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NATURAL RESOURCES AND RESEARCH COMPLEXITY IN DEVELOPING COUNTRIES

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ABSTRACT

The objective of this paper is to analyze the effect of natural resources on research complexity in 91 developing countries over the period 2000-2020. The results of the two-stage least squares (2SLS) estimation method show that dependence on natural resources negatively and significantly affects research complexity in developing countries. Furthermore, information and communication technologies, income, education and social dependency constitute the key determinants of research complexity. The results of this paper recommend that developing countries properly manage resource wealth with productive investments and the establishment of strong institutions to avoid a long-term curse. In addition, they must strengthen collaboration between industry and university, because scientific research presents itself as a niche of innovative ideas which, when implemented, will accelerate the process of export diversification in natural resource-intensive industries.

Keywords: Natural Resources, Research Complexity, 2sls, Developing Countries.

1. INTRODUCTION

The quality of a country's productive system is both an indicator of its productive capacities and its organization, but also a determinant of its economic and social development. Since Adam Smith's formulations of the division of labor, authors have continued to research the causes of the wealth of nations, but unanimously affirm that the resources available to a country, their allocation and the manner in which cognitive and productive uses them is the fundamental key to the development gaps observed between countries today. In the literature, one of the most complete realizations of this thought is the economic complexity of Hidalgo and Hausmann (2009).

Economic complexity is a multidimensional concept that goes beyond its index, also encompassing productive complexity and research complexity. This study will focus on research complexity. Thus, research complexity is defined as the capacity of a country to produce scientific publications by research field (Stojkoski et al., 2023). Research is an activity that requires the use of qualified labor. A University with qualified teachers will perform better in its research activities because it has qualified students capable of publishing articles in good journals. In addition, human capital makes it possible to identify, apply and discover new research techniques. Only educated people understand the theories used in research and ensure the transmission of research skills to future generations (Dimos and Pugh, 2016).

In facts and literature, the authors tend to demonstrate that if certain countries lag behind in development, it is due to the fact that their productive structure is concentrated on the exploitation and marketing of natural resources. Indeed, natural resources in the pioneering work of Sachs and Warner (1995) are considered a curse for countries rich in them because they compromise their accumulation of physical capital (Wang et al., 2023), their accumulation of capital human (Cockx and Francken, 2014; Cockx and Francken, 2016; Alvarez and Vergara, 2022; Tadadjeu et al., 2023), innovation (Omidi et al., 2019; Kamguia et al., 2022; Xiao et al. , 2023), many other aspects of development (Awoa et al., 2022; Njangang et al., 2022; Tadadjeu et al., 2022), but above all the quality of regulatory policies and institutions (Collier and Hoeffer, 2002; Mehlum et al., 2006; Van der Ploeg, 2011; Badeeb et al., 2017; Henri, 2019; Shahbaz et al., 2019; Dell'Anno, 2020).

Today, not a month, or even a day, goes by without a new study strengthening our understanding of these mechanondoa isms of deterioration of economic development in countries rich in natural resources. In this study, we follow the same research perspective as (Cockx and Francken, 2014; Cockx and Francken, 2016; Ajide, 2022; Boeing et al., 2022; Kamguia et al., 2022; Omidi et al., 2019; Alvarado et al., 2023; Liu and Tian, 2023; Ondoa and Andela, 2023). More precisely, in line with the work of Boeing et al. (2022), Kamguia et al. (2022), Ondoa and Andela (2023), which demonstrate that natural resources compromise the research sector in developing countries, this study studies and expands this research, this time considering a new dimension of economic complexity that This is research complexity.

Indeed, a look at the structure of dependence on natural resources and the economic complexity of developing countries shows that Africa represents one of the regions richest in natural resources. According to the World Bank (2023), African countries earn on average around 40% of the revenue they could potentially draw from their natural resources. In this sense, these resources represent approximately 40% of global gold reserves and 12% of global oil or gas reserves. These performances show that many African countries rich in natural resources have drowned in the sea of natural resource curse. According to data from the Observatory of Economic Complexity, scientific research is relatively developed in certain African countries such as South Africa, Egypt, Tunisia and Morocco and is less developed in Congo, Mauritania, Angola and in Niger. According to World Bank data during the period 2002-2020, African countries devoted 0.3% of their GDP to the R&D sector. However, in countries like Tunisia and South Africa, this statistic exceeds 0.66%, compared to only 0.03% in Angola. However, the contribution of natural resources to GDP is 32% in Angola.

This study contributes to the existing literature in two ways. First, this study uses a dimension of economic complexity rarely discussed in the literature: research complexity. Second, we disaggregate research complexity into an index of commercial complexity and the number of scientific publications. This study will provide an answer to the impact of natural resources on research complexity in developing countries.

Using data from the World Bank database (World Bank indicators and governance indicators) and the Economic Complexity Observatory, our sample consists of 91 developing countries covering the period 2000-2020. We show that dependence on natural resource rents has a negative and significant effect on research complexity. The results also show that dependence on natural resource rents limits research complexity in developing countries. However, the quality of institutions mitigates this negative impact in the productive sector.

