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Research Paper

Do natural resources impact economic growth: An investigation of P5 + 1 countries under sustainable management

Sanjeet Singh [a], Gagan Deep Sharma [b], Magdalena Radulescu [c,d,*], Daniel Balsalobre-Lorente [e,f], Pooja Bansal [a]

[a] University Centre for Research and Development, Chandigarh University, Gharuan, Mohali, Punjab, India
[b] University School of Management Studies, Guru Gobind Singh Indraprastha University, Dwarka, Delhi, India
[c] Department of Finance, Accounting and Economics, University of Pitesti, Pitesti 110040, Romania
[d] Institute for Doctoral and Post-Doctoral Studies, University "Lucian Blaga" Sibiu, Sibiu 550024, Romania
[e] Department of Applied Economics I, University of Castilla-La Mancha, Spain
[f] Department of Management, Faculty of Economics and Management, Czech University of Life Sciences Prague, Prague 16500, Czech Republic

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ABSTRACT

Natural resources represent the base of our living and the entire economic activity. Their depletion is a major challenge for the economic development of both developed and developing economies. Their efficient use is an indispensable requirement and must be the aim of the public policies designed by the authorities worldwide. In this research, we have investigated the impact of the natural resources rent on the economic growth in some major wealthy economies of the world (P5 + 1 countries namely: US, UK, France, China, Russia, and Germany). We have applied a quantile-on-quantile regression to analyse this impact on different quantiles and a cross-sectional autoregressive distributed lag (CS-ARDL) approach for the panel of these six countries. The Dumitrescu-Hurlin panel causality test was also used to check the causality between natural resource rents and economic growth in these countries. Results show a negative relationship between natural resources rent and economic growth for the panel but a different impact on quantiles in each country. Only for China and the US, a positive effect can be noticed for both lower and higher quantiles of natural resources and economic growth. The Dumitrescu-Hurlin causality test shows that natural resources can predict economic growth only in China, the U.S., and the panel. In contrast, no causality was found for the other four countries included in the panel. We suggest that nations invest in wind and solar projects, use biofuels and nuclear energy, introduce a temporary profit tax to protect consumers from escalating energy prices, and increase energy efficiency in buildings and industry. Businesses would benefit from a regulatory framework that is uniform and exhaustive, as well as easier to traverse and more receptive to innovation and creativity. Public-private partnership investments in innovation, innovation incentives, and environmental sector opportunities may foster long-term economic growth.

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1. Introduction

Last century global warming was related directly to its anthropological impacts, like burning of fossil fuel, natural resources waste, and high pollutant emissions (Loo et al., 2015). Natural resources are critical for production processes, living and social development (Bansal et al., 2021; Chopra et al., 2022). They represent an essential part of the wealth of a country and should be managed sustainably to determine long-term economic development (World Bank, 2011). Developed and developing countries face difficulties balancing using natural resources and achieving economic growth and development. That is why authorities should be concerned about designing and implementing public policies to promote sustainable production and consumption of natural resources and increase their use efficiency (Dogan, 2016; Hassan et al., 2019; Lampert, 2019; Altinoz and Dogan, 2021). Economic activity determines the depletion of scarce natural resources impedes sustainable development (Ramzan et al., 2022; Shahzad et al., 2022). The relation between natural resources and economic growth was primarily investigated because of the paradox that

* Corresponding author at: Department of Finance, Accounting and Economics, University of Pitesti, Pitesti 110040, Romania.
E-mail address: magdalena.radulescu@upit.ro (M. Radulescu).

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emerging countries are rich in natural resources while rich countries have scarce resources (Ahrend et al., 2007; Badeeb et al., 2017; Amiri et al., 2019). This paradox (so called "resource curse") was explained in terms of export specialization of emerging countries for few products with declining prices (Harvey et al., 2014), more volatile prices of the commodities that negatively impact on exports, savings and investments and induce macroeconomic instability in the poor countries exploiting natural resources (Jacks et al., 2011; Owusu-Antwi et al., 2019), an earlier and intensive specialization in manufacturing sectors of the developed economies with scarce natural resources (Kuralbayeva and Stefanski, 2013), while others explained that a large share of primary commodities into exports negatively impacts on the economic growth directly through the crowding out effect of manufacturing (so called "Dutch Disease" effect) (Sachs and Warner, 1997; Kronenber, 2004; Powell, 2008; Torres et al., 2013) or through some indirect effects induced by weak institutional factors in some countries that lead to higher corruption (Damania and Bulte, 2003) and inefficient bureaucracies, a bad management of natural resources (Sachs and Warner, 2001; Mehlum et al., 2006; Brunnschweiler, 2008; Torvik, 2009; Abdulahi et al., 2019) and becomes a reason for a poor economic performance (Zagozina, 2014). Papyrakis and Gerlagh (2007) studied the relationship between resource abundance and economic growth in the US and reached the same conclusion supporting the resource curse hypothesis. The same results confirming the resource curse were found for natural resource-rich economies (Dogan et al., 2020c), developed countries (Dogan et al., 2020b); Chinese provinces by Zhang et al. (2008) and Shao and Qi (2009). Lack of diversification of exports, income inequality, low social welfare, and centralized political decisions are the main reasons for the lack of economic performance in emerging countries endowed with natural resources, such as former Soviet Union states for example (Amineh, 2006; Starr, 2006; Franke et al., 2009; Meissner, 2010). Sala-i-Martin et al. (2004) also examined the relation between GDP generated in mining and economic growth and found a strong and significant positive effect through a direct economic channel. Ji et al. (2014) found a positive effect of resource abundance on Chinese provinces' economic growth from 1990 to 2008 based on a panel time-variant coefficient model and a conventional data panel approach. Still, this effect depended on the institutional quality long run. The main challenge of the emerging countries is to adequately manage the revenues gained from their abundant natural resources for investing in human and social capital and thus supporting the sustainable economic development of these nations (Gylfason, 2001; Goorha, 2006; OECD, 2011). Arezki and Ploeg (2008) demonstrated that higher trade openness could support economic growth and hinder the resource curse.

However, this paradox is counter-backed by some examples of countries rich in resources that managed them well and achieved economic growth and economic development (Norway, Botswana, South Africa) (Kronenber, 2004; Zagozina, 2014). On the other hand, diversification of exports determines some countries rich in resources to compete globally and avoid sectoral shocks (such as Asian tigers – Malaysia, South Korea, or such as Turkey) (Amineh, 2006). Also, choosing the correct proxies for natural resource determine different empiric results. Perälä (2003) showed that countries exporting fuels and minerals experience slower economic growth than those exporting raw materials. Korhonen et al. (2004) proved that non-fuel sectors impact the most economic growth negatively, but fuel exports are negatively correlated with democracy and political freedom. Brunnschweiler (2008) considered mineral resources the best proxy, while agricultural exports should not be included in his analysis or included separately. Despite the other results, the study demonstrated a positive relationship between resources and economic growth. Alexeev and Conrad (2011) proved that mineral and/or oil resources support long-term economic growth for the economies in transition in particular and Kubiniwa (2012) showed that Russia has benefited from the increased prices of natural commodities (oil and gas). However, it displays a weak institutional framework. Still, Alexeev and Chernyavskiy (2014) have shown that mineral and hydrocarbon resources are not very significant for the economic growth in Russia after the implementation of taxes in these sectors in 2002. However, the provinces endowed with natural resources are still more prosperous than others. Zagozina (2014) also demonstrated a positive relationship between oil, gas, mineral, and agricultural exports and economic growth in the former Soviet Union States. Still, the most significant positive impact is agricultural exports. Smith (2015) used the share of oil exports to total exports. Torvik (2009) stated that most natural resource measurements are not exogenous so that the results can be biased. Brunnschweiler and Bulte (2008) discussed the difference between resource abundance and resource dependence and their different impact on economic growth, and they showed that resource dependence suffers from endogeneity (Van der Ploeg and Poelhekke, 2010). The applied empirical methods also influence the achieved results (cross-sectional analysis or panel analysis with fixed effects, the latter allowing to estimate multiple phenomena over time, and there is necessary to test serial correlation, quantile-on-quantile regression) (Kronenber, 2004; Torvik, 2009; Haseeb et al., 2021). Many studies have concentrated on analysing different regions of the same country because the cultural, historical, and institutional differences are not as significant as those among countries (Alexeev and Chernyavskiy, 2014). Such studies were focused on the US (Papyrakis and Gerlagh, 2007; James and Aadland, 2011), China (Fang et al., 2009) and Russia (Freinkman and Plekhanov, 2009; Libman, 2013).

Havranek et al. (2016), in their *meta*-analysis of 43 studies, have focused on the natural resources and economic growth relationship elaborated during two recent decades and found that 40% of the total studies discovered a negative effect, 40% found no effect, and 20% found a positive one. So, no consensus on this issue has been reached so far. Still, they have concluded their *meta*-analysis because the achieved results cannot support the resource curse theory, which is weak if the data and method heterogeneity is considered. They explained these differences among the results by the role of the institutional quality (the higher it is, the resource curse effect is weaker, as Mehlum et al. (2006) pointed out. This study applied different types of natural resources (oil per average supports economic growth, as some studies proved Alexeev and Conrad (2011) or Smith (2015)) or controlling for the level of investment activity (natural resources tend to diminish investment level as it was demonstrated by Gylfason and Zoega (2006)).

So, the opinions of the previous studies on this topic are mixed, although there is a consensus that natural resources enhance the wealth of a country (Holden, 2013). In light of the Russia-Ukraine scenario, the connection between natural resources and economic development has become even more prominent. Since Russia is a key supplier of the world's natural resources, nations that exclude Russia from commerce, etc., limit the overall quantity of natural resources, hence raising the price of natural resources and ultimately restraining economic development (Zhang et al., 2008; Sharma et al., 2021). Alternately, the nations may invest in the discovery of other (non-natural) resources, again reversing the paradigm of economic development.

