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Natural ressources and innovation: A new insight

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ABSTRACT
The natural resource abundance and innovation is an emerging debate, and the literature has not yet provided all the elements to refute or confirm if natural resources are cursing or blessing . This article inspects the outcome of natural resources on innovation capacity. The data came from secondary sources collected over the period 1996-2015 in a range of 58 developing and developed countries. Applying ordinary least squares regression, the result shows that (1) abundance of natural resources negatively affects innovative ability; However, considering the sorts of resources, (2) petroleum, forestry gas rent reduce the ability to innovate, while mining and coal rent increase this capacity; (3) The results also show that official development assistance not targeted at local innovation systems and poor institutional quality are mechanisms through which natural resources abundance negatively impacts innovative capacity; (4) Finally, considering heterogeneity between countries, the results also show that the natural resources abundance positively impacts the innovation capacities in low-income economies, while discouraging innovation in high-income economies. Therefore, to improve innovative capacity in resource-dependent, the governments of developed countries should direct official development assistance in developing countries to the local innovation system. In return, developing countries must improve the quality of their institutions.

Contribution/Originality: This work contributes to the debate on the relationship between natural resource abundance and innovation in developing and developed countries. It demonstrates that how the abundance of natural resources can harm or bless the capacity to innovation.

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1. BACKGROUND

Natural resources are important factors for the ability to innovate. They can either increase prosperity or inhibit a country's economic growth (Brunnschweiler, 2008). Empirical studies with different specifications and data have been ambiguous in many ways as to whether natural resources are cursing or blessing (Konte, 2013; Ploeg, 2011). Since Sachs and Warner (1995) concluded that resource-rich nations have outperformed their resource-poor counterparts in development, several studies seem to have tested this hypothesis with mixed results. However, a dominant trend seems to be emerging around the resource curse. This trend is based on the fact that the higher the percentage of resource rents in GDP, the more likely countries are to adopt policies of rent redistribution by raising labor costs at the expense of economic diversification and encouraging entrepreneurial mechanisms (Auty, 2005; Sachs & Warner, 1995).

This dilemma is also reflected in the natural resources and innovation nexus. The results of Chen, Wang, and Li (2020) show that for every 1% increase in a region's natural resource wealth, the region's innovation capacity decreases by 18.94%. The authors explain that resource-rich regions attract an influx of local workers engaged in the exploitation of natural resources, leading to a weakening of the region's innovative capacity (Chen et al., 2020). Kamguia, Keneck-

Massil, Nvuh-Njoya, and Tadadjeu (2022) complemented these results by showing that natural resource negatively affects research and development spending. In addition, previous studies show that in nations or regions rich with natural resources, the part of government spending on education as a percentage of national income, the expected number of school years for girls, and the gross enrollment rate in secondary schools are inversely proportional to the part of natural capital in the country's national prosperity. Thus, it appears that natural capital crowds out human capital and slows down the development of economic activity (Chen et al., 2020; Gylfason, 2001; Kamguia et al., 2022; Sun, Sun, Geng, & Kong, 2018).

However, even if this dominant trend seems to confirm the cursing of natural resource (Sachs & Warner, 1995) a comparative analysis of some resource-rich countries still leads to a cautious attitude towards the link between natural resources and innovative capacity. This is true of pre-collapse countries like Botswana, Norway, Canada, Indonesia and Venezuela that made the most of natural resources and developed successful national innovation systems (Auty, 2005, 2017). Another unsurprising example is the United Arab Emirates, which is harnessing natural resources by setting up sovereign wealth funds, which in turn make it possible to fund innovation activities and the development of smart cities like Dubai. Similarly, Shahbaz, Destek, Okumus, and Sinha (2019) show for the United States case that natural resources abundance has led to financial development, which is a proven driver of innovation (Khan, Hussain, Shahbaz, Yang, & Jiao, 2020). In fact, Khan et al. (2020) show that combining natural resources with innovation can have positive effects on financial sector development. Recently, authors have shown that good quality of institutions and human capital are instruments to alleviate the negative impact of natural resources on innovative capacity (Kamguia et al., 2022). Given the above considerations, it seems clear that natural resource abundance and innovation nexus is an emerging debate, to which the literature has not yet provided all the elements to refute or confirm whether natural resources are cursing or blessing. Thus, this study contributes to the debate mainly by trying to fill these gaps. It offers a clear answer that can illustrate how the abundance of natural resources can harm or bless the capacity to innovation.

2. LITERATURE REVIEW

In this section, we provide some theoretical elements to improve the understanding of link between resource endowments and innovation. In fact, the influence of natural resources endowment on economic growth is an old debate, and the underlying theme of this debate is the quantity and quality of natural resources and their importance as engines of economic growth. There has long been a tendency to believe that endowment with natural resources promotes economic growth and improves nations' ability to innovate. This intuition goes back to Adam Smith's theory of absolute advantage. According to Smith, an economy has absolute advantage in manufacturing a good if it can produce that good at an inferior cost than another economy because of endowment with natural resources and the availability of other production factors. Basically, natural resources are the core element for technological innovation and economical production (Miao, Fang, Sun, & Luo, 2017).