The rest of his papers are organized as follows. Section 2 presents the review of theoretical and empirical literature. Section 3 describes the econometric data and specifications. In section 4 and 5, we respectively present all our different results and discussions. Ultimately, section 6 will be reserved for the conclusion.

2. LITERATURE REVIEW

In this part, it will be a question of presenting, on the one hand, the theoretical foundations of the relationship between natural resources and research complexity; on the other hand, to present the empirical controversies of this relationship.

2.1 Theoretical review

Endogenous growth theories emphasize the importance of research and development (R&D) in the growth process (Aghion and Howitt, 2008). Innovation reflects the capacity of a country to generate novelty in the techniques it uses and the products and services it produces for the local and international market (Fagerberg and Srholec, 2008). It is therefore not surprising that studies on innovation tend to operate with the perception of the mechanisms of industrial development based on the manufacturing sector. This is consistent with the views of early structuralists who saw few opportunities for learning and innovation, and linkages in association with natural resource-based industries, and who attributed all development potential to the manufacturing sector (Hirschman, 1958; Prebisch, 1950; Singer, 1975).

These structuralists analyze the relationship between natural resources and research complexity from a negative approach. According to these theorists, this relationship leads to a natural resource curse; however, resource-rich countries tend to have low scientific and technical production. Natural resources can be an effective way for resource-rich countries to increase their human capital budgets. However, emerging literature shows that natural resources are negatively associated with health spending (Cockx and Francken, 2014) and education spending (Cockx and Francken, 2016). Theoretical research has revealed a negative relationship between dependence on natural resources and innovation (Omidi et al., 2019). Natural resource rents are seen to cause resource-rich governments to neglect other important sectors such as human capital development and new investments, paying less attention to other productive economic activities, thereby reducing the level of research complexity in an economy.

In the new structuralist theory, the authors show that natural resources constitute constrained supports of research complexity. These constraints are linked to institutional factors and skill allocations. The quality of institutions is an important determinant of R&D investments. Choi et al. (2014) emphasize that effective institutions can encourage R&D investments by minimizing the agency problem among decision-makers. Better institutions also promote the liberalization of financial markets, which encourages investments in R&D by reducing financial constraints. Alam et al. (2019) show that government effectiveness, rule of law and regulatory quality have positive and significant effects on R&D spending. The authors explain that government effectiveness, the rule of law and the quality of regulation in a country can stimulate investment in R&D by facilitating access to finance, ensuring market entry, attracting foreign investment, increasing investor confidence and protection and accelerating technology investments. On the other hand, Allard et al. (2012) find that political instability following resources undermines a country's capacity for innovation and the quality of its scientific institutions. In addition, it reduces R&D spending at the company level and at the level of cooperation agreements between university communities.

Economies rich in natural resources appear particularly prone to socially harmful rent-seeking behavior on the part of producers. The idea that resource dependence affects the type of political regimes (democracy versus autocracy) is based on the concept of the rentier state (Ross, 2001;

Haber and Menaldo, 2011). For Ross (2011), resource-rich countries, particularly oil-producing countries, are on average less democratic than their peers who have less resources due to three effects of resource rents on governments: taxation effect, spending effect, and protest effect. The taxation effect suggests that when governments generate sufficient revenue from natural resources, they tax their populations less. In turn, the population is less likely to hold the government accountable (Tilly, 1977). The spending effect assumes that rents lead to patronage, which destroys latent pressures for a strong demand for democracy (Atkinson and Hamilton, 2003). The protest effect suggests that the government uses its largesse to prevent the formation of protest groups (Mahdavy, 1970; Anderson, 1987; Ross, 2001; Andersen and Aslaksen, 2013). According to the author, these mechanisms contribute to altering democracy in countries rich in natural resources.

2.2 Empirical review

Several empirical studies have explored the effect of dependence on natural resources on the research sector. The contributions of the literature are controversial with positive, negative, and mixed and reverse effects. A battery of studies has shown that natural resources have an impact on human capital (Cockx and Francken, 2014; Cockx and Francken, 2016; Kim and Lin, 2017; Alvarez and Vergara, 2022; Tadadjeu et al., 2023), on institutional constraints (Ross, 2001; Mehlum et al., 2006; Van der Ploeg, 2007; Brunnschweiler, 2008; Erum and Hussain, 2019; Zalle, 2019) and on the allocation of skills (Haber and Menaldo, 2011; Ross, 2015; DellAnno, 2020).

To our knowledge, a minority of works have been discussed on the relationship between natural resources and research and development. Among these works, three (Boeing et al., 2022; Kamguia et al., 2022; Ondoa and Andela, 2023) caught our attention.

More recently, Ondoa and Andela (2023) evaluated the effect of natural resource rents on scientific and technical research in 51 African countries during the period 2000-2020. Using data from the World Bank (WDI and WGI), these authors use the dependent variable which is the number of scientific and technical articles and the variable of interest which is the rent of natural resources. GDP, life expectancy at birth, corruption, access to the internet and electricity are control variables. In analyzing the results, the authors use the two-stage least squares (2SLS) method and find that the natural resource curse hypothesis in the African research sector is valid. Additionally, the authors find that the natural resources that further delay scientific performance are minerals, forests and oil.