This paper investigates the role of the natural resources rent in achieving economic growth in P5 + 1 countries (US, UK, France, China, Russia, and Germany) that are permanent members of the UN Security Council and the largest and most powerful economies in the world. These countries present sizeable natural resource reserves. Russia is a prominent exporter of mineral fuels such as gas, oil, and coal and minerals such as gold and diamonds (World Bank, 2019). China also has an extensive palette of mineral resources, such as fossils: natural gas, coal, and crude oil, but also it has large rare metals reserves. China ranks in the first position in the world for its natural resource reserves, while Russia is in the 5th position, and the US is in the 7th position (World Atlas, 2018a). The US has large coal, timber, gold, natural gas, and oil. The UK ranks in the 5th position among the world economies and has arable land, petroleum, coal, and other minerals such as zinc, lead, iron ore, salt, and silica (World Atlas, 2018b). France has the 6th largest economy globally after the US, China, Japan, Germany, and the UK. It has vast arable land supporting large-timer production and crop food. However, its mineral resources are not so considerable nowadays because they were heavily exploited and depleted during the industrial revolution. It has reserves of coal, natural gas, uranium, and renewable energy (wind, hydroelectric, thermal, and solar energy) (World Atlas, 2018c). Germany has extensive reserves of coal, natural gas, timber, arable land, uranium, and copper (World Atlas, 2018d).

This research has contributions to the literature for the following directions: (1) it is the first paper analysing the natural resource curse for these top wealthy P5 + 1 large economies of the world, which can lead to designing some important policy implications for the natural resources management in these countries, especially in the context of the current Ukraine-Russia war which brought big changes for all the countries, and Russia being one of the country included in this investigated panel; and (2) we have applied 2nd generation estimations methods that consider cross-sectional dependence among the panels and we have also applied quantile on quantile regressions that allows us to emphasize the differences of the results among different quantiles. Moreover, we completed our analysis with a causality analysis for these variables, which was performed only by few studies before. We have applied a quantile-on-quantile regression (QQR) to reveal the asymmetric relationship between the quantiles of natural resources and economic growth because a linear regression can't capture these aspects (Sim and Zhou, 2015), and the results can be based. We have also applied a panel cross-sectional autoregressive distributed lag (CS-ARDL) and checked for the robustness of the panel estimations using cross sectional dependence tests such as $CD_{LM,}$ bias-adjusted LM test, and slope homogeneity test. The causality was checked using the Dumitrescu-Hurlin causality panel test applied for heterogeneous panels.

Section 2 discusses the findings of previous studies analysing the natural resource curse for different countries, Section 3 presents the methodology we have applied and data we have used in the empirical model, and in Section 4 we present the results and discuss them. The last section concludes our research, design some policy recommendations for the investigated countries and presents some limitations and directions for further research on this important topic.

2. Review of literature

We employ a systematic and transparent literature search to ensure this study's unbiased and robust review. We reviewed eighty papers related to the theme using Boolean operators on the Scopus and Web of Science databases for initial search and following the PRISMA guidelines for including and excluding the records (see Fig. 1 for a detailed exhibition).

The literature studies the relation between natural resources and economic growth, which finds that the existing literature involves mixed results (Stijns, 2005; Li et al., 2013; Havranek et al., 2016), with 40% of the publications on this topic concluded with negative effect; 40% with no effect and 20% with positive effect. The study also points out the role of institutional quality, investment, the difference in the impact of natural resource abundance and dependence, and the type of natural resource (Havranek et al., 2016). The research methodology for the literature review, especially the paper selection and structure, was adapted from the systematic reviews (Talan and Sharma, 2019; Sharma et al., 2020a, 2020b, 2021; Srivastava et al., 2020).

The major themes and sub-themes in the research on the impact of natural resources on economic growth or GDP growth are visualized in Fig. 2.

Further in this section, we classify the studies among those finding a positive vis-à-vis the ones finding a negative impact and those finding no impact of natural resources on economic growth.

2.1. Positive impact on economic growth

Natural resources include both renewable and non-renewable natural sources. Several studies have shown the positive impact of natural resources and economic growth (Barlowe, 1960; Haseeb et al., 2021; Hayat and Tahir, 2021; Sharma et al., 2021; Chopra et al., 2022; Ramzan et al., 2022; Shahzad et al., 2022; Tahir et al., 2022; Zhao et al., 2022). For example, the positive impacts of natural resources on economic growth in Asia, Europe, and America were identified (Aslan and Altinoz, 2021). The impact can be short-term or long-term. Both renewable and non-renewable energy sources can foster economic growth, but renewable energy sources should be preferred for sustainable growth due to the reduced emissions (Arshad et al., 2020; Surya et al., 2021; Awosusi et al., 2022). The results related to the study on the long-term relationship between the management of natural resources and the economic growth in Pakistan show positive relation, and this is a good indication for the policy intervention for the better management of natural resources (Hussain et al., 2009; Hye and Siddiqui, 2010) and also the technology, security and intellectual management (Hassan et al., 2019). Banking sector depth, change in banking sector depth, and the impact of the banking sector depth can be major determinants affecting countries with abundant natural resources (Al-Moulani and Alexiou, 2017). Equally important is the development of the financial system for channelizing the advantages of natural resources to promote economic growth (Erdoğan et al., 2020) and investments (Gylfason and Zoega, 2006); discount rate of natural resources (Winter-Nelson, 1996). The income level of countries plays an important role in the relation and impact of natural resources and economic development, and they are different for high, middle, and low-income economies (Topcu et al., 2020).

Natural resources are essential factors in food patterns in the economy, and food patterns can influence the economy. In this way, too, natural resources can impact economic growth (Gerbens-Leenes et al., 2010). The volatility of prices of natural resources is another factor affecting economic growth. Policy factors are crucial in containing this factor (Cui et al., 2021; Guan et al., 2021) and the geography of natural resources and place of economic growth (González-Val and Pueyo, 2019). The volume of natural resource export can significantly affect the FDI and, thereby, the economy's economic growth (Hayat, 2018; Hayat and Tahir, 2020; Hussain et al., 2009).

The property rights of the natural resources are another determinant affecting economic growth (Borissov and Pakhnin, 2018; Coulibaly et al., 2018; Qiang and Jian, 2020); and the quality of property rights, too (Coulibaly et al., 2018). Private ownership of natural resources promotes much more economic growth than public ownership. Still, inequality is another outcome of private

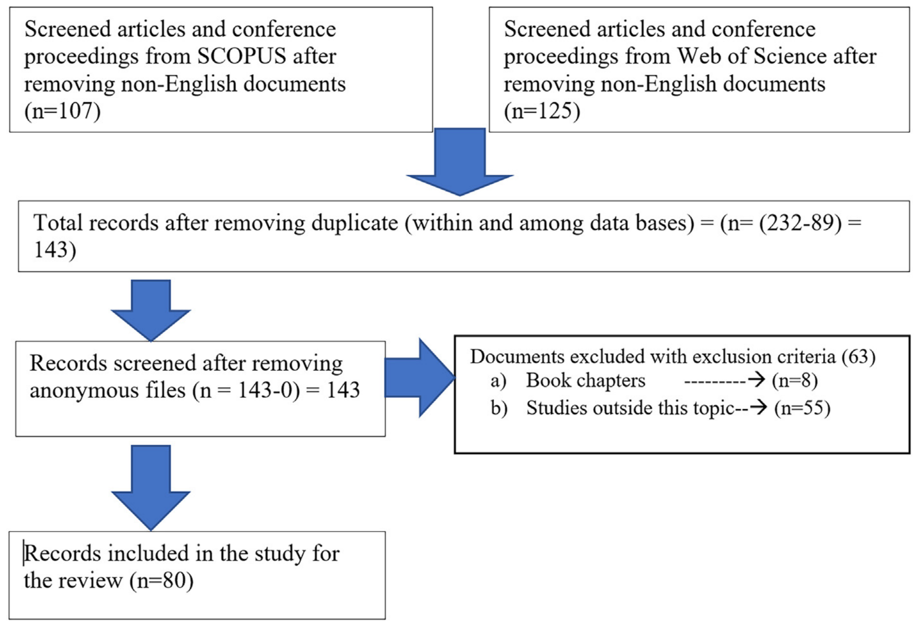

Fig. 1. Inclusion/exclusion criteria for the review of related literature.

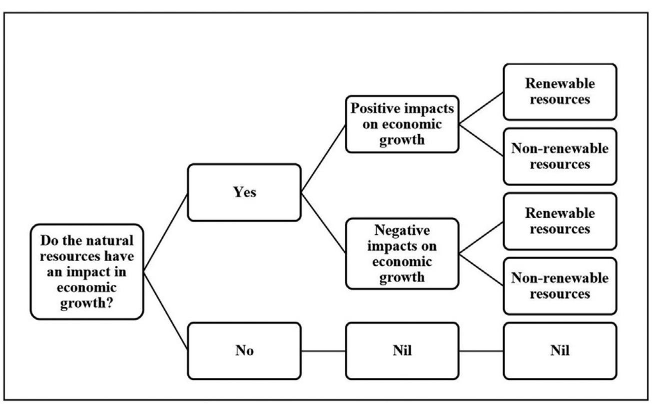

Fig. 2. Themes and sub-themes in the extant literature.

ownership of natural resources, which should be controlled by policy initiatives (Borissov and Pakhnin, 2018).