However, since Sachs and Warner (1995) showed that growth is inversely related to resource endowment, the supposed natural resource curse has received considerable scholarly attention (Hodler, 2006). Much work suggests that natural resource richness can be considerate as cursing (Gylfason, 2001; Sachs & Warner, 2001). Furthermore, analyzing both the direct and indirect influence of natural resources on growth outcomes and investments in physical and human capital, many authors has been provided evidence of the resource curse (Konte, 2013; Leite & Weidmann, 2002; Papyrakis & Gerlagh, 2004, 2007). Specifically, articles explain that economies with a high part of export earnings from the natural resource sector tend to have poor economic performance (Shahbaz et al., 2019; Shahbaz, Naeem, Ahad, & Tahir, 2018). Other empirical results have noted the existence of this negative correlation, but it is mitigated by trade openness, human capital, and the development of financial sector (Khan et al., 2020; Shahbaz et al., 2019).

Another group of researchers has done extensive research concerning natural resources rents and innovative ability nexus (Auty, 2005; Chen et al., 2020; Kamguia et al., 2022) and the results are consistent with rent-cycle theory. According to this theory, the higher the share of rents from natural resources to Gross domestic product (GDP), the more likely countries are to follow rent-distribution policies at the expense of funding research and innovation and entrepreneurial activities. In other words, the distribution of pensions, to the detriment of the emergence of innovative capacity through entrepreneurial mechanisms, creates economic distortions and market failures, which makes countries vulnerable to external shocks and commodity price volatility. Changes in the cost of natural resources, increased collapse of national innovation systems. Although the natural resource curse thesis is inherent in the innovation process and economic development, previous research has begun to empirically identify conditions in which cursing of natural resource can be transformed into a boon for resource-rich economies (Andersen & Aslaksen, 2008; Collier & Hoeffler, 2009; Konte, 2013; Mehlum, Moene, & Torvik, 2006). In this regard, some studies have concluded that resource-rich nations need to diversify their economies to avoid the natural resource curse (Gylfason, 2006). Thus, this paper follows previous line of research, showing two main channels for attenuating the natural resource curse hypothesis and encouraging innovative capacity. The first channel is official development assistance (ODA). In fact, ODA is one of the levers that rich economies use to help poor economies to improve the living conditions of the population and enable economic and institutional development (Alemu & Lee, 2015). As Morrissey (2001) points out, ODA increases the ability to import capital goods; increases investment in physical and human capital; which can put pressure on resources (Lee, Choi, Lee, & Jin, 2020). Thus, the indirect effect of ODA on innovation stems from the fact that the bulk of ODA is spent on technology transfer and investment in information and communication technologies (ICT) (Kim & Jang, 2012) which hampers innovation (Kumar, 2009). For instance, Tigabu, Berkhout, and van Beukering (2017) find that ODA has been instrumental in influencing important innovation actions linked to enhanced cookstoves in Rwanda and Kenya. However, contributor subsidy has mainly concentrated on the improvement and dissemination of technological knowledge. The authors also note that model base on ODA has not encouraged balanced and effective technological and local innovation systems. Contrary, this model has conducted to the failure of the large-scale deployment of improved cooktops. In addition, the process of technology transfer within official development assistance (Motoki & Taichi, 1999) relies on a policy of patenting and intellectual property rights protection, sometimes at odds with the objectives of the local innovation system. This debate is often framed in a North-South context, where the prevailing view is that Southern economies tend to bear the costs of implementing intellectual property right (IPR) systems, which limits their ability to innovate (Branstetter, 2006; Dinopoulos & Segerstrom, 2010). The reason for this loss is that intellectual property protection will increase the market power of innovative firms in the North and raise prices in developing countries (Chin & Grossman, 1990). Therefore, even taking into account general equilibrium factors, the South does not necessarily benefit from an increase in innovative capacity, in part due to the negative terms-of-trade effect and the possible slowdown of Northern innovation over time. Therefore, one can conclude that foreign official aid is the channel through which natural resources impede innovation.

The second channel that negatively connects natural resources to innovation is the quality of institutions. Indeed, recent works paid more care to the effect of institutional quality on economic growth (Tran, Le, & Nguyen, 2021; Wandeda, Masai, & Nyandemo, 2021). Other work has focused on the social and political characteristics of a society that impact the nexus between natural resources and economic growth (Mideksa, 2013; Tsani, 2013). One approach has been to assume that institutions are endogenous to natural resources (Gylfason & Zoega, 2006). Rent-seeking models suggest, for example, that natural resources degrade institutional qualities (Isham, Woolcock, Pritchett, & Busby, 2005) and attract entrepreneurs from productive sectors to rent-seeking activities (Canh, Kim, & Thanh, 2020; Torvik, 2002). An alternative approach is to view natural resource endowment as a cause of poor economic performance, political instability, and poor institutional quality (Dwumfour & Ntow-Gyamfi, 2018; Olsson, 2003). For example, in the 1990s, numerous armed groups trusted on natural resources revenue to fund conflict and shape power strategies around valuable resource areas and trade networks (Le Billon, 2001). In some cases, one can also imagine situations where political leaders use the rents from natural resources to assert their sovereignty instead of investing in high value-added sectors such as knowledge and innovation (Auty, 2005; Chen et al., 2020). From this perspective, Becker-Blease (2011) finds that only agreements that managers and directors actively hold have a positive association with innovation; weak institutional quality is generally negatively linked with innovation. Furthermore, the results of Konte (2013) show that good quality of institutions plays a significant role in the process of transforming the natural resource curse into blessing. Kamguia et al. (2022) find that institutional quality and human capital allow to mitigate the cursing of natural resource on innovation. Given the above literature research, the following hypotheses are formulated:

Hypothesis 1: Abundance of natural resources negatively influences the ability to innovate.

Hypothesis 2: Institutional quality and official development assistance are the potential channels through which natural resources negatively affect innovative capacity.