Along the same lines, Kamguia et al. (2022) examine the effect of natural resources on research and development spending. Using data from 82 developed and developing countries, the study uses research and development expenditure and total natural resource rent as the dependent and explanatory variable respectively. The authors use several macroeconomic determinants, including income, foreign direct investment, trade openness, financial development and ICT. Using two estimators, notably the system GMM and the two-step GMM, the authors show that natural resources have on average a negative effect on investments in research and development. They also find that natural resources are negatively associated with research and development spending in the public sector, higher education and the business sector. By distinguishing between different natural resources, the authors note that only one-off resources deteriorate investments in research. Innovation, as one of the explanatory factors of R&D spending, is also affected by the abundance of natural resources (Ajide, 2022). Research has found a negative correlation between dependence

on natural resources and innovation (Omidi et al., 2019). Natural resource rents have been found to cause resource-rich governments to neglect other important sectors such as human capital development, paying less attention to other productive economic activities. By looking at another R&D factor, notably human capital expenditure, Douangngeune et al. (2005) confirm the negative effect of natural resources, notably land endowment on educational investment. These authors explain that countries firmly believe that their greatest advantage lies in their natural resources and may inadvertently, and sometimes deliberately, neglect the development of their human resources and unjustified expenditure on human capital. Not surprisingly, schooling at all levels tends to be inversely related to natural resource endowment, as measured by the share of the labor force engaged in raw material production in all countries (Gylfason et al., 2001).
In the same logic, Ulku (2007) shows through a fixed effects regression analysis and a GMM estimator for a sample of 26 OECD countries and 15 non-OECD countries over the period 1981-1997, that an increase in the proportion of full-time equivalent researchers devoted to R&D sectors leads to an increase in innovation as measured by patent applications. Furthermore, the author finds that the effect of secondary school enrollment is not clear because with the fixed effects methodology it is positive and significant in most of the samples used (full OECD, small market, high-income and low-income) and it is not significant in most samples. Applying two-stage least squares (2SLS) regression, Shirazi and Hajli (2021) conclude that higher education defined as the average gross enrollment rate in higher education and science and engineering degrees positively affects the sustainable innovation.
However, Boeing et al. (2022) study the impact of research and development (R&D) subsidies on R&D inputs and their broader economic effects. Their studies use a structural vector autoregressive (VAR) model in a panel of Chinese provinces during the period 2000-2010. They use six dependent variables, including R&D subsidy intensity, human capital measured by private R&D investment, technological growth rate, physical capital investment rate, employment rate, and GDP real per capita. In support of a view of partial crowding out, it appears that public R&D subsidies allocated to large and medium-sized enterprises increase the total R&D inputs represented by total R&D personnel, despite the reduction in funded R&D inputs. by the private sector. Specifically, the authors find that an increase in R&D subsidies decreases private R&D spending, but increases total R&D personnel in small and medium-sized firms. Similarly, the rapid increase in R&D inputs is associated with a decrease in production growth in China, which implies a decrease in research productivity (Boeing and Huenermund, 2020). On the other hand, R&D subsidies tend to increase the rate of investment in residential buildings, which suggests a misallocation of public funds (Yang et al., 2020).
Le and Le Van (2016) develop an endogenous growth model to study how different types of natural resources, including renewable and non-renewable, affect sustainable growth and R&D. The authors believe that negative growth can occur in an economy with non-renewable resources. To emerge from this stagnant growth, the research sector must be highly productive. Furthermore, these authors find that non-renewable resources are not necessarily dominated by their renewable counterparts in terms of production growth and welfare.

3. METHODOLOGY

In this part, it will be a question of discussing on the one hand the variables and the data of the analysis; on the other hand, to present the econometric specification and the estimation technique of this analysis.

3.1 Variables and data

Our sample consists of 91 developing countries at different income levels according to the World Bank classification. We choose the period 2000-2020 due to the continued availability of data on a large number of countries. Data comes from the World Bank database (World Bank indicators and governance indicators) and the Economic Complexity Observatory. Thus, Table A1 in the appendix gives the descriptive statistics for all variables. Then, Tables A2 respectively present the correlation matrices in the relationship between natural resources and research complexity. Finally, Table A3 in the appendix lists the list of countries and codes.

3.1.1 Measuring research complexity

Research complexity is the capacity of a country to produce scientific publications by field of research. A large number of research studies have attempted to measure the effects of scientific knowledge. Since the seminal work of Solow (1956), a large number of studies have integrated science and technology into the production function, to study their influence on production and productivity growth, at the firm level, district or country (Adams, 1990; Coe and Helpman, 1995; Vernon, 1970; Zeira, 2011). The majority of these works use research and development (R&D) to represent scientific knowledge, while only a few studies approach it using scientific results such as articles, reviews and citations. Among these, an influential study is that of Adams (1990) who developed a set of indicators of accumulated academic science based on the number of published articles and measured their effects on the productivity of manufacturing industries in the States-United. The author highlighted scientific knowledge as a major contributor to productivity growth. Furthermore, teachers train students and the latter use the knowledge acquired to generate other knowledge through research (Lucas, 1988). In Romer (1990) model, all researchers have the opportunity to use the accumulated knowledge incorporated into existing production plans and research activities increase with the number of qualified researchers.