2.1.1. Renewable natural resources and economic growth

Renewable natural sources can positively affect economic growth in countries with abundant non-renewable energy sources (Chambers and Guo, 2009; Acikgoz et al., 2016). The lower and upper-middle-income countries in this category can benefit more from renewable energy adoption (Acikgoz et al., 2016). This is an important factor in making decisions related to energy policies.

2.1.1.1. Non-renewable natural resources and economic growth. Oil is an important non-renewable natural resource and can positively impact economic growth (Brunnschweiler, 2008; Adabor et al., 2022). The results from Ghana show that a 1% increase in the oil resource rent can generate a 0.84% increase in economic growth in the long-term scenario but an insignificant positive effect in the short term (Adabor et al., 2022). Similarly, a study of eleven countries (next eleven countries) has found that when financial deepening is over 45%, a unit increase in oil exports can generate 7% economic growth (Erdoğan et al., 2020). The case of the non-renewable energy-dependent countries is also not different, but such economies should adopt capital-intensive technologies for efficiency and economic growth (Arif and Saeed, 1989). Moreover, the impact of natural resources on economic growth is also declining, especially the impact of oil palms on the economic growth of southeast Asian countries in recent years declining in comparison with the impacts of forest industries in the economy of Finland and Sweden during the nineteenth century (Bruno, 2023).

A positive relation between natural resources, especially oil, and financial development was spotted in a study in Pakistan, and this points out the role of natural resources in economic growth and the need for professional management of these resources for growth and prosperity (Atil et al., 2020) but a contradiction in findings is also raised (Ridzuan et al., 2021). Similar results in Nigeria and natural resources have non-uniform relations with economic growth (Isham et al., 2005; Inuwa et al., 2022). The negative impact of renewable energy on economic growth was observed (Dogan et al., 2020a).

2.2. Negative impact on economic growth

Natural resources have a diversified relationship with economic growth (Ofori and Grechyna, 2021). Several studies have concluded the negative impact of natural resources on economic growth (Gerelmaa and Kotani, 2016; Aslan and Altinoz, 2021). For example, such negative relations exist in Africa (Aslan and Altinoz, 2021). Dutch disease and resource curse theories no longer exist in recent decades (from 1990 onwards), and natural resources foster economic growth (Gerelmaa and Kotani, 2016). However, these concepts are still popularly used in the literature related to natural resources and negative economic growth. Moreover, the scarcity of natural resources can also have negative impacts on economic growth (Uri, 1996).

2.2.1. Non-renewable natural resources and economic growth

Even though natural resources positively impact economic growth, several natural resource-abundant countries have failed to use those resources for economic growth (Wu et al., 2018; Ben-Salha et al., 2021). Even though oil is strategically important, several studies have pointed out the "natural resource curse phenomenon". The "resource curse" is inability to utilize the abundance of natural resources for prosperity, which is called the "resource curse". The improper management of resources can cause the same (Amini, 2018). Globalization creates the platform for this phenomenon, and the main reasons for the natural resource curse can be associated with the existence of corruption (Brueckner, 2010; Gbatu et al., 2018; Namazi and Mohammadi, 2018; Adams et al., 2019; Erum and Hussain, 2019), poor transparency and accountability, institutional weaknesses and poor governance. (Adams et al., 2019). The other reasons for the resource curse can be poor checking (Brueckner, 2010); political stability, and will (Park and Lee, 2006; Brueckner, 2010; Jixia, 2015; Ngondjeb and Nlom, 2017; Namazi and Mohammadi, 2018; Vasilyeva and Libman, 2020; Kwakwa et al., 2022); lack of diversification (Gbatu et al., 2018); poor governance (Park and Lee, 2006); The role of governance in economic development by using natural resources was rejected (Ridzuan et al., 2021) and lack of innovation (Namazi and Mohammadi, 2018).

Institutional weakness and policies are important factors in using natural resources for economic growth (Ciriacy-Wantrup, 1969; Morales-Torrado, 2011; Ji et al., 2014; Ngondjeb and Nlom, 2017; Epo and Faha, 2020; Qiang and Jian, 2020), but the role of institutions is controversial as there are studies in both sides. Brunnschweiler considers that Institutional weakness cannot be considered a reason for the resource curse (Brunnschweiler, 2008), but Ciriacy-Wantrup (1969) and Adams et al. (2019) found the other way. Institutional structural weakness can be the leading cause of the resource curse of Africa (Ndjokou and Tsopmo, 2017; Gbatu et al., 2018). The institutions can turn the resource curse into a blessing. Revolutionary changes in the institutional management of resources are needed to reap the positives of natural resources for economic growth (Moshiri and Hayati, 2017).

The resource curse phenomenon was also found in the case of Iran. In the case of Iran, a 1% increase in natural resources can result in a 0.47% decline in GDP, which shows the need for better management of natural resources for better economic growth (Ahmed et al., 2016). Iran's oil-rich country has a negative relationship between oil export with economic growth and vice versa (Safdari et al., 2011). The case of Algeria is similar to Iran in exploiting the oil resources for economic growth (Chekouri et al., 2017), and Brazil in terms of commodity export (Veríssimo and Xavier, 2014). The resource curse phenomenon has been identified in mineral-rich countries like the Democratic Republic of Congo (DRC), Australia, Canada, India, and Saudi Arabia.

Natural resource-abundant countries are experiencing high-income inequality. Income inequality inhibits economic growth, and countries with abundant natural resources should handle the issues of inequality to ensure economic growth (Anyanwu et al., 2021). The price of natural resources can hinder the economic growth of resource-abundant economies (Betrán, 2005; Zubikova, 2018).

Trade openness can be a measure to come out of the resource curse (Ampofo et al., 2020; Yasmeen et al., 2021), contradicting findings (Hamdi and Sbia, 2013; Ridzuan et al., 2021). The treatment difference of the natural resources can also be a reason for the resource curse as the speciality of the natural resource and resource operator are important determinants of converting natural resources to economic growth (Bunte et al., 2018). The specialization in natural resources can negatively affect the economic growth of economies. However, treatment differences are experienced in the Community of Central Africa (CEMAC) countries (Diaw and Lessoua, 2013). The shortage of natural resources can cause a dragging effect on the economic growth trajectory of economies (Liu and Xie, 2013). Human capital development can also promote economic growth, along with natural resource usage, and can be a good measure against the natural resource curse (Shao and Yang, 2014; Zallé, 2019; Rahim et al., 2021; Shittu et al., 2022); and knowledge base expansion (Sepehrdoust and Shabkhaneh, 2018). Transparency can be another alternative to the resource curse problem (Williams, 2011).

2.3. No impact of natural resources on economic growth

Limited studies have an insignificant connection between natural resources and economic growth (Ding and Field, 2005; Hayat and Tahir, 2021). However, this study also concluded that natural resource dependence hurts economic growth, and resource endowment positively impacts it (Ding and Field, 2005).

The major factors affecting the role of natural resources in promoting economic growth are the quality of institutions managing the natural resources, their skills, potential, management, and ownership patterns and interests. Quality improvement of institutions can be a solution to this through policy measures. The investment level in using natural resources for economic growth is another factor. The capital investment in technology, human capital, and knowledge base is crucial here. Proper human capital management policies, skill updating opportunities, and technology updations are essential for using natural resources for economic growth. The types of natural resources, the diversification in usage, and the availability of a diversified set of natural resources are essential for diversification and avoiding resource crunch and related negative growths. The creation of value-added products is more important for economic growth than the mere exporting of natural resources. Pollution control measures, controlling price fluctuation of the natural resources, etc., should be focused on while managing the natural resources. Financial development, the strength of the financial system, including banking, plays a crucial role in unlocking economic growth from natural resources. Equally important are the income level of countries and the inequality level. High inequality of income and low-income level are challenges for using natural resources for economic growth. Property rights, quality of property rights, and ownership patterns are important for commercial use of natural resources. The major challenges in using natural resources for economic growth are poor transparency, corruption, poor governance, poor monitoring, and political instability. The major solutions for better usage of natural resources for economic growth can be better planning and policy initiatives, diversification, promotion of renewable energy, innovations, strengthening of institutions and monitoring, and better implementation.

3. Data and methodology

3.1. Data

The annual data from 1988 to 2019 on Gross Domestic Product (GDP per capita) as an indicator of economic growth and Total natural resources rent (% of GDP) as an indicator of natural resources was obtained from data.worldbank.org for P5 + 1 (China, France, Germany, UK, Russia, and the USA) countries.

3.2. Methodology

3.2.1. Quantile-on-quantile regression (QQR)

Recently, the methodology of quantile regression (QR) introduced by Koenker and Bassett (1978) has gained popularity in modelling the time-varying degree and structure of dependence between variables. The robustness of QR to provide tail dependence information (i.e. upper and lower tails) in addition to the central measures like mean has proven its advantage over linear or non-linear regression analysis. As an advancement to QR, the non-parametric regression methodology of quantile-on-quantile regression (QQR) was introduced to capture the entire dependence structure. The methodology of quantile on quantile regression proposed by Sim and Zhou (2015) is explained in brief to study the impact of NR on GDP.