3. METHODOLOGY

3.1. Data

This section describes the variables and data sources for the empirical part of our study. This study measures the influence of natural resources on innovation capacity. To this end, this study includes 58 developed and developing nations. The time period is between 1996 and 2015. The raisons to choice these nations and times depends on the availability of data. The data used for dependent, independent, and control variables is selected from multiple sources, including World Governance Indicators (WGI) and World Development Indicators (WDI).

3.2. Keys Variables of the Study

3.2.1. Dependent Variable

The dependent variable of this study is innovation. Indeed, innovation is a term denoting the product of new goods, processes and ideas (Burrus, Graham, & Jones, 2018). It is also a process leading to an outcome: this outcome is, by definition, new in the sense that it is an object or practice that did not exist before (Burrus et al., 2018). Innovation can also be viewed as the fabrication of goods that are labor and capital intensive. The most commonly used data on innovation activity is the part of research and development (R&D) spending in GDP (Pegkas, Staikouras, & Tsamadias, 2019; Thompson, 2018). This variable measures gross domestic expenditure on R&D as a percentage of GDP. They take account both capital and current expenditures across the following sectors: corporate, public, higher education, and private non-profit organizations.

In fact, it is no easy to measure innovation activity with a sole dimension. Indeed, Oltra, Kemp, and De Vries (2010) point out that R&D spending is a useful measure of a national level of innovative capacity and technological development, since data for many regions is readily available over a long period of time. But Sweet and Maggio (2015) emphasize that the index of economic complexity is an innovation measure that captures both tangible and intangible innovation outcomes. Therefore, following Kumar and Singh (2019) another innovation proxy is used, explicitly the Economic Complexity Index (ECI). According to Sweet and Maggio (2015) innovation is a cumulative process, achieved through the accumulation of both tacit and explicit knowledge, and using research and development spending. Thus, patent and R&D expenditure use as an indicator of innovation reflect only the explicit component of innovative activities. The ECI indicates the level of development of a nation's exports and is calculated based on the diversity of a country's output (Hausmann et al., 2014). Sweet and Maggio (2015) emphasize that the ECI is an innovation measure that not only captures the tangible innovation output or production, but also reflects intangible outputs and innovations. An improvement in the complexity index shows a nation's ability to combine vast amounts of information between individuals and firms to generate a range of innovative products.

3.2.2. Explanatory Variable

Our main independent variable is natural resource rents. This variable measures total resource rents as a percentage of GDP and is derived from the World Bank Indicator (2021). It represents a set of five natural resource rents: oil, forestry, gas, coal and mining. This indicator has been widely used in the resource curse literature (Sachs & Warner, 2001; Tigabu et al., 2017).To control for natural resource heterogeneity, the study decomposes the initial measure to examine how each type of natural resource influences innovation.

3.2.3. Control Variables

To control the quality of our finding, the paper examines a number of variables that are considered determinants of innovation in the literature. These variables can be divided into three groups. The first one includes macroeconomic variables including financial development (Aghion & Howitt, 2005) openness to trade (Bloom, Draca, & Van Reenen, 2016) education (Rodríguez‐Pose & Wilkie, 2019) entrepreneurship (Anokhin & Schulze, 2009). The second category concerns demographic variables, approximated by population density (Gopalan & Rajan, 2016). Finally, the paper includes institutional variables (Cirera & Maloney, 2017; Dincer, 2019). Table 1A in the appendix presents all study variables, including some descriptions and sources.

3.3. The Econometric Model Specification

The reasoning in this subsection makes it possible to identify two variables (foreign aid (% GDP) and institutional quality) as potential channels through which the natural resource curse could be transformed into a boon. In line with the literature (Bhattacharyya & Hodler, 2014; Carmignani & Avom, 2010; Munyanyi & Churchill, 2022) a two-step approach is used to study the validity of these variables as a mechanism. In order for a variable to qualify as a transmission channel, it must first be significantly correlated with natural resources (Equation 1). Then, in the second step, after introducing the potential transmission channel as an additional covariate in the regression linking natural resources to innovation, the coefficient associated with natural resources must decrease in magnitude or importance (Equation 2). Given the above, the following models are formulated:

$$U_{i,t} = \alpha + \gamma_1 \text{nat\_ressources}_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$R\&D_{i,t} = \alpha + \beta_1 \text{nat\_ressources}_{i,t} + \beta_2 Z_{i,t} + \beta_3 U_{i,t} + \varepsilon_{i,t} \quad (2)$$

Where $U_{i,t}$ is the vector of transmission channels (institutional quality and aid development assistance), $R\&D_{i,t}$ represents innovation measurement, $\text{nat\_ressources}_{i,t}$ represents natural resources and $Z_{i,t}$ represents the vector of control variable, and $\varepsilon_{i,t}$ represents the error term. i is the country dimension and t is the time dimension. γ_1 and β_i is the coefficient to be estimated. In fact, models (1) and (2) allow to confirm or not the second hypothesis. In practice, as the name suggests, these equations are estimated one by one: two-step approach. However, with the development of data analysis software, these equations can be estimated more easily, and the appropriate estimation technique is Ordinary Least Squares (OLS) .

4. RESULTS

In this section, the empirical results are presented and discussed. First, the results of the preliminary analysis. Second, the OLS estimates are presented, with Panel A considering R&D expenditure as a measure for innovation. Then, in a third step, the robustness analyzes are presented, with panel B considering the economic complexity index as alternative measure for innovation. Finally, the section ends with the transmission path results.