3.1.2 Measurement of natural resources

The main explanatory variable of our study is the total rent of natural resources (% of GDP) obtained in the World Bank database (WDI, 2020). Total resource rents are the sum of oil rents, natural gas rents, coal rents, mining rents and oil rents. The choice of proxy is consistent with the influential work of Arezki and Gylfason (2013) and Crivelli and Gupta (2014). In our study we consider this ratio as a measure of dependence rather than as a measure of abundance. Thus, resource dependence refers to the proportion of income from natural resources in national income, while resource abundance rather refers to a country's estimated limited endowment in underground wealth or mineral deposits, oil and gas (Brunnschweiler and Bulte, 2008). There are several reasons to choose this measure over others, such as resource income or resource stock. First, total natural resource rents are quite widely available across countries, which minimizes the risk of sample selection bias and also provides a reasonably long dimension. Secondly, going in the same direction as Antonakakis et al. (2017), we argue that to examine the resource curse hypothesis, we need a variable that can capture the extent to which government authorities exhibit rent-seeking behavior. Natural resource dependence provides a measure of rent-seeking behavior, since the more dependent an economy is on these resources, the more likely it is that political elites will engage in rent-seeking behavior (Sachs and Warner, 2001).

3.1.3 Control variables

We will discuss our six control variables, including education, per capita income, age dependency, gross fixed capital formation, ICT and governance.

- **Education**

An indicator of human capital is used, namely education. This variable is supposed to have a positive influence on scientific production. Research is an activity that requires the use of qualified labor. The quality of doctoral and master's theses depends on the quality of teachers in the education system. Only educated people understand the theories used in research and ensure the transmission of research skills to future generations (Dimos and Pugh, 2016). In addition, teachers train students, and students use the knowledge acquired to generate other knowledge through research (Lucas, 1988).

- **Income**

Kamguia et al. (2022) find that income increases R&D investments. Similarly, in studies on R&D and innovation, Braconier (2000) and Wang (2010) consider income as an important determinant of investment in R&D. Per capita income shows a country's capacity to engage in R&D. Using panel data on patent applications and R&D for the period 1981-1997 in 20 OECD and 10 non-OECD countries, Ulku (2007) shows the existence of a positive relationship between GDP per capita and innovation using fixed effects and the Arellano-Bond GMM estimator. Similarly, Yueh (2009) finds that GDP per capita has a positive effect on innovation using a Poisson model, the dependent variable being the patent issued in China over the period 1991-2003. However, Khan et al. (2017) distinguishing between resident and non-resident patent applicants, show for the G7 countries over the period 1995-2013 the existence of a negative relationship between resident patent applicants and GDP per capita, and a positive relationship for non-resident patent applicants

- **Social dependency**

The measurement of social dependency has been studied by several authors. Hidalgo and Hausmann (2009) point out that excessive dependence can lead to limited specialization in sectors with low added value. This specialization reduces diversification in the research and development sector. Some authors believe that social dependency can create risks on the volatility of commodity prices and subsequently negatively affects macroeconomic stability and low allocation of resources in the research sector (Auty and Gelb, 2001).

- **Gross fixed capital formation**

Lemer (1999) argued that public investments used in research and development help certify the quality of researchers and allow them to be competitive for venture funding. David et al. (2000) pointed out that public funding of research can create intertemporal benefits. Public investment can mitigate market failures by lowering the unit costs of research and increasing the expected return on research and development projects, and by increasing the expected return on funded scientific projects, thereby providing incentives for increased private research spending. and development (Hall and Van Reenen, 2000). Jiang al. (2018) identified other determinants of scientific performance such as the achievement of large-scale investments, the nationality of authors and language barriers. According to Braconier et al. (2001), foreign investments improve innovation.

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- **ICT**

We consider access to ICT based on the percentage of the population using the internet. Access to the internet, for example, offers academics the opportunity to share ideas with researchers from other universities (Ondoa and Andela, 2023). The dynamics observed in the research sector in recent years can be explained by the widespread use of the Internet in developing countries. Since research-related activities require internet access (Martin and Nguyen-Thi, 2015), better internet access leads to increased public spending.

- **Governance**

Several studies show that the quality of institutions is an important determinant of R&D investments. Choi et al. (2014) point out that effective institutions can encourage R&D investments by minimizing the agency problem among decision-makers. Better institutions also promote the liberalization of financial markets, which encourages investments in R&D by reducing financial constraints (Leaven, 2003). Similarly, Allam et al. (2019) show that government effectiveness, the rule of law and the quality of regulation have positive and significant effects on R&D spending. In addition, several authors show that political instability negatively affects investments in R&D activities (Allard et al., 2012; Alam et al., 2019). Political instability undermines a country's capacity for innovation and the quality of its scientific institutions. It is associated with a reduction in R&D spending at the corporate level, a reduction in cooperative agreements between academic communities and businesses and a reduction in public spending on technology (Allard et al., 2012).