The QQR model for q-quantile of GDP as a function of NR variable and lagged GDP is defined as in Eq. (1):

$$GDP_t = \alpha^q(NR_t) + \gamma^q GDP_{t-1} + \varepsilon_t^q \tag{1}$$

where ε_t^q is an error term with zero q-quantile. The unknown link function $\alpha^q(.)$ using first-order Taylor expansion is linearized as in Eq. (2):

$$\alpha^q(NR_t) \approx \alpha^q(NR^p) + \alpha^{q\prime}(NR)(NR_t - NR^p) \tag{2}$$

Following the (Sim and Zhou, 2015) method, the above Eq. (2) can be rewritten as Eq. (3):

$$\alpha^q(NR_t) \approx \alpha_0(q,p) + \alpha_1(q,p)(NR_t - NR^p) \tag{3}$$

Eq. (1) reduces to Eq. (4):

$$GDP_t = \alpha_0(q,p) + \alpha_1(q,p)(NR_t - NR^p) + \gamma(q)GDP_{t-1} + \varepsilon_t^q \tag{4}$$

$$GDP_t = \underbrace{\alpha_0 + \alpha_1(NR_t - NR^q) + \gamma(q)GDP_{t-1}}_{*} + \varepsilon_t^q \tag{5}$$

$$\gamma(q) = \gamma^q, \alpha_0 = \alpha_0(q,p) \text{and} \alpha_1 = \alpha_1(q,p)$$

Part (*) in Eq. (5) denotes the qth conditional quantile of GDP and captures the relationship between the q-quantile of GDP and p-quantile of NR as α_0 and α_1 are indexed in both q and p.

The estimated Eq. (5) is obtained by minimizing the following as in Eq. (6):

$$\min_{\alpha_0\alpha_1} \sum_{i=1}^{n} \varnothing_q\left[GDP_t - \alpha_0 - \alpha_1(NR_t - NR^p) - \gamma(q)GDP_{t-1}\right] * M\left(\frac{H_n(NR_t) - p}{h}\right) \tag{6}$$

where $\varnothing_q$ corresponds to the absolute value function which gives the q conditional quantile of GDP as a solution. Then the Gaussian kernel M(.) is conducted to weight the observation according to normal probability distribution based on bandwidth h. Based on previous studies a bandwidth of 5% (h = 0.05) was selected (Sim and Zhou, 2015). The empirical distribution function is estimated as in Eq. (7):

$$M_n(P_t) = \frac{1}{n}\sum_{k=1}^{n} I\left(\widehat{NR}_k < \widehat{NR}_t\right) \tag{7}$$

The weights are reversely linked to distance of $H_n(NR_t)$ from p, where p is the value of the distribution function corresponding to NR^p.

3.2.2. CS-ARDL methodology

To compare the relative effects of Natural Resources Rent (NR) on the Gross domestic product (GDP) across P5 + 1 countries, the following model (expressed in Eq. (8)) is studied:

$$GDP_{it} = \alpha_{1i} + \alpha_{2i}NR_{it} + \epsilon_{it} \tag{8}$$

3.2.3. Cross-sectional dependence and slope homogeneity

Estimators obtained via applying standard panel data methods are biased as they assume cross-sectional independence and Homogeneity of slope coefficients (Chudik and Pesaran, 2013). Hence, cross-sectional dependence and slope homogeneity are checked in the preliminary stage. CD_{LM} (Pesaran, 2004) and bias adjusted LM-test (Pesaran et al., 2008) was applied to test cross-sectional dependence. The test statistics are calculated as in Eq. (9) for $\mathrm{CD_{LM}}$ test and in Eq. (10) for LM adjusted:

$$CD_{LM} = \left(\frac{1}{N(N-1)}\right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(D_{\hat{r_{ij}}}^2 - 1\right) \tag{9}$$

$$LM_{adj} = \left(\frac{2}{N(N-1)}\right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(\frac{[D-m]_{\hat{r_{ij}}}^2 - \mu_{D_{ij}}}{W_{D_{ij}}}\right) \tag{10}$$

where $W_{D_{ij}}$, $\mu_{D_{ij}}$ and $\hat{r_{ij}}$ represent variance, mean, and correlation between cross-sectional units. The null and alternative hypothesis for both the test statistics is:

H_0: Cross-sectional independence.

H_A: Cross-sectional dependence.

To test for Heterogeneity in panel data analysis following statistic was developed by Pesaran and Yamagata (2008) as in Eqs. (11) and (12):

$$\tilde{\Delta} = \sqrt{N}\left(\frac{\frac{\bar{S}}{N} - m}{\sqrt{2m}}\right) \tag{11}$$

$$\tilde{\Delta}_{adj} = \sqrt{N}\left(\frac{\frac{\bar{S}}{N} - E(H)}{\sqrt{Var(H)}}\right) \tag{12}$$

where $\bar{S}$ is Swamy test statistic (Swamy, 1970), and m is the number of explanatory variables. $\tilde{\Delta}_{adj}$ is bias adjusted statistic for $\tilde{\Delta}$. $H = m$ and $Var(H) = 2m(D-m-1)/(D+1)$.

The null and alternative hypotheses for slope homogeneity are:

$H_0 : \beta_i = \beta$, i.e. Homogeneity of slope coefficients.

$H_A : \beta_i \neq \beta$, i.e. Heterogeneity of slope coefficients.

Subsequently, the stationarity of variables is examined with a cross-sectional augmented Dickey-Fuller test (CADF).

3.2.4. Panel unit root test

The CIPS statistic based on cross-sectional augmented dickey fuller unit $CADF_i$ the panel, I developed (Pesaran, 2007) is applied to check for stationarity. The test statistic is given in Eq. (13):

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \tag{13}$$

With CADF regression with lagged values to prevent serial correlation is given in Eq. (14):

$$\Delta y_{it} = \beta_i + \rho_i^* y_{i,t-1} + k_0 \bar{y}_{t-1} + \sum_{j=1}^{p} k_{j+1}\Delta\bar{y}_{t-j} + \sum_{l=1}^{p} h_l \Delta y_{i,t-l} + \epsilon_{it} \tag{14}$$

The null hypothesis is the presence of unit root in the panel dataset and can be applied for N > T and T > N.

3.2.5. Cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model

The Cross-sectionally augmented ARDL (CS-ARDL) model estimates the short and long-run coefficients (Chudik and Pesaran, 2015). The model provides robust estimation results when the repressors are I_0, I_1, or a combination of both, and the series may be co-integrated or not (Chudik et al., 2017). The method is the ARDL version of the Dynamic Common Correlated Estimator and is based on individual estimations with lagged dependent variables and lagged cross-section averages. The method is robust to cross-sectional dependency and Heterogeneity of slope coefficients. The CS-ARDL is based on the following regression as in Eq. (15):

$$y_{it} = \beta_i + \sum_{i=1}^{k}\gamma_{ik}y_{i,t-k} + \sum_{i=1}^{k}\beta_{ik}x_{i,t-k} + \sum_{i=1}^{k}\varnothing_{ik}Z_{i,t-k} + \epsilon_{it} \tag{15}$$

where $Z_{i,t-k}$ refers to lagged cross-sectional averages s.t. $Z_{i,t-k} = \left(\bar{y}_{i,t-k}, \bar{x}_{i,t-k}\right)$. The long-run coefficients of the mean group are given by Eqs. (16) and (17):

$$\hat{\theta}_{CS-ARDL,j} = \frac{\sum_{i=1}^{k} \hat{\beta}_{ij}}{\sum_{i=1}^{k} \hat{\varnothing}_{ij}} \tag{16}$$

$$\hat{\theta}_{MG} = \frac{\sum_{i=1}^{N} \hat{\theta}_i}{N} \tag{17}$$

where $\hat{\theta}_i$ denotes the individual estimations of each cross-section.

3.3. Panel granger causality

The Dumitrescu-Hurlin (DH) test developed by (Dumitrescu and Hurlin, 2012) is an extension of Granger causality (Granger, 1969) designed to detect causality in panel data. The underlying regression equation is expressed in Eq. (18):

$$y_{i,t} = \beta_i + \sum_{i=1}^{k} \gamma_{ik} y_{i,t-k} + \sum_{i=1}^{k} \beta_{ik} x_{i,t-k} + \epsilon_{it}\, f \text{ or } i = 1, \cdots, N \text{ and } t = 1, \cdots, T \tag{18}$$

where $y_{i,t}$ and $x_{i,t}$ are the observations of two stationary series at time point t of individual i. The lag order k is assumed to be identical for all individuals, and the panel must be balanced. DH test assumes there may be a causality for some individuals. The null and alternative hypothesis is given as:

$$H_0 : \beta_{i1} = \cdots = \beta_{ik} = 0 \quad \forall i = 1, \cdots, N$$

$$H_A : \beta_{i1} \neq 0 \text{ or } \cdots \text{ or } \beta_{ik} \neq 0 \quad \forall i = N_1 + 1, \cdots, N$$

where $N_1 \in [0, N-1]$ is unknown. If $N_1 = 0$, then there is causality for all individuals in the panel with condition $N_1 < N$.

The test is designed to detect causality at the panel level. DH test is based on Wald statistic W_i obtained by running N individual regressions stated in Eq. (14) and final computation of averaged Wald statistic given by Eq. (19):

$$\bar{W} = \frac{1}{N} \sum_{i=1}^{N} W_i \tag{19}$$

The $\bar{W}$ is asymptotically robust and can be used for detecting panel causality.

4. Empirical findings and discussion

4.1. Results

The paper covers the period from 1988 to 2019. The summary statistics for P5 + 1 countries along with results of tests of normality (Jarque Bera and Shapiro Wilk) are given in Table 1.

For applying quantile on quantile regression methodology, the annual data is converted into monthly data by employing a quadratic match-sum method specific to each country. Compared to other interpolation methods, this method eliminates the point-to-point data variations for converting low-frequency data into high-frequency data. Thus, eliminating the seasonal variations (Cheng et al., 2012; Sbia et al., 2014).

The results of ADF test of stationarity for variables at level and at first differences are summarized in Table 2. The variables were found to be non-stationary at level but stationary at the first difference of log-transformed values.

The results of the BDS test of non-linearity are given in Table 3. The non-normality and non-linearity of variables indicate that methodology based on quantiles will provide us with unbiased results compared to linear regression.

The first difference of logarithmically transformed values is used for further analysis.