4.1. Preliminary Analysis

The results of the preliminary tests of this study are articulated around three points. The first sheds light on the descriptive statistics for all the study's variables (Table 1). As for the second, it presents a negative link between innovation and the measurement of rent from natural resources for all countries in the sample (Figure 1). Finaly, the third sheds light on the correlation analysis taking into account the nation's economic growth (Figure 2).

Table 1. Summary statistics.

Variables	Obs.	Mean	Std. dev.
Research and development	974	-0.204	1.023
Total natural resources rents	1139	-0.208	2.087
ECI_	969	-0.365	0.754
Oil rents	1139	1.795	4.049
Gas rents	1139	0.311	0.725
Forest rents	1139	0.364	0.64
Coal rents	1139	0.33	1.321
Mineral rents	1139	0.425	1.536
Trade	1139	4.263	0.538
Education	1140	1.866	0.153
Popdensity	1140	4.196	1.395
Dcredittoprivatesecto	1034	3.928	0.795
Selft	1140	3.063	0.661
ODA	502	2.261	1.377

This result tends to validate the natural resource curse hypothesis. However, when the sample is broken down into stages of development (low-income and high-income countries), heterogeneity emerges. Figure 2 shows that natural resources are positively correlated to innovation in low-income nations and a negative correlation in high-income nations. However, since correlation does not imply causation, the paper proceeds with an explanatory analysis.

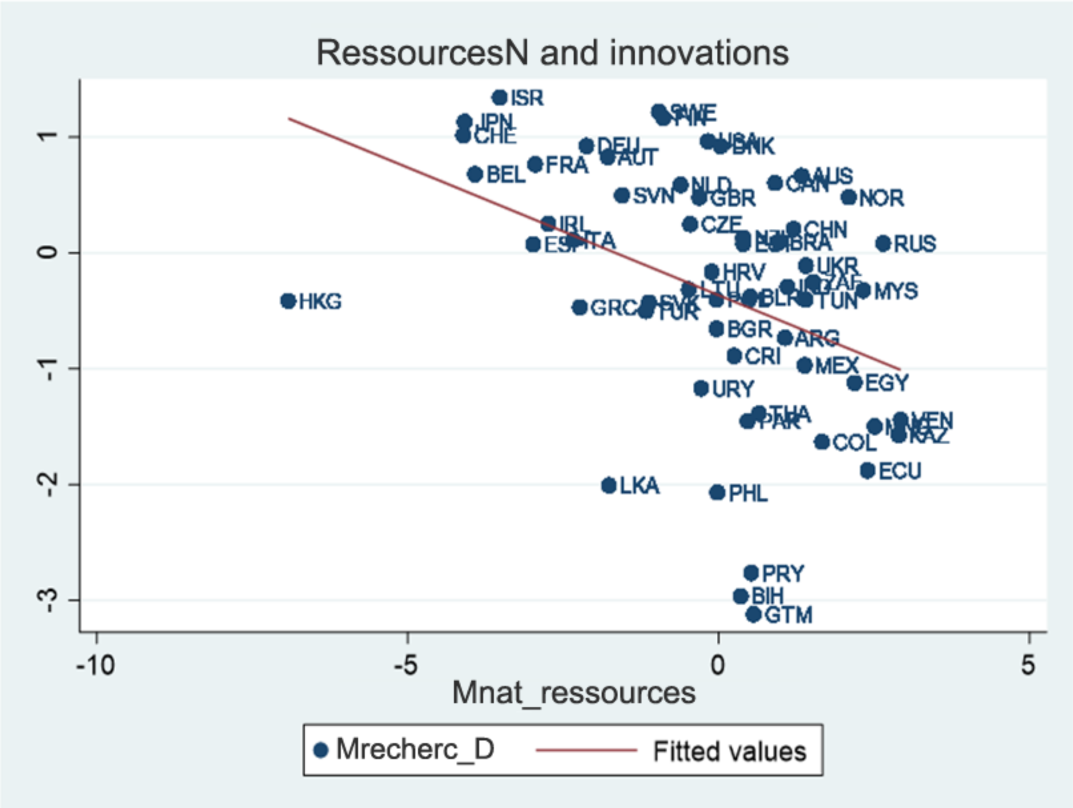

Figure 1. Natural resources and innovation.