3.2 Econometric specification and estimation using the two-stage least squares method

Inspired by the work of Edwards (2015) which analyzed the effect of the exploitation of the mining sector on health and education, in this study we will use an instrumental variable double least squares (2SLS) approach. This overcomes the endogeneity problem. The search complexity model is estimated as follows:

$$CR_{it} = \beta_0 + \beta_1 RN_{it} + \beta_2 X_{it} + \nu_i \qquad (1)$$

Where CR_{it} represents the search complexity; RN_{it} represents the total rent of natural resources; X_{it} is the vector of control variables. And, $\nu_i = \eta_i + \delta_t + \varepsilon_{it}$. η_i represents the fixed effect or the country heterogeneity factor (it takes into account all unobserved factors, constant over time and which have an impact on research complexity); λ_i represents the time-specific effect, and ε_{it} represents the error term which takes into account unobserved factors that vary over time, with $i = 1 \ldots N$ et $t = 1 \ldots T$ which represents countries and years.

For macro econometric analyses, numerous estimation techniques have been developed by authors to take into account endogeneity problems; problems that can arise from several sources: simultaneity, unobserved heterogeneity, measurement error and the inclusion of the lagged independent variable in the regression. As part of this study, we use the two-stage least squares (2SLS) method. This method was introduced by Basmann (1957) and Theil (1961).

The 2SLS estimation is done in two stages. Firstly, it involves regressing the endogenous variables on all the predetermined variables of the system (estimation of a form reduced by ordinary least squares). The first step therefore purifies the endogenous variables explaining the influence of the error term. Second, it is a question of replacing the explanatory endogenous variables by their estimated values in the structural equations and applying ordinary least squares.

The 2SLS technique asks the question of model identification, and three main tests are generally performed. The first is the classification test, which is an underidentification test developed by Kleibergen and Paap (2006). This test makes it possible to determine whether the correlation between endogenous variables and instruments is statistically different from zero. The second test, developed by Stock and Yogo (2005), characterizes the weakness of the selected instruments, for which a multivariate specification was previously developed by Cragg and Donald (1993). Hansen (1982) and Sargan (1983) also proposed a test for over-identification of all instruments, commonly called instrument validity testing. Like the previous tests, it makes it possible to validate the relevance of the selected instruments.

4. RESULTS

In order to determine the effect of natural resources on research complexity, we opted for the two-stage least squares method. We produced two results, including a global and regional result. The overall results present two regressions, such as the effect of natural resources on research complexity, and in robustness we analyze the effect of natural resources on scientific publications. At the regional level, we will subdivide developing countries into four regions, including Africa, America, Asia and Europe; and we showed the effect of natural resources on research complexity and on scientific publications. Thus, Table 1 presents the basic results and robustness. This section is made up of two subsections. It firstly provides a descriptive analysis of the correlations; and secondly, it presents the results of the econometric analysis.

4.1 Preliminary analysis

Before interpreting the basic results, we discuss a correlation analysis between dependence on natural resource rents and research complexity in developing countries over a period 2000-2020.
From a global point of view, graph 1 illustrates the decrease in the trend. This relationship shows that natural resources reduce research complexity. This relationship is in perfect agreement with the correlation matrix presented in the appendix in Table A2. On the graph, we see that most countries rich in natural resources such as Angola, the Democratic Republic of Congo, the Republic of Congo and Gabon have low complexities of scientific production, particularly in terms of scientific publications by field of research. research. These countries are mainly African countries and present weak trends ranging from -0.5% to -2%. On the other hand, Kuwait, Pakistan, Romania, Senegal and Ireland are above the trend and present fairly relevant performances, ranging from -0.5% to 0.5%. We still observe on the same graph that certain countries present a high concentration at the average of the trends. In addition, South Africa, Turkey, Brazil, Chile, Russia and Korea, which are countries less dependent on natural resources, show strong performance in the field of scientific and technical research. Their performance in the scientific research sector allows them to diversify and boost their economies. In addition, this graph is linked to table A1 of descriptive statistics in the appendix. We see in this table that dependence on natural resource rents changes on average by 1.77 with a standard deviation of 1.11; on the other hand, the search complexity decreases by 0.24 with a standard deviation of 0.6.