The quantile-on-quantile regression (QQR) model, as stated in Eq. (1), was fitted for each country, and the graphs of intercept and slope coefficients in the quantile grid, q = [0.05, 0.95] are summarized in Figs. 3–8 and discussed as below:

For China, the slope coefficients were found to be positive for all quantiles of GDP and all quantiles of NR (q < 0.8) for quantile on quantile regression fit (Fig. 3). The intercept and slope coefficients were found to positive and significant over all the quantile grids for quantile regression fit. Indicating NR has a significant positive impact on GDP for quantile distribution.

For Germany, the slope coefficients were positive for lower quartiles of NR (q < 0.25) and for all quantiles of GDP, indicating that an increase in NR causes an increase in GDP for lower concentrations of NR. The coefficients are negative for quantiles below the GDP median and above the NR median. A similar trend is observed for quantiles above the median of GDP and quantiles below the median of NR. Further, a positive trend was observed for the upper tails of NR and all quantiles of GDP, as can be observed from Fig. 4 of quantile on quantile regression fit. For quantile regression fit, the intercept coefficients were positive and significant for all q > 0.35, while the slope coefficients were positive for all quantiles and significant for q = [0.45–0.85].

For France, the slope coefficients were positive for lower tails of NR and quantiles below the median of GDP. Further, the coefficients were positive for quantiles above the median of GDP and quantiles, q = [0.5–0.85], of NR. The coefficients were negative for lower tails of NR and quantiles above the median of GDP and quantiles, q > 0.35, of NR and quantiles, q < 0.55, of GDP, as can be observed from Fig. 5 of quantile on quantile regression fit estimates. For quantile regression fit, the positive was below the median and significant for all quantiles, while the slope coefficients were negative and non-significant.

For the UK, the slope coefficients were positive for all quantiles of GDP and quantiles, q = [0.35–0.95], of NR, while negative for all quantiles of GDP and lower quartiles of NR for quantile on quantile regression fit (Fig. 6). For quantile regression fit, the intercept coefficients were negative for quantiles, q < 0.35 and significant for all quantiles, while the slope coefficients were negative for quantiles, q = [0.35–0.7] and non-significant for all quantiles.

For Russia, the slope coefficients were positive for lower tails and quantiles, q = [0.35–0.6], of NR and all quantiles of GDP. The coefficients were negative for quantiles below the median of GDP and q > 0.65, of NR for quantile on quantile regression fit (Fig. 7). The intercept coefficients were negative for quantiles below the median and significant for all quantiles for quantile regression fit. In contrast, the slope coefficients were negative for quantiles, q = [0.2–0.4] and non-significant for all quantiles.

For the USA, the slope coefficients were positive for quantiles, q > 0.3, of GDP and quantiles of NR for quantile on quantile regression fit (Fig. 8). For the quantile regression fit, the intercept coefficients were positive and significant for all quantiles, and slope coefficients were positive for all quantiles and significant for quantiles, q = [0.4–0.7].

4.1.1. Robustness of QQR methodology

The linear quantile regression model is defined as:

$$GDP_t^q = \beta_0^q + \beta_1^q NR_t + \beta_2^q GDP_{t-1}^q + \varepsilon_t^q \tag{20}$$

Table 1
Descriptive statistics for GDP and natural resources.

S. No	Country	Variables	Mean	Std Dev	Sk	Ku	JB	SW
1	China	GDP	3192.8	3284.43	0.93	−0.64	4.89	0.81*
		NR	3.92	2.31	0.71	−0.27	2.72	0.93*
2	Germany	GDP	34,006.9	9702.22	0.017	−1.45	2.67	0.91*
		NR	0.123	0.06	1.09	1.12	6.58*	0.91*
3	France	GDP	31,671.82	8960.815	0.018	−1.62	3.25	0.89*
		NR	0.059	0.029	1.46	1.96	13.24*	0.86*
4	UK	GDP	33,647.27	10,882.7	−0.217	−1.45	2.89*	0.91*
		NR	0.718	0.26	−0.008	−0.23	0.19	0.99
5	Russia	GDP	6592.63	819.20	0.655	−0.99	3.48	0.86*
		NR	12.851	0.85	0.008	−1.18	1.88	0.96
6	USA	GDP	41,172.21	2286.98	0.14	−1.14	1.86	0.95
		NR	0.88054	0.058	0.70	2.23	6.33	0.95

*: *p*-values significant at 5% value of significance.

Table 2
Stationarity and unit-root testing.

		China	Germany	France	UK	Russia	USA
ADF-test	GDP	18.1	2.64	2.3	2.81	1.59	27.72
	L(GDP)	21.84	3.34	3.04	4.48	2.20	29.07
	D(GDP)	−5.57*	−11.71*	−11.84*	−10.51*	−10.49*	−5.14*
	NR	−1.3	−0.63	−2.45	−0.56	−0.005	−0.98
	L(NR)	1.49	0.06	2.81	0.037	−2.35*	0.60
	D(NR)	−12.79*	−12.64*	−11.28*	−11.4*	−12.13*	−12.93*

*: *p*-values significant at 5% level of significance.
L(.) – log-transformed variables.
D(.) – First difference of log-transformed variables.

Table 3
BDS test of non-linearity.

Country	Indicator	Dimension			
		M = 2	M = 3	M = 4	M = 5
China	GDP	50.99*	74.86*	115.69*	189.72*
	NR	158.75*	289.27*	574.09*	1237.46*
Germany	GDP	269.03*	500.88*	1018.88*	2251.91*
	NR	132.09*	231.44*	438.69*	898.34*
France	GDP	263.78*	464.51*	885.71*	1825.09*
	NR	87.27*	138.42*	233.61*	421.44*
UK	GDP	252.83*	458.44*	904.29*	1932.5*
	NR	185.79*	351.32*	725.52*	1626.08*
Russia	GDP	70.77*	111.74*	187.8*	337.46*
	NR	302.63*	561.19*	1134.41*	2489.48*
USA	GDP	704.19*	1451.84*	3320.96*	8321.49*
	NR	135.54*	236.28*	443.3*	893.66*

* *p*-values significant at a 5% level of significance.

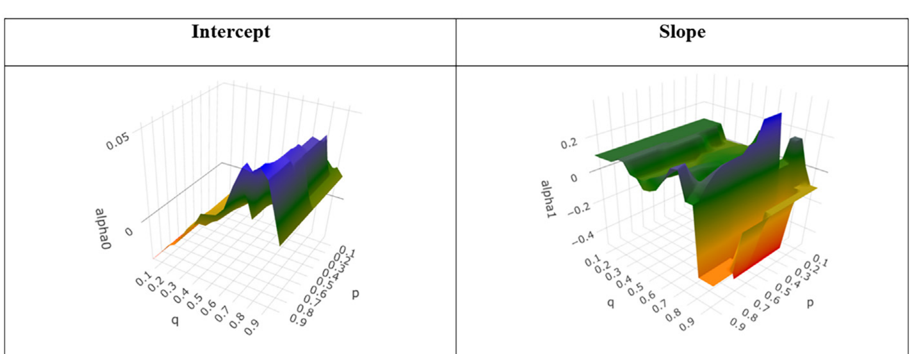

Fig. 3. QQR estimates for China (intercept and slope).

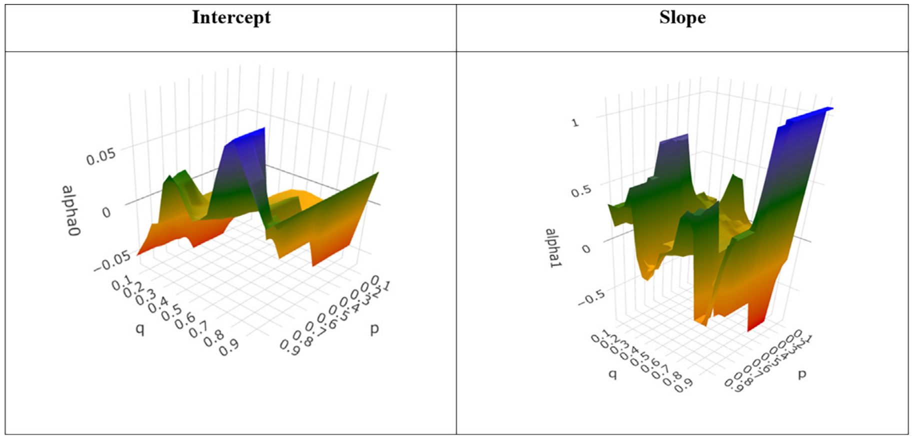

Fig. 4. QQR estimates for Germany (intercept and slope).

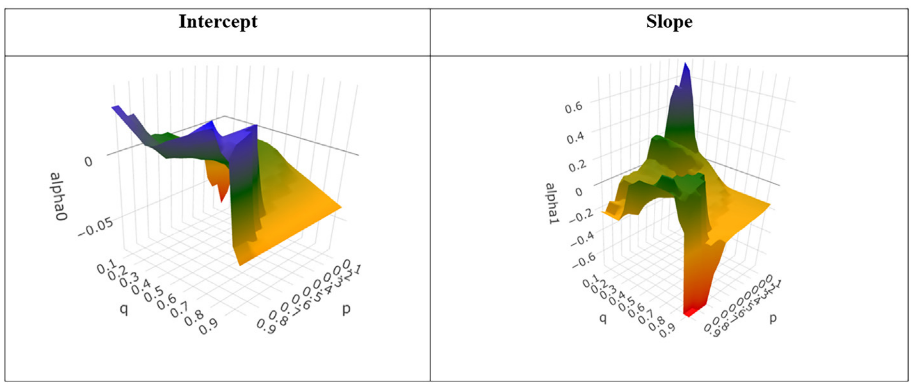

Fig. 5. QQR estimates for France (intercept and slope).