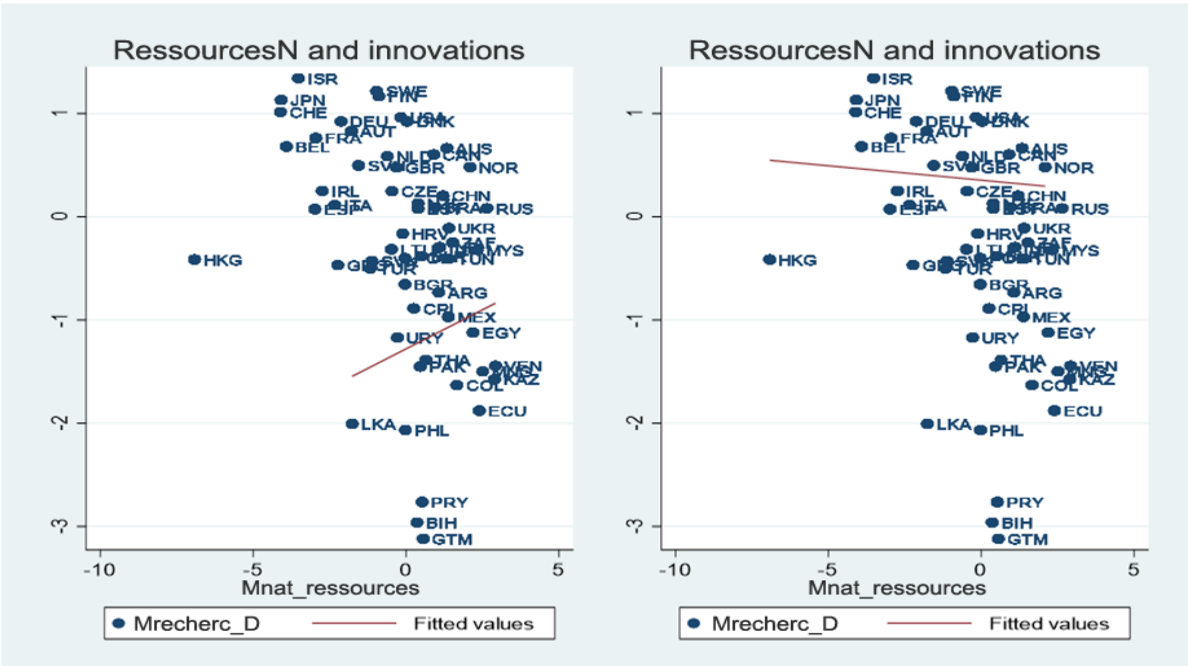

Figure 2. Presentation of the correlation analysis taking into account the nation's economic growth.

4.2. Estimation of the Basic Model

As mentioned above, the main variable is rent from natural resources. To account for time effects, time dummies are included in all models. Table 2 shows the results obtained from OLS.

Table 2. Effect of natural resources on innovation (OLS, 58 countries).

Variables	R&D	R&D	R&D	R&D	R&D	R&D
Nat_ressources	-0.2056*** (0.0150)	-0.2155*** (0.0135)	-0.2130*** (0.0135)	-0.2763*** (0.0157)	-0.1440*** (0.0145)	-0.0755*** (0.0151)
Trade		-0.1549*** (0.0491)	-0.1646*** (0.0497)	-0.1066** (0.0505)	-0.3875*** (0.0403)	-0.4247*** (0.0396)
S_education			0.3159 (0.2065)	14.9448*** (2.5863)	12.9192*** (2.1571)	9.8473*** (2.0221)
Popdensity				-0.1439*** (0.0295)	0.0008 (0.0239)	-0.0122 (0.0226)
Selft					-0.9164*** (0.0447)	-0.8453*** (0.0411)
Dcredittoprivatesecto						0.4658*** (0.0534)
Constant	-0.3754*** (0.1285)	0.2479 (0.2366)	-0.3006 (0.4338)	-13.7000*** (2.4431)	-7.9107*** (2.0691)	-7.1503*** (1.8747)
Observations	974	974	974	974	974	876
R-squared	0.1779	0.1842	0.1861	0.2270	0.4960	0.5883
Time effect	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses (*** p<0.01, ** p<0.05).

Column 1 shows the results of a bivariate model where the dependent variable is the indicator of R&D spending. In this column, the link is tested without control variables. Here, the main finding shows negative impact of natural resource abundance on R&D spending. The coefficient related to natural resource abundance is negative and significant at 1%, signifying that a 10% increase in natural resource abundance leads to an average 0.20% deterioration in innovation, if everything is equal. This result confirms the natural resource curse thesis previously proposed by Chen et al. (2020) in the context of China; and that of Kamguia et al. (2022) on a large group of 82 developed and developing countries. This result could be explained by the fact that politicians in developing countries prefer to redistribute the rent from the sale of natural resources, particularly through an increase in the wage bill, rather than diversifying their economies through investment in human capital, entrepreneurship and R&D spending. Nonetheless, the hypothesis of the curse of natural resources can only be accepted in developed countries under the hypothesis of economic saturation. Indeed, during the "thirty glorious", a period marked by the emergence of waves of technological innovation, the industrialized countries reached a certain degree of economic saturation with regard to the use of natural resources. By the end of the 1990s, these nations began to experiment with less natural resource-intensive and more human capital-intensive models of innovation. Although our findings prevent the empirical validation of such claims, a number of control variables were introduced into the base model to make our results a little more meaningful. Thus, columns 2-6 of Table 2 show that the introduction of the control variable does not change the basic result. In other words, one can still observe negative and significant nexus between natural resource abundance and innovation capacity at the 1%. In addition, one can observe a progressive improvement in the R-squared, evidence that the introduction of these variables brings additional information to our basic model. In addition, column 6 of the table shows that the coefficient related to the variable of interest becomes less and less important, also indicating that the control variables have a mitigating effect on the resource influence on innovation. According to control variables, finding shows positive and significant association between education and innovation, suggesting that an increase in 10% of the year's number of education is related with a 12.91% increase in the level of innovation (column 5, Table 2).

Furthermore, paper find that in the presence of education, the coefficient associated with natural resources becomes lower, consistent with evidence from endogenous growth theory (Barro, 1990; Romer, 1990) which shows that human capital is the material that natural resources need transformed into fuel for innovation. Recently, Kamguia et al. (2022) state that human capital is a mechanism to mitigate the negative effect of natural resource abundance on innovative ability. The paper also finds that a 10% increase in external openness reduces the ability to innovate by 42 percentage points, all things being equal. This result is in contradiction to previous work. Indeed, in analyzing a dynamic game among natural resource exporting and an importing nation, Harris and Vickers (1995) find that the importer's R&D effort increases over time.The paper also finds that the self-employment variable, which captures entrepreneurship, negatively affects innovative ability. This result reinforces the natural resource curse thesis and shows that given the abundance of natural resources, people tend to move from productive sphere such as entrepreneurship and business creation to non-productive sphere and the search for rent. Similarly, people also tend to engage in extractive activities, which limits entrepreneurship and innovation. This result agrees with those of Sun et al. (2018) show the main transmission channels of natural resource abundance to backward economic development. Finally, the results show a positive and statistically significant connection between the financial development, recorded by the volume of credit in the private sector, and innovations at the 1% threshold. These results propose that a 10% increase in credit supply to private sector increases the ability to innovate by 46 percentage points. These results is consistent with Hsu, Tian, and Xu (2014) although they find that the influence of financial development on innovation is more pronounced in emerging than in low-income nations.