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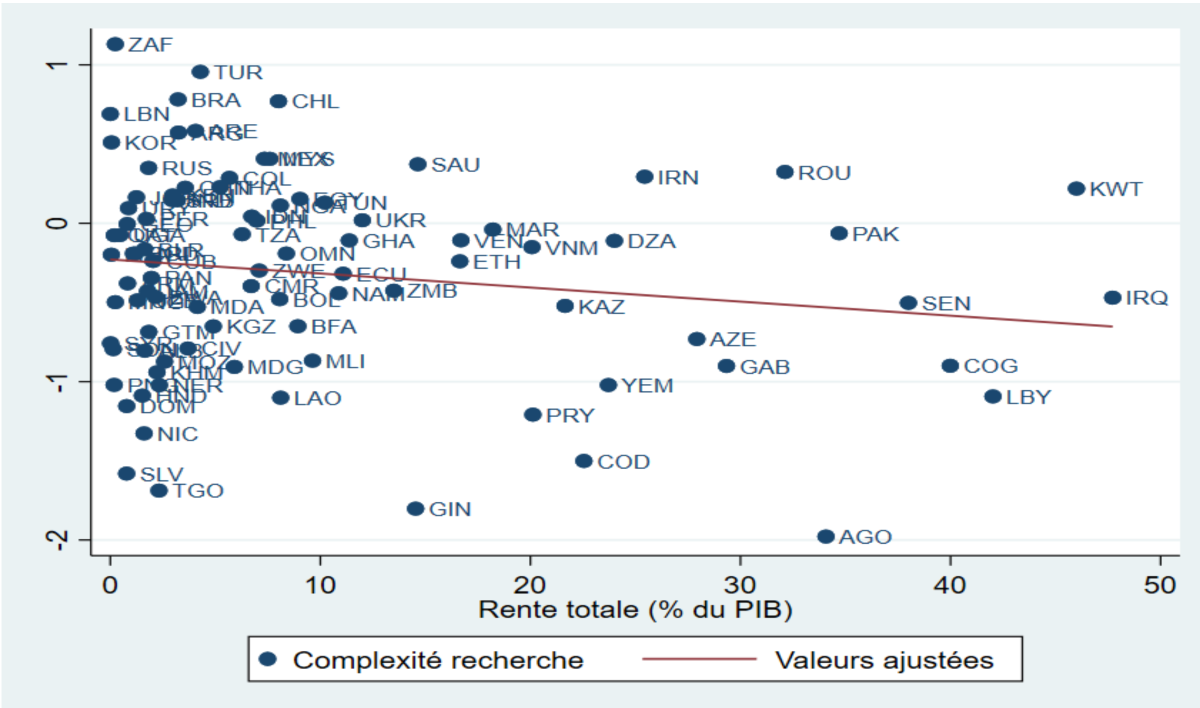
Figure 1: Natural resources and research complexity: a global analysis



Source: Author's construction.

4.2 Basic results of the two-stage least squares method

Econometrically, the Fisher test is conclusive for both estimates since its probability is below the 1% threshold. This therefore means that our models are overall significant. In addition, the underidentification test (Kleibergen-Paap) validates the correlation between endogenous variables and instruments. The same goes for weak identification tests (Cragg-Donald and Stock-Yogo). Finally, Hansen's over-identification test is also conclusive and allows us to validate our instruments. Indeed, the p-value of this statistic is greater than the threshold of 10% in our two regressions, which does not allow us to reject the null hypothesis of validity of the instruments.

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Table 1: **Natural resources and research complexity in developing countries: 2SLS**

Variables	**Research Complexity**	**Scientific Publication**
	(1)	**(2)**
Total rent	**-0.038*****	**-0.075*****
	(0.0379)	**(0.136)**
Education	0.137*	0.242
	(0.0768)	(0.313)
Income	0.153***	0.165***
	(0.0461)	(0.177)
Social dependency	-0.155**	-0.774***
	(0.0708)	(0.279)
Investment	0.0383	0.382***
	(0.0790)	(0.317)
ICT	0.0786**	0.126
	(0.0383)	(0.151)
Governance	0.0602	-0.221
	(0.0271)	(0.107)
Fixed effects	Yes	Yes
Constant	-1.013*	-1.216
	(0.572)	(2.297)
Observations	791	754
Fisher (P-value)	**0.000**	**0.000**
R-squared	0.711	0.646
Kleibergen-Paap rk LM stat	50.96	75.89
Cragg-Donald Wald F statistic	6.260	10.99
Stock-Yogo (5%)	20.25	20.25
Hansen (P-value)	**0.642**	**0.571**

Note: Values in parentheses are standard deviations. *, **, and * indicate significance at 10%, 5%, 1% respectively.**
Source: Author's construction.

Table 2 below presents the results of the effect of natural resources on research complexity and scientific publications (robustness) by region. The second column of the table presents the baseline results in the four developing regions, including Africa, America, Asia and Europe. The third column of Table 2 gives the robustness results.

Econometrically, the Fisher test is conclusive for both estimates since its probability is below the 1% threshold. This therefore means that our models are overall significant. In addition, Hansen's over-identification test is also conclusive and allows us to validate our instruments. Indeed, the p-value of this statistic is greater than the threshold of 10% in our two regressions, which does not allow us to reject the null hypothesis of validity of the instruments. As well as on a theoretical level, our results obtained are mostly in line with previous work.