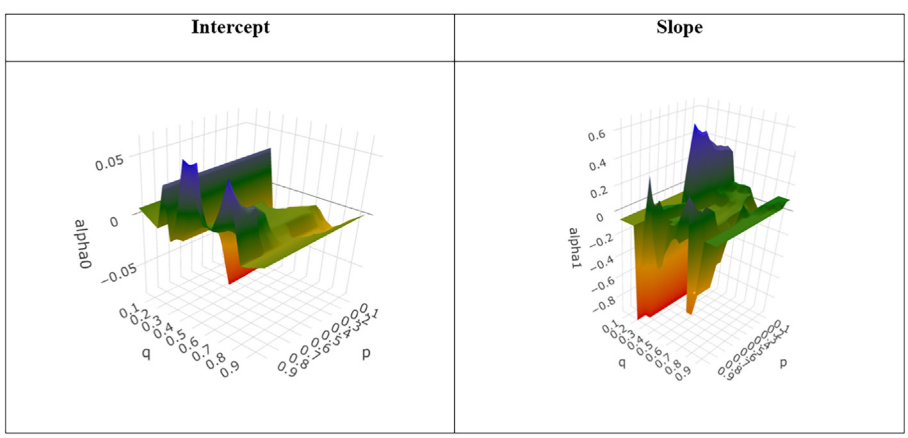

Fig. 6. QQR estimates for UK (intercept and slope).

where GDP_t^q is the qth conditional quantile of the dependent variable and the parameter $\beta_0^q = \beta_0$ are the intercept and the regression estimator $\beta_1^q = \beta_1$ is a function of q.

The QQR estimates decompose QR estimates specifically for different quantiles of response variables. The QR approach regresses the qth quantile of GDP, whereas the QQR approach regresses the qth quantile of NR variable on pth quantile of GDP, and as a result, its parameters are functions of (q, p). Hence, the QQR method conveys more information about the relationship between variables than the QR approach.

The following relationships hold for QR and QQR estimates:

$$\widehat{\beta}_0 = \frac{1}{m}\sum_p \widehat{\alpha}_0 = \widehat{\bar{\alpha}}_0 \text{and} \widehat{\beta}_{1j} = \frac{1}{m}\sum_p \widehat{\alpha}_1 = \widehat{\bar{\alpha}}_1 \tag{21}$$

where j = 1,2,...,m, and m is the number of points of the quantile grid q= (0, 1).

Hence, the averaged QQR estimates should be approximately equal to QR estimates. The estimates from QR and averaged QQR are plotted and summarized in Fig. 9. As can be observed, the intercept estimates coincide while the slope estimates follow a similar

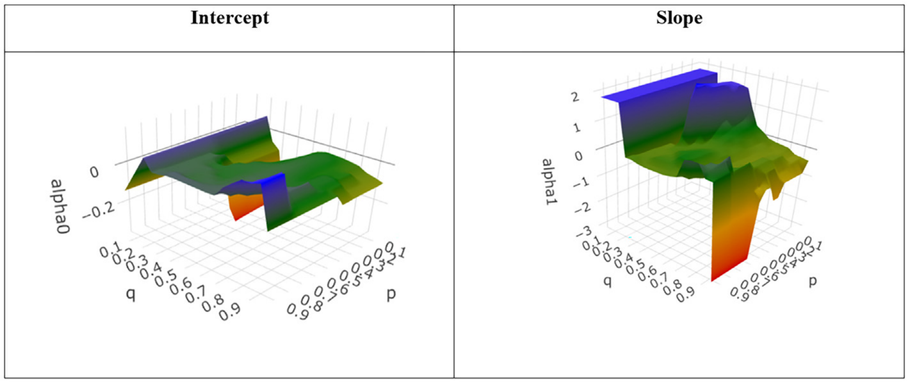

Fig. 7. QQR estimates for Russia (intercept and slope).

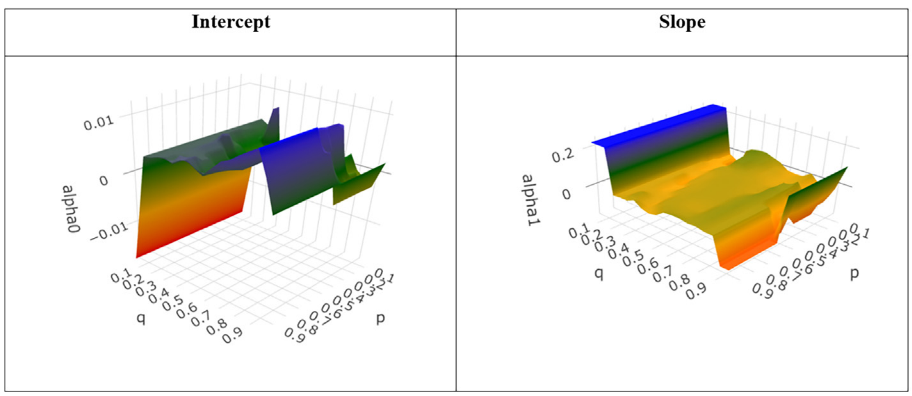

Fig. 8. QQR estimates for USA (intercept and slope).

trend approximately. Therefore, the applicability of the QQR methodology is justified.

4.1.2. CS-ARDL empirical results

The cross-sectional dependence and homogeneity assumptions were checked to achieve robust estimations for panel data analysis. The findings of cross-sectional dependence tests: CD_{LM} (Pesaran, 2004). Moreover, the bias-adjusted LM test (Pesaran et al., 2008) and slope homogeneity test (Pesaran and Yamagata, 2008) are given in Table 4. The null hypothesis of no cross-sectional dependence and no homogeneity are rejected at a 5% significance level, indicating methods based on cross-sectional dependence and slope heterogeneity shall be used for further analysis.

Further, the CIPS unit root test was applied to test the stationarity of variables. The findings reported in Table 5 indicated that the null hypothesis of unit root is rejected at a 5% level of significance for the GDP in the first differenced form. At the same time, NR was found stationary in level form.

The preliminary analysis shows different orders of stationarity, cross-sectional dependence, and slope heterogeneity suitable for the CS-ARDL approach's applicability.

The CS-ARDL model is applied to deal with country-specific coefficients, and the results of the estimation are summarized in Table 6 and Fig. 10. According to the results, NR consumption hurts GDP per capita growth, and this effect is significant at 5%, according to CS-ARDL. A 1% improvement in NR use decreases economic growth by 13%. The impact is negative and significant at a 5% level of significance. These results show that NR consumption results in a decrease in economic growth. The short-run coefficient provided similar results to the long-run coefficient. The coefficient of NR is negative and significant in the short run.

In addition to QQR and CS-ARDL estimation, the causal relationship between the variables was assessed by applying Granger non-causality test for heterogenous panels (Dumitrescu and Hurlin, 2012). The results reported in Table 7 and Fig. 11 indicate null hypothesis for non-causality was rejected, and the NR Granger caused GDP overall as well as country-specific for China and the USA at a 5% level of significance. However, the reverse causality from GDP to NR was insignificant for all countries.

4.2. Discussion of results

Our findings of QQR for China align with Haseeb et al. (2021), who applied the same quantile-to-quantile methodology for analysing the impact of natural resources rent of GDP on GDP/per capita in 5 Asian countries rich in natural resources and among them, China during 1870–2018. They have found a positive relationship between natural resources rent and economic growth, which is even more visible at high quantiles of these variables. These results are also supported by the findings of Ji et al. (2014), Li and Xiao (2019), and Li et al. (2019) for Chinese provinces. China benefits from extensive natural resources, and it uses them to boost economic growth. However, the efficient use of natural resources represents an important goal for China's authorities (Hao et al., 2019; Wang et al., 2019).

Russia can achieve economic growth even with small natural resources rent, but this rent should significantly increase during the recession. Russia is among the countries with the largest natural resources on the planet, together with China and USA. Zagozina (2014) found a positive effect of natural resources on economic growth in former Soviet Union states. Kubiniwa (2012) showed that Russia has benefited from the increased prices of natural com-