4.3. Robustness Testing

To check the robustness of the fundamental results, the paper performs a sequence of sensitivity analyses. To deal with measurement bias, an alternative measure of innovation is first used, namely the economic complexity index. Second, estimating income differences is used to deal with the heterogeneity bias.

4.3.1. Alternative Measure of Innovation: Taking into Account the Measurement Bias

As previously announced, the Index of Economic Complexity (Kumar & Singh, 2019) is used as alternative measure of innovation. It is defined by Hidalgo and Hausmann (2009) as the degree of product development through the size of a nation's exports, but also as knowledge intensity. Thus, in Table 3, it is observed that the impact of natural resources does not change. There remains a negative and significant link at the 1% between natural resources and innovation. The fact that a nation is rich in natural resources does not allow it to increase the knowledge of its people and increase the volume of exports.

Table 3. Effect of natural resources on economic complexity (OLS, 58 countries).

Variables	EC	EC	EC	EC	EC	EC
Nat_ressources	-0.1593*** (0.0095)	-0.1474*** (0.0101)	-0.1454*** (0.0101)	-0.1377*** (0.0127)	-0.0879*** (0.0117)	-0.0481*** (0.0115)
Trade		0.1648*** (0.0395)	0.1583*** (0.0394)	0.1536*** (0.0419)	-0.0046 (0.0411)	-0.0513 (0.0397)
S_education			0.2254 (0.1425)	2.1912 (1.5094)	0.3379 (1.4773)	-1.3179 (1.6842)
Popdensity				0.0229 (0.0216)	0.1135*** (0.0212)	0.1247*** (0.0214)
Selft					-0.3870*** (0.0380)	-0.3710*** (0.0358)
Dcredittoprivatesecto						0.2691*** (0.0397)
Constant	-0.4149*** (0.0742)	-1.0845*** (0.1795)	-1.4763*** (0.3253)	-3.3514** (1.4066)	0.0565 (1.4384)	0.6094 (1.5664)
Observations	969	969	969	969	969	864
R-squared	0.1964	0.2099	0.2120	0.2134	0.2867	0.3331
Time effect	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses (*** p<0.01, ** p<0.05).

The sign and significance of the control variables remained unchanged from the baseline regression. In fact, this result shows that natural resource wealth does not positively explain a country's economic complexity. It is more likely that the economic complexity leading to high levels of innovation (Hidalgo & Hausmann, 2009; Sweet & Maggio, 2015) is a function of the state of research and development spending rather than basically from the abundance of natural resources. Thus, the results indicate that a 1% natural resources abundance helps reduce economic complexity, and hence the ability to innovate, by almost 16%, other things being equal. This result is all the more interesting given that most of the world's countries are reducing their dependence on natural resources through the technological path in favor of the knowledge economy. This becomes visible through the reorientation of the entire production sphere towards the promotion of renewable energies, artificial intelligence, all scientifically framed by the green economy or the circular economy.

4.3.2. Natural Resources and Innovation: Analysis Based on the Levels of Economic Growth

This subsection tests the robustness of the results obtained above on a large sample of developed and developing economies by introducing economic growth. For this reason, it is important to distinguish between low-income and high-income countries according to the World Bank (2021) classification. The results of the estimates are summarised in Table 2A. Columns 1 to 6 show the test results for low-income countries and columns 7 to 12 show the test results for high-income countries. The influence of natural resources on innovation varies according to income level. The natural resources abundance has a positive influence on innovation in low-income countries, while it have a negative influence in high-income countries. As mentioned above, a likely explanation for these results is that low-income countries have high potential for innovation in natural resources. This potential can be realized through good institutions and better management of the returns from the natural resources exploitation, such as funding education or funding entrepreneurship, which are real innovation boosters. These results are reliable with Shahbaz et al. (2019) showing that the natural resources abundance has led to financial development that is a proven driver of innovation (Khan et al., 2020). However, it seems that high-income countries have already reached a level of saturation that prevents them from using natural resources in innovation production. Furthermore, it seems that high-income countries are more probable to use a high level of knowledge for their innovative projects as opposed to using natural resources. Furthermore, this result is consistent with work based on local innovation systems and local innovations developing from local resources, local labor and local know-how (Hoffecker, 2018) compared to innovations based in developed countries, in Laboratories and based on the use of intense knowledge.