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Table 2: **Natural resources and research complexity at the regional level: 2SLS**

VARIABLES	(A)				(B)			
	Research Complexity				Scientific Publication			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Africa	**America**	**Asia**	**Europa**	**Africa**	**America**	**Asia**	**Europa**
Total rent	**-0.128****	**-0.216****	**-0.650*****	**0.073**	**-0.465*****	**-0.817*****	**-0.646*****	**0.783**
	(0.0639)	**(0.0952)**	**(0.109)**	**(0.238)**	**(0.173)**	**(0.305)**	**(0.177)**	**(0.164)**
Education	0.239	0.609***	0.685**	0.873***	0.598	0.335***	0.067***	0.408
	(0.144)	(0.227)	(0.319)	(0.696)	(0.488)	(0.802)	(0.603)	(0.903)
Income	0.168*	0.533***	0.351***	0.385***	-0.598	0.761***	0.521***	0.973***
	(0.0912)	(0.183)	(0.126)	(0.132)	(0.424)	(0.501)	(0.333)	(0.355)
Social dependency	-0.132	0.911***	0.233	-0.474***	-0.212	-0.041***	0.993**	0.744***
	(0.193)	(0.194)	(0.176)	(0.551)	(0.682)	(1.369)	(0.435)	(0.613)
Investment	0.612***	0.372*	0.483**	0.349***	0.463	0.439***	0.539***	0.0235
	(0.146)	(0.210)	(0.241)	(0.346)	(0.418)	(0.788)	(0.610)	(0.956)
ICT	0.314***	0.176**	-0.0167	-0.679***	0.953***	0.186***	0.223	0.458
	(0.0718)	(0.0871)	(0.109)	(0.146)	(0.312)	(0.905)	(0.245)	(0.320)
Governance	0.00281	-0.240***	-0.156*	-0.645***	-0.471	-1.309***	-0.252	-0.171
	(0.0369)	(0.0835)	(0.0849)	(0.151)	(0.128)	(0.210)	(0.200)	(0.229)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.851**	-14.47***	1.815	-15.67***	8.000***	-2.733	21.31***	-34.33***
	(0.784)	(1.731)	(1.542)	(4.181)	(2.798)	(8.186)	(4.370)	(6.367)
Observations	181	179	207	87	208	191	234	98
Fisher (P-value)	**0 .000**	**0 .000**	**0 .000**	**0 .000**	**0 .000**	**0 .000**	**0 .000**	**0 .000**
R-squared	0.543	0.674	0.518	0.758	0.549	0.804	0.753	0.887

Kleibergen-Paap	37.97	29.98	38.28	17.81	44.71	60	66.29	34.94
Cragg-Donald Wald	22.79	12.47	5.958	4.534	23.06	8.076	19.86	10.35
Stock-Yogo (5%)	20.25	20.25	20.25	19.86	20.53	18.30	20.53	20.25
Hansen (P-value)	**0.114**	**0.146**	**0.180**	**0.350**	**0.110**	**0.323**	**0.154**	**0.318**

Note: Values in parentheses are standard deviations. *, **, and * indicate significance at 10%, 5%, 1% respectively.**
Source: Author's construction.

5. DISCUSSION

We first discuss the basic results of the overall analysis on the relationship between dependence on natural resources and research complexity (5.1). Second, we discuss the results of the analysis at the regional level (5.2).

5.1 Discussion of the results of the overall analysis

On a theoretical level, the results obtained in Table 1 are mostly in line with previous work both for the expected effect for the total rent of natural resources and for research complexity and its alternative measurement.
Column (1) of Table 1 highlights a negative and significant effect of the total rent on research complexity at the 1% threshold. The coefficient associated with natural resources is 0.038 with a magnitude suggesting that all things being equal, an increase of 1% in total resource rent is associated with a reduction in research complexity of 0.038 points. Thus, when countries rely largely on income generated from the exploitation of natural resources, this creates dependence on these sectors. This dependence discourages investment in other sectors, including research and development. Our results are in perfect collaboration with the work of Kamguia et al. (2022) who find that natural resources are negatively associated with research and development (R&D) spending in the public sector, higher education and business sectors. Also, Ondoa and Andela (2023) find that natural resource rent delays the development of research in Africa.
Regarding the control variables, the expected signs generally agree with the theory; this is the case for income, education and ICT.
Income improves research complexity in developing countries. The results reveal a positive and significant relationship at the 1% threshold between income and search complexity. Indeed, this relationship describes that a 1% increase in income improves search complexity by 0.153 points. The positive influence of income on scientific research is due to the fact that research generates costs that must be financed. In other words, scientific research is a normal good, which means that its demand increases with income (Romer, 1990; Badeeb et al., 2017). Additionally, per capita income shows a country's capacity to engage in research and development. Several studies have shown that income plays a positive role in research and development investments (Guloglu and Tekin, 2012).
Education and technology improve research complexity. Our estimates respectively lead to a positive and significant result at 10% for education and 5% for ICT. Regarding education, only

educated people understand the theories used in research and ensure the transmission of research skills to future generations (Dimos and Pugh, 2016). Additionally, teachers train students, and students use the knowledge acquired to generate other knowledge through research (Lucas, 1988). Furthermore, in Romer's (1990) model all researchers have the opportunity to use the accumulated knowledge incorporated into existing production plans and research activities increase with the number of qualified researchers. Concerning ICT, it is justified by the fact that activities linked to research require access to the internet (Martin and Ngugen-Thi, 2015), better access to the internet leads to an increase in spending on research and development. Additionally, access to technologies based on the number of people using the internet encourages investments in research and development (Edquist and Henrekson, 2017).

