresponds to a 0.14--p.p. increase in the productivity growth rate. For the developed countries, the addition of the technological export shares did not change neither the magnitude nor the significance of the NR-productivity correlation.

TABLE 6 The relationship between NR exports, ICT exports and productivity growth (estimates of Equation 2).

	1	2	3	4	5
Dependent variable: $g(y)_{it}$	**TOTAL NR**	**FUEL**	**FORESTRY**	**MINERAL**	**METAL**
$y_{i,t-1}$	−0.022***	−0.021***	−0.021***	−0.023***	−0.023***
	[0.0023]	[0.0024]	[0.0022]	[0.0022]	[0.0022]
$NR_{i,t-1}$	−0.005	−0.010**	0.050*	−0.008	0.024***
	[0.0040]	[0.0047]	[0.0288]	[0.0098]	[0.0062]
$T_{i,t-1}$	0.018**	0.015**	0.027***	0.023***	0.029***
	[0.0072]	[0.0069]	[0.0068]	[0.0070]	[0.0068]
No. of obs.	3358	3264	3257	3333	3240
No. of countries	160	160	160	160	160
K–P rk Wald F	9267.795	22237.431	502.887	1836.138	7407.393
K–P rk LM	415.314	858.664	86.677	190.025	291.670
K–P rk LM (p-value)	.000	.000	.000	.000	.000

Note: As under Table 5.

Source: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010).

TABLE 7 The relationship between NR exports, TECH exports and productivity growth (estimates of Equation 2).

	1	2	3	4	5
Dependent variable: $g(y)_{it}$	**TOTAL NR**	**FUEL**	**FORESTRY**	**MINERAL**	**METAL**
$y_{i,t-1}$	−0.024***	−0.022***	−0.023***	−0.025***	−0.025***
	[0.0031]	[0.0032]	[0.0026]	[0.0026]	[0.0026]
$NR_{i,t-1}$	−0.003	−0.008	0.052*	−0.006	0.027***
	[0.0049]	[0.0053]	[0.0289]	[0.0101]	[0.0065]
$T_{i,t-1}$	0.011*	0.008	0.014***	0.013***	0.016***
	[0.0059]	[0.0053]	[0.0044]	[0.0047]	[0.0045]
No. of obs.	3358	3264	3257	3333	3240
No. of countries	160	160	160	160	160
K–P rk Wald F	10541.141	13605.858	507.626	2590.774	15868.519
K–P rk LM	1117.358	1206.426	85.712	298.207	1082.118
K–P rk LM (p-value)	.000	.000	.000	.000	.000

Note: Robust standard errors in parentheses; all specifications contain time fixed effects; K–P refers to Kleibergen–Paap test statistics. Instrumented variables: *NR*, *T*. Constant included—not reported.

*, **, ***Significance at the 1%, 5% and 10% levels, respectively.

Source: Based on 6-digit HS export data from BACI CEPII (CEPII, 2021; Gaulier & Zignago, 2010).

Estimations for the group of developing countries (results in Appendix S2: Tables B5 and B6 and B10–B12) indicate that the only type of NR exports that can enhance productivity growth in a statistically significant way is metals. Other things being equal, a 1-p.p. increase in the share of metal exports raises the productivity growth rate by 0.029 points. And while the effect is positive and statistically significant, it is still very small. Turning to technological factors, ICT and TECH exports correlate positively with productivity growth in the developing countries.

Additionally, given that some resource abundant countries report very high shares of NR in exports (nearly 100%), we have also checked the robustness of the results once outliers (defined as observations below 1st and above 99th percentiles of the dependent variable) are excluded. The results are reported in Appendix S2: Tables B13–B16 and they confirm the main regression outcomes, both in terms of statistical significance and the magnitude of the relationship.

5 | CONCLUSIONS

The conventional wisdom, with much of the 'resource curse' literature, holds that the growth of developing countries is hampered by overspecialisation in natural resources, while in the developed world technological advance drives growth. But today's world is considerably more complicated than this simple schema would suggest. Some low-income countries produce advanced technologies, some countries totally escape the resource curse and increase the technological content of their exports, and some economies, finally, have comparative advantages in both commodity-based and technology-intensive goods. In short, the relationship between natural resources, growth and technological progress is not so obvious or straightforward.

We analyse this issue for a large sample of 160 countries (109 developing and 51 developed economies) from 1996 to 2018. Detailed product level trade data allow us to distinguish various types of resources and of technologies embodied in exports. Specifically, our analysis considers such types of natural resources as forestry products, fuels, metals or minerals, while tech exports generically defined are distinguished from newer generation technologies embodying ICT and 4IR solutions.

Descriptive analysis of NR and technologically advanced exports, conducted in Section 3.2, reveals that specialisation patterns can change over time. Developing petroleum-dependent countries like Egypt, Georgia or Iran increased their technology export shares over the course of 23 years we analysed (1996–2018). While some high-income economies keep their shares of natural resource and middle-tech products constant (Saudi Arabia, Norway and Kuwait), others combine high share of technological exports with growing contribution of natural resources (e.g. Finland, USA) or even abandon technological increase in favour of expanding NR sector (e.g. Australia).

The GMM estimates of a conditional productivity convergence model confirm that greater total NR exports slow productivity growth and impede, weakly, the catch-up process. However, we find that the type of resources exported matters: In particular, metals can enhance it (this result applies to the whole sample and is also sustained for the subsample of developing countries). For technological exports too, type matters but the magnitude of the estimated effects is small, and in any case, it does not affect the relationship between natural resources and productivity growth.

As far as the policy implications are concerned, the most pressing issues that natural resource countries deal with are related to climate changes, inevitable resource depletion, domination of renewable energy sources and ongoing technological acceleration (BP, 2021; OPEC, 2021). Therefore, governments of resource-dependent economies should reinforce more sustainable use of non-renewable natural resources, creating a long-term, holistic plan of economic diversification (like in the case of Saudi Arabia—Alam & Haque, 2017). Our study proves that export focus on natural resources can slow down productivity growth, so diversifying away from high NR dependence towards more balanced trade structures is desirable. The examples of countries, at various stages of development, present in our analysis prove that it can be done. Such changes do not come overnight and are not always spectacular, but even small steps, for example, using by-products of crude oil distillation (polymers or fertilisers), that can be used in middle or high tech economic activities, might be a good starting point.

Knowing that oil exporting countries are the ones who were able to initiate the diversification process towards the technological production, possible extension for our work could include the division of fuel resources into subsequent three groups—coal, natural gas and oil. This will help in verifying whether all fossil fuels act in the same way in the productivity growth process. Further additions to the empirical model could consist of interaction terms between the share of NR and technological exports and the incorporation of GVC and FDI as control variables.

ACKNOWLEDGEMENT

We gratefully acknowledge valuable comments received from the participants of XXIII Conference on International Economics (2022), two anonymous Referees and the Editor.

FUNDING INFORMATION

The research has been conducted within the project financed by the National Science Centre, Poland (2020/37/B/HS4/01302).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Bridge of Knowledge at https://doi.org/10.34808/2cf4-9e23 (Zarach & Parteka, 2023).

DECLARATION

All errors are the authors' responsibility.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Zarach, Z. H., & Parteka, A. (2023). Productivity effects of trade in natural resources—comparison with mechanisms of technological specialisation. *The World Economy*, *46*, 2684–2706. https://doi.org/10.1111/twec.13456