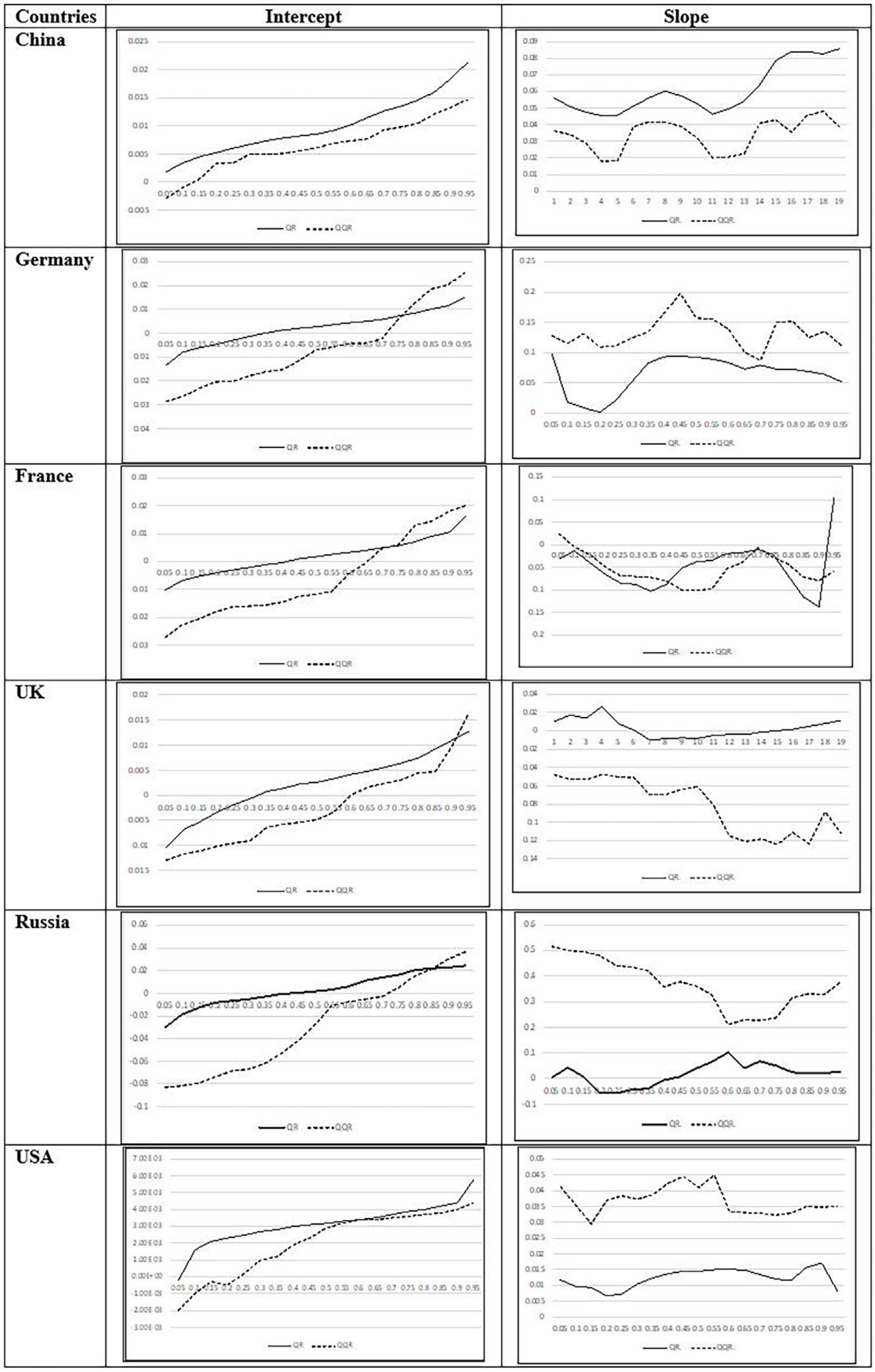

Fig. 9. Comparison of QQR and QR estimates for the countries under study.

Table 4
Cross-sectional dependence and slope homogeneity.

	Test	Statistic	*p*-value
Cross-sectional dependence	LM	278.3	<0.0001*
	LM adj	151.6	<0.0001*
	LM CD	16.41	<0.0001*
	Pesaran's – CD	19.791	<0.0001*
Slope homogeneity	Delta	6.215	<0.0001*
	Delta adj	6.529	<0.0001*

* *p*-values significant at a 5% level of significance.

Table 5
CIPS unit root test results.

	Level	First difference	Result
GDP	4.79 (1.000)	−5.361(<0.0001)*	I_1
NR	−2.43 (0.0075)*	–	I_0

* *p*-value significant at 5% level of significance.

Table 6
CS-ARDL estimation results.

	Coefficient	Statistics (*p*-value)
Short-run		
ΔGDP_{t-1}	−0.0277	−1.99 (0.046)*
ΔNR	−0.1347	−2.14 (0.032)*
Long-run		
NR	−0.133	−2.08 (0.038)*
Error correction	−1.0277	−73.85(<0.0001)*
F-statistics	1.76 (0.01)*	
Adjusted R^2	0.70	

* *p*-value significant at 5% level of significance.

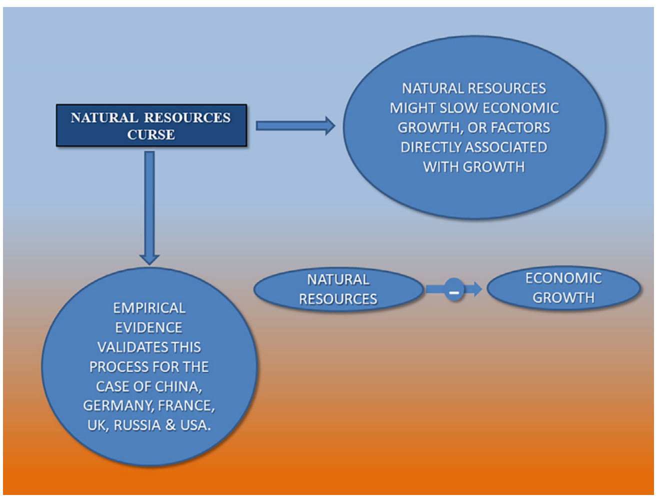

Fig. 10. Summarized results of the CS-ARDL estimations.

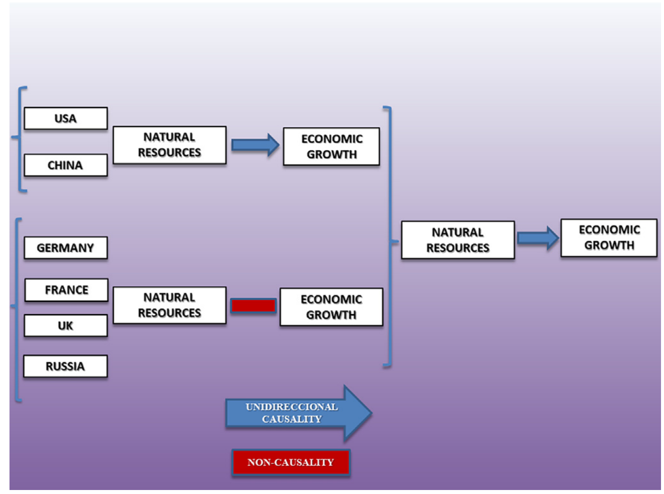

Fig. 11. Results of the Dumitresc-Hurlin causality test.

modities (oil and gas), although it displays a weak institutional framework.

Russia is a country with large natural mineral and gas resources. Gaddy and Ickes (2013) analyzed two periods: one for the Soviet Union and another for the Russian Federation. During the Soviet Union, the rents of natural resources were not much correlated with economic growth. Before the 1980s', the rents grew faster than GDP (because of the boom in oil prices). After rents collapsed in the 1980s, GDP continued to increase at the same pace as before, partly due to the maintenance of gas rents. Nowadays, rents and GDP growth are much more correlated in Russian Federation, although the rents are much higher now than in the 70s–80s. The increase in oil prices after 1998 supported Russia's steady economic growth

Table 7
Granger causality results of *X* cause *Y* ($X \rightarrow Y$).

S. No	Country	Statistic (*p*-value)	GDP → NR	NR → GDP
1	China	$\bar{W}$	1.712	4.048
		$\bar{Z}$	0.504 (0.614)	2.156 (0.031)*
		$\bar{Z}-tilde$	0.393 (0.694)	1.839 (0.066)*
2	Germany	$\bar{W}$	0.071	0.146
		$\bar{Z}$	−0.657 (0.511)	−0.604 (0.545)
		$\bar{Z}-tilde$	−0.623 (0.533)	−0.576 (0.564)
3	France	$\bar{W}$	0.796	0.435
		$\bar{Z}$	−0.145 (0.885)	−0.399 (0.689)
		$\bar{Z}-tilde$	−0.174 (0.862)	−0.397 (0.691)
4	UK	$\bar{W}$	0.108	0.093
		$\bar{Z}$	−0.630 (0.528)	−0.642 (0.521)
		$\bar{Z}-tilde$	−0.599 (0.549)	−0.609 (0.542)
5	Russia	$\bar{W}$	0.734	2.703
		$\bar{Z}$	−0.188 (0.851)	1.204 (0.228)
		$\bar{Z}-tilde$	−0.212 (0.832)	1.0068 (0.314)
6	USA	$\bar{W}$	1.385	11.235
		$\bar{Z}$	0.272 (0.786)	7.237 (<0.001)*
		$\bar{Z}-tilde$	0.191 (0.849)	6.289 (<0.001)*
Overall		$\bar{W}$	0.801	3.11
		$\bar{Z}$	−0.345 (0.730)	3.654 (0.0003)*
		$\bar{Z}-tilde$	−0.418 (0.656)	3.083 (0.002)*

* *p*-value significant at 5% level of significance.

since Russia is one of the leading players in the energy market worldwide (Yamawaki, 2016). Sapir (2005) has demonstrated that the "Dutch Disease" effect was present after 1998 because of its high dependence on oil for its economic growth, which led to a decrease in employment in the manufacturing sectors and a rise in the services sectors that were underdeveloped in the communist era (Dobrynskaya and Turkisch, 2010), although the industrial production has increased (Ahrend, 2005). So, Russia experienced growth due to increased internal demand and the high competitiveness of its products in the external markets, but part of this growth was determined by the high inefficiency of the industrial sectors during the Soviet era (Ahrend, 2005). Alexeev and Conrad (2011) also found little evidence for Dutch disease in Russia, investigating the relation between oil resources and economic growth. Russia faced great pressure from the appreciation of its currency due to its exports being dependent on resources, which caused some serious challenges for the monetary policy (Anon, 2006). Direct taxation of the natural resources sector somehow alleviated the burden on the manufacturing industry, and the creation of the stabilization fund was aimed at protecting the economy against socks in oil prices (Tompson, 2005; Gianella, 2007). Rent-seeking effects in Russia are determined not by an economic factor but by a weak legal system, lax property rights system, and the control and ownership in the natural resources sectors (Frayne, 2012). The gas sector is controlled by Gazprom, while the oil sector is private-owned. This can explain the gas sector's stagnation and the oil sector's significant growth (Anon, 2006; Ahrend et al., 2007). The government's interference in the energy sector inhibits foreign investments or reinvesting profit because of existing restrictions and unclear legal norms (Dobrynskaya and Turkisch, 2009). However, the bad management of the state-owned energy sector in Russia supported the development of the manufacturing sector, attracted foreign investments, and prevented Dutch Disease at some level. With the privatization of its oil sector, Russia is better positioned than the other emerging markets with abundant natural resources (Tompson, 2005; Dobrynskaya and Turkisch, 2009). However, the situation in Russia is quite different from that of other countries, such as the UK, which faced a resource shock due to resource discovery. Moreover, Russia inherited from the communist era a sound industrial infrastructure that was protected somehow from Dutch Disease (Frayne, 2012).