4.4. Estimating Transmission Channels

Table 3A presents the results of alternative models including potential channel as additional covariates in the baseline analysis. Note that column 1 of Table 3A corresponds to column 6 of Table 2 and represents the baseline model with control variables accounted for. Column 2 of Table 3A contains the first transmission channel, ODA. The first observation that emerges from this result is that the natural resources variable, which was previously significant and had a negative sign, becomes positive and insignificant. In addition, it can be observed that the coefficient associated with the natural resources variable is less important in column 2 than in column 1, evidence that the introduction of the ODA variable mitigates the impact of natural resources on innovative capacity. In short, this result supports the hypothesis that official development assistance is one of the channels through which the natural resources abundance negatively influences innovative capacity in both developed and developing economies. This result is all the more interesting as the coefficient associated with the ODA variable suggests that targeting this aid could increase the innovative capacity of the countries in our sample by almost 27%. These results confirm the work of Kumar (2009) which shows that development aid has a negative impact on innovation, as aid is targeted at sectors such as ICT and technology transfer and not at national or local innovation systems. Finally, we can also observe from column 3 to column 8 that the introduction of institutional variables systematically decreases the magnitudes of variables associated with natural resource abundance. This result proves that the quality of the institutions has a mediating effect between the wealth of natural resources and the ability to innovate. This result is consistent with previous work (Auty, 2005; Chen et al., 2020; Le Billon, 2001) showing the impact of the cursingof natural resource in nation characterized by low quality of institution.

5. DISCUSSIONS

Regarding the literature, the results of this paper is consistent with the conclusions of Chen et al. (2020) and Kamguia et al. (2022). All of these studies have found that the natural resources abundance can slow down the ability to innovate. Furthermore, Papyrakis and Gerlagh (2004) find evidence for a negative association between natural resource and innovation. They explain this hypothesis by saying that consumer's trade leisure for consumption and firms trade innovation for production (Papyrakis & Gerlagh, 2004). Therefore, increases in resource revenue counteract nation's growth into two means: directly, by decreasing labor demand, and indirectly, by inducing a smaller part of the labor force to engage in innovation production (Papyrakis & Gerlagh, 2004). The results of Miao et al. (2017) seem to be a little more optimistic, showing that while Green Technology Transformation Funds and technology workforce funding have a negative impact on the efficiency of natural resource use, Green Technology Adoption Funds and subsidies for the development of green new products do however, have a significant positive impact (Miao et al., 2017). The authors argue for the judicious use of natural resources and different modes of financing technological innovations. These results confirm our claim that directing ODA funds to local or national innovation systems can maximize the efficient use of natural resources. According to the study's findings, innovation and the availability of natural resources are not mutually beneficial. The poor quality of the institutions and the focus of official development aid policy, on the other hand, serve to emphasize this connection. Therefore, boosting local innovation (Hoffecker, 2018) and significantly raising institutional quality are two strategies for maximizing the use of natural resources or to turn natural resources curse into bless.

6. CONCLUSION AND RECOMMENDATIONS

This work was aimed at analysing the influence of natural resource curse on innovation. Indeed, very little consideration has been paid to this branch of study, although innovation is an important indicator of entrepreneurship, which the Sustainable Development Goals see as a new driver of economic development. Based on data from 58 countries for the period 1996-2015 and using the OLS regression, two main results emerged: First, the paper shows that natural resources abundance negatively influences the ability to innovate. This result tends to verify the natural resource curse hypothesis. However, taking into consideration the nature of natural resources, the results show that oil, gas and forestry rents reduce innovative capacity, while mining and coal rents increase this capacity. Paper also shows that natural resources has a positive influence on innovation capacities in low-income countries, while discouraging innovation in high-income countries. Second, paper shows that institutional quality and ODA are the channels through which natural resources negatively influence innovation. Therefore, in order to improve innovative capacity in resource-dependent situations, governments in developed countries should direct official development assistance to the local innovation system, instead of the famous technology transfer; in return, developing countries must improve the quality of institutions. This study has some limitations based on which future studies can be conducted. Indeed, futures work would be to analyze the relationship between natural resource wealth and R&D spending by looking at the role of the internet and mobile phones. It may also be possible to study the impact of natural resources and R&D spending nexus by looking at political leadership and the profile of the leader such as age, education, gender, etc.

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APPENDIX

Table 1A. Data sources and descriptive statistics.

Variables	Definitions	Sources
Research and development	R&D represents current expenditure and investment expenditure; both public and private in creative work undertaken to increase knowledge,	WDI
Total natural resources rents	Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (Hard and soft), mineral rents, and forest rents.	WDI
ECI_	The ECI indicates the sophistication of a country's exports	Simoes and Hidalgo (2011)
Oil rents	Oil rents are the difference between the value of crude oil production at world prices and total costs of production.	WDI
Gas rents	Natural gas rents are the difference between the value of natural gas production at world prices and total costs of production.	WDI
Forest rents	Forest rents are round wood harvest times the product of average prices and a region-specific rental rate.	WDI
Coal rents	Coal rents are the difference between the value of both hard and soft coal production at world prices and their total costs of production.	WDI
Mineral rents	Mineral rents are the difference between the value of production for a stock of minerals at world prices and their total costs of production.	WDI
Trade	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	WDI
Education	Human capital index measured by the average years of schooling in the population.	WDI
Popdensity	Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship	WDI
Dcredittoprivatesecto	Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations	WDI
Selft	Self-employed workers are those workers who, working on their own account or with one or a few partners or in cooperative	WDI
ODA	Net official development assistance per capita is disbursement flows (Net of repayment of principal)	WDI
Effectiveness	Estimate of governance (Ranges from approximately -2.5 (Weak) to 2.5 (Strong) governance performance)	WGI
Political_stability	Estimate of governance (Ranges from approximately -2.5 (Weak) to 2.5 (Strong) governance performance)	WGI
Regulatory	Estimate of governance (Ranges from approximately -2.5 (Weak) to 2.5 (Strong) governance performance)	WGI
Rule of law	Estimate of governance (Ranges from approximately -2.5 (Weak) to 2.5 (Strong) governance performance)	WGI
Accountability	Estimate of governance (Ranges from approximately -2.5 (Weak) to 2.5 (Strong) governance performance)	WGI
Corruption	Estimate of governance (Ranges from approximately -2.5 (Weak) to 2.5 (Strong) governance performance)	WGI

Table 2A. Income type (OLS, 58 countries).

Variables	R&D	R&D	R&D	R&D	R&D	R&D	R&D	R&D	R&D	R&D	R&D	R&D
	Low income countries						High income countries					
Nat_ressources	0.0667* (0.0378)	0.0713* (0.0379)	0.0846** (0.0381)	0.1173** (0.0472)	0.1402*** (0.0412)	0.0843** (0.0418)	-0.0237 (0.0156)	-0.0455*** (0.0121)	-0.0450*** (0.0118)	-0.0549*** (0.0179)	-0.0907*** (0.0147)	-0.0681*** (0.0154)
Trade		-0.1652** (0.0749)	-0.1911*** (0.0714)	-0.1407* (0.0718)	-0.4071*** (0.0658)	-0.5518*** (0.0682)		-0.3139*** (0.0418)	-0.2943*** (0.0398)	-0.2778*** (0.0435)	-0.3523*** (0.0432)	-0.3185*** (0.0450)
S_education			0.8846*** (0.3318)	14.3228** (6.0237)	24.4050*** (5.5010)	24.2815*** (5.3964)			-0.5670*** (0.1521)	1.9464 (3.5606)	0.5740 (3.5360)	-3.6706 (3.4638)
Popdensity				0.1114*** (0.0354)	0.2168*** (0.0369)	0.1275*** (0.0406)				-0.0200 (0.0256)	-0.0547*** (0.0208)	-0.0668*** (0.0222)
Selft					-0.6849*** (0.0448)	-0.7695*** (0.0493)					-0.8843*** (0.0603)	-0.9217*** (0.0593)
Dcredittoprivatesecto						0.4295*** (0.0600)						0.1725*** (0.0580)
Constant	-1.1876*** (0.1880)	-0.5304 (0.3453)	-2.0482*** (0.7002)	-14.819*** (5.2607)	-20.3203*** (4.7478)	-20.3148*** (4.6299)	0.2804** (0.1242)	1.5323*** (0.2152)	2.5284*** (0.3848)	0.0833 (3.4425)	4.0909 (3.4566)	7.0724** (3.4006)
Observations	430	430	430	430	430	425	544	544	544	544	544	451
R-squared	0.0204	0.0283	0.0451	0.0706	0.2780	0.3459	0.0291	0.1007	0.1191	0.1202	0.4145	0.4736
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 3A. Roles of institutional quality and foreign aid (OLS, 58 countries).

Variables	R&DE	R&DE	R&DE	R&DE	R&DE	R&DE	R&DE	R&DE
Nat_ressources	-0.0755*** (0.0151)	0.0019 (0.0486)	0.0179 (0.0158)	-0.0363** (0.0174)	-0.0098 (0.0160)	0.0208 (0.0162)	-0.0128 (0.0163)	-0.0039 (0.0158)
Trade	-0.4247*** (0.0396)	-0.3249*** (0.0775)	-0.4166*** (0.0373)	-0.5433*** (0.0447)	-0.4569*** (0.0412)	-0.4263*** (0.0364)	-0.4008*** (0.0394)	-0.4134*** (0.0389)
S_education	9.8473*** (2.0221)	9.0846 (5.5681)	10.6361*** (1.8357)	11.0994*** (2.0160)	11.7474*** (1.9524)	10.9704*** (1.7349)	13.8501*** (1.8757)	9.6493*** (1.8222)
Popdensity	-0.0122 (0.0226)	-0.0390 (0.0438)	0.0508** (0.0203)	0.0689** (0.0271)	0.0387* (0.0234)	0.0672*** (0.0201)	0.0547** (0.0222)	0.0474** (0.0220)
Selft	-0.8453*** (0.0411)	-0.5932*** (0.0697)	-0.5495*** (0.0368)	-0.7351*** (0.0450)	-0.7051*** (0.0373)	-0.6294*** (0.0351)	-0.7464*** (0.0370)	-0.6179*** (0.0407)
Dcredittoprivatesecto	0.4658*** (0.0534)	0.5474*** (0.0618)	0.1214** (0.0494)	0.4326*** (0.0653)	0.2916*** (0.0681)	0.1781*** (0.0560)	0.4170*** (0.0666)	0.2844*** (0.0621)
ODA		-0.2698*** (0.0387)						
Effectiveness			0.6254*** (0.0465)					
Political_stability				0.2385*** (0.0465)				

Variables	R&DE	R&DE	R&DE	R&DE	R&DE	R&DE	R&DE	R&DE
Regulatory					0.3778*** (0.0480)			
RuleofLaw						0.4924*** (0.0421)		
Accountability							0.2786*** (0.0407)	
Corruption								0.3620*** (0.0392)
Constant	-7.1503*** (1.8747)	-7.8776 (4.8368)	-8.4698*** (1.7073)	-8.3452*** (1.8379)	-9.0610*** (1.7917)	-8.5321*** (1.5871)	-11.562*** (1.6754)	-7.7545*** (1.6699)
Observations	876	383	778	778	778	778	778	778
R-squared	0.5883	0.3961	0.6861	0.6049	0.6229	0.6605	0.6172	0.6310
Time effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses(*** p<0.01, ** p<0.05, * p<0.1).