Jović et al. (2016) investigated the sensitivity of economic growth to the natural resources rent, such as mineral rent, coal rent, forest rent, natural gas rent, and oil rent as a share of GDP for EU countries. The results demonstrated a significant impact of natural resources on economic growth for European countries. Results supporting the natural curse hypothesis and causality between natural resources rent and economic growth were achieved by James and Aadland (2011) for US, and by Fang et al. (2009) for China.

The findings of CS-ARDL estimations are supported by previous research such as Papyrakis and Gerlagh (2007) for the US, Zhang et al. (2008), Shao and Qi (2009) for Chinese provinces, and Starr (2006), Meissner (2010), Franke et al. (2009) or Amineh (2006) for former Soviet Union states. Havranek et al. (2016) also performed a *meta*-analysis of many studies elaborated on this topic and concluded that the studies that found a negative effect between natural resources and economic growth were much more than the ones that found a positive effect. Shahbaz et al. (2019) investigated the resource-growth link in the US economy and found that natural resources, especially oil resources, negatively impact economic growth in the long run. Gerelmaa and Kotani (2016) investigated the relationship between natural resources and economic growth for 182 economies from 1970 to 2010 using quantile regression. Between 1970 and 1980, the Dutch disease effect was demonstrated, but from 1990 up to 2010, the increase in natural resources determined a positive impact on economic growth.

Shabbir et al. (2020) found the same uni-directional causality between natural resources (water and forestry resources) and GDP growth in Pakistan based on data during 1972–2016 as we did for the overall panel, for China and USA.

5. Conclusions and policy recommendations

5.1. Conclusions

Considering the lack of consensus among researchers on the effect of natural resources on economic growth and the so-called resource curse, this research aimed to check the relationship between natural resources and economic growth in top wealthy largest P5 + 1 economies (China, the US, France, the UK, Russia, and Germany). This panel includes the world's most significant and more robust economies, and some of them also rank in the top positions considering the natural resources endowment (China, the US, and Russia). We have applied a quantile-on-quantile analysis, a CS-ARDL for the panel, and a Dumitrescu-Hurlin panel causality test for heterogeneous panels. The robustness of the panel estimations was checked using $CD_{LM,}$ bias-adjusted LM test, and slope homogeneity test.

The results of the CS-ARDL for the entire panel show that both in the long-run and in the short-run, the impact of natural resources on economic growth is significant and negative. However, for each country included in the panel, the results of quantile-on-quantile regression display some differences. In China, this relation is positive for all analyzed quantiles. In Germany and Russia, the effect of natural resources on economic growth was positive for lower quantiles of natural resources and all quantiles of economic growth. Germany and Russia will achieve economic growth even with low natural resources rent.

On the other hand, for Germany and Russia, the slope coefficient was negative for higher quantiles of natural resources and lower quantiles of economic growth, which means that the rent of natural resources should be high to support economic growth during the recession periods. For France, a positive relation was found both at lower quantiles of natural resources and GDP and at higher quantiles of natural resources and GDP. A slight increase in rent causes economic growth during boom periods, and a significant rent increase determines economic growth during recession periods. For the UK, a positive relationship was found between median and higher quantiles of natural resources and all quantiles of GDP. The slope coefficient was negative for lower quantiles of natural resources and all quantiles of GDP. Even with a low rent increase for natural resources, the UK will still achieve economic growth during the recession or boom periods. For the US, the coefficients were positive for all quantiles of natural resources or GDP. The results of the causality analysis show that natural resources can predict economic growth for China and US, and the overall panel. The reverse causality from economic growth to natural resources was insignificant for all the countries and the entire panel.

For all quantiles, a positive relationship between natural resources and economic growth was observed for China and the US. These are countries affluent in natural resources. In Germany and Russia, a significant rent increase is necessary to fight recession times, although Russia also displays large reserves of natural resources and China and the US. The UK achieves economic growth even with a slight increase in rent due to large resource discovery. France displays smaller natural resources than the other countries included in this panel, mainly arable land, and it needs high increases in rent to fight the recession. For the overall panel, an adverse effect of natural resources on economic growth was found.

5.2. Policy recommendations

Decoupling natural resources from economic growth is an SDG goal on Agenda 2030 (SDG-12) for mitigating environmental deterioration and ensuring the well-being of people through better management of waste in many economic sectors, the most important being the construction and tourism sectors.

China's government adopted a plan for a more balanced economy and better conservation of its natural resources, including a stimulus package for green targets and decoupling resources used from economic activity (UNEP, 2013). China also adopted a circular economy approach to achieving sustainable development. It ranks among the top countries (Germany and US) regarding renewable energy use based on solar and wind energy. Still, China needs better policy enforcement and implementation at the local authorities' level, better monitoring, and more technical, financial, and human resources allocated for these aims. Moreover, China has become largely dependent on imports, especially metals, because of its increasing consumption, making it vulnerable to the volatility of commodity prices. China's position as a consumer and producer of metals will somehow restrain its market interventions. Still, China will play a major role in the metals market and settling their price.

The US offers stable and low-cost energy sources. It hosts major petroleum, gas, and oil producers and has many renewable energy sources, from wind, sun, and water up to biodiesel. The US has large arable lands and forest land, and timber production supports many industries. It is a world leader in agriculture innovation and the largest food producer and exporter.

However, climate change has begun to impact agricultural resources worldwide significantly negatively. This will threaten international food prices and international fossil fuel prices. Other threats are represented by population growth and the rise of consumption in emerging markets, weak governance of resource producers, decreasing production from the existing producers, and tighter supply conditions. Water availability, volatility of international food prices and oil prices, and disrupted physical access to critical fuels and/or minerals are considered the major threats to the US. In contrast, energy and food resources threaten China's water availability. Russia deals with food security and is exposed to the volatility of international food prices. Russia should attract foreign investments in the gas sector to avoid being exposed to volatile gas prices and adverse economic shocks because of investment risks in crisis periods. It should consolidate its macroeconomic policies for long-term economic growth (Anon, 2006). European Union countries display the lowest risk in this field, but most depend on importing gas from Russia, which can be considered a great exposure. So, European countries should invest in wind and solar projects, use bioenergy and nuclear energy, impose a short-term tax on profits to protect consumers against high electricity prices, and improve energy efficiency in buildings and industry. Some natural assets have critical thresholds, so governments should intervene so that the prices reflect the actual environmental cost. Otherwise, the natural resources will not be allocated or consumed sustainably.

Tensions between USA-Europe-China caused by the increasing commercial deficits exert more constraints on the balanced development and management of natural resources. Although these countries can use alternative energy sources as renewables (wind, hydroelectric) or nuclear energy sources, they have their own environmental concerns (Ramkumar et al., 2021).

Moreover, climate change affects all the countries around the world. To ensure resource availability, it is necessary to grant access to natural resources in terms of exports and investments, grant subsidies for resource extraction, adopt trade measures (tariffs, quotas), and stimulate investments in infrastructure and innovation in this particular field to correct market failures (National Intelligence Council Report, 2013). Legislation should be adapted to diminish the administrative burden on business, support innovation, and represent a coherent and adequate regulatory framework in the long run. Investments in innovation using public–private partnerships, granting incentives for innovation, and providing opportunities for environmental sectors will support long-term economic growth.

Natural resource consumption depends on demographic factors and economic development. According to the IEA, energy demand is projected to increase by 50% by 2030 (National Intelligence Council Report, 2013). According to UNEP, the annual consumption of minerals, fossil fuels, and biomass could increase three times by 2050. Increased income, population growth, and the growth of manufacturing sectors in developing countries (China, Russia) have led to a significant increase in consumption, determining the depletion of resources. Emerging markets dominate the resource production of all types, except the US, in the field of agricultural products. These structural changes in resource production will erode OECD countries' position, especially in energy. Commodity markets attract 2/3 of total FDI inflows, mainly in the emerging markets in mining, quarrying, and petroleum (National Intelligence Council Report, 2013). Natural resources are essential assets, especially for emerging countries, and emerging markets have become large importers of natural resources, making resource management crucial. Authorities that design and implement economic policies in developed and developing countries and cooperation agencies have an important role in managing natural resources, especially in emerging countries, for sustainable economic growth. This can be attained by financing programs elaborated for the community-based co-operatives or organizations that operate natural resources, clearly settling resource rights of the people and resource management rights, or elaborating multilateral environmental agreements that address the poor's needs (OECD, 2008).

Further research should discuss and compare the effect of resource abundance and resource dependence on economic growth in P5 + 1 countries. It should also be interesting to compare the impact of natural resources rent on the economic growth of natural resources such as minerals, fuels or raw materials because the countries included in this panel display different types of natural resources. The effect of institutional factors can also be investigated because China and Russia's situation is different from the other four countries included in this panel. Also, the panel could consist of top countries rich in resources to study the effect of natural resources rent on economic growth in the long run.

CRediT authorship contribution statement

Sanjeet Singh: Conceptualization, Formal analysis. **Gagan Deep Sharma:** Investigation, Conceptualization. **Magdalena Radulescu:** Investigation, Writing – original draft. **Daniel Balsalobre-Lorente:** Validation, Writing – review & editing. **Pooja Bansal:** Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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