Concerning social dependency, our results describe a negative relationship between social dependency and search complexity. This relationship is significant at the 5% level. Economically, when a country's resources are primarily allocated to social needs (poverty reduction, education and health care), there may be limited allocation of financial, human and material resources for scientific research. This can lead to reduced research budgets and a lack of advanced research infrastructure (Lin, 2012).

Furthermore, certain variables, notably investment and governance, although positive, are not significantly linked to research complexity. This can be explained by the fact that investment in fixed capital provides a material basis for research, insufficient levels of investment can limit its significant impact. Additionally, governance, which includes policies and institutions, plays a crucial role in how resources are allocated and used. If governance is weak, with inadequate policies, this can limit the effectiveness of investment and reduce its impact on research complexity (Alam et al., 2019; Allard et al., 2012). Thus, insufficient investment and poor governance can reinforce each other, leading to a positive but not significant effect on research complexity.

Column (2) of Table 1 presents the robustness results. To do this, we used an alternative measure of the dependent variable, notably the number of scientific publications. This is a measure widely used in the literature. The estimation results summarized in Table 1 in column 2 show that the coefficient associated with total natural resource rent is negative and statistically significant within 1%. Thus, an increase of 1% in the total rent from natural resources leads to a decrease of 0.075 in the number of scientific publications. This confirms the hypothesis according to which natural resources have, on average, a negative effect on scientific publications. Our result is therefore robust to the use of an alternative dependent variable. Additionally, we find that income increases the number of scientific publications. This is explained by the fact that income is used to finance research trips or to allow teaching staff to participate in major international conferences which require the production of scientific articles.

5.2 Discussion of the results of the regional analysis

The results of model (A) in Table 2 show that in the African, American and Asian regions, the total rent of natural resources reduces research complexity. An increase of 1% in the total rent respectively deteriorates the research complexity by 0.128 in Africa; 0.216 in America and 0.650 in Asia. On the other hand, in the European region, the total resource rent has a positive and insignificant effect. For example, in Africa these results can be explained by the fact that natural resource rents are often used to finance personnel costs in all sectors and not to invest in research. As a result, research sector wages may increase when resource rents are high, but other research inputs such as libraries and laboratories are lacking, delaying research development in Africa. These results collaborate with recent work by Ondoa and Andela (2023) who find that natural resource rents reduce the research sector in Africa.

In the case of the control variables, the expected signs generally agree with the theory in certain regions. In the African region, income, investment and ICT have positive and significant effects on research complexity. In America, education, income, social dependency, investment and ICT have positive and significant effects on research complexity, but governance has a negative and significant effect on research complexity. In Asia, education, income and investment have a positive and significant influence on the research sector; unlike governance which has a negative and significant effect on research. Finally, in the European region, we see that education and income have a positive and significant influence at the 1% threshold; on the other hand, the other control variables reduce the research complexity.

Model (B) of Table 2 presents the robustness of our results at the level of the four developing regions. We used the number of scientific publications as an alternative measure of the dependent variable. These results show that total natural resource rent reduces the number of scientific publications in the first three regions (Africa, America and Asia). Unlike the European region, the rent drawn has a positive and insignificant effect on the number of scientific publications. This result validates our basic results.

6. CONCLUSION

The objective of this paper was to assess the effect of natural resources on research complexity in developing countries over the period 2000-2020. From the literature point of view, endogenous growth theories emphasize the importance of research and development (R&D) in the process of economic growth. Structuralists analyze the relationship between natural resources and research complexity under a negative approach. According to these theorists, this relationship leads to a natural resource curse; however, resource-rich countries tend to have low scientific and technical production. On the other hand, in the approach of the new structuralist theory, the authors show that natural resources constitute constrained supports of research complexity. These constraints are linked to institutional factors and skill allocations. From these analyses, it appears that natural resources limit the complexity of research in developing countries. In addition, income, education and ICT and social dependency are determinants of research complexity; on the other hand, investment and governance are not found to be important. At the regional level, total resource rent reduces research complexity in the African, American and Asian regions; on the other hand, at the European level, it is rather improving. In terms of robustness, the oil rent confirms our basic results. Ultimately, the results obtained are consistent with the second hypothesis formulated that natural resources limit the complexity of research in developing countries. The results of this paper recommend that developing countries properly manage resource wealth with productive investments and the establishment of strong institutions to avoid a long-term curse. In addition, they must strengthen collaboration between industry and university, because scientific research presents itself as a niche of innovative ideas which, when implemented, will accelerate the process of export diversification in natural resource-intensive industries.

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ANNEX

Table A1: Descriptive statistics of research complexity, natural resources and macroeconomic variables in developing countries

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
Research complexity	1,873	-.2410803	.6086495	-1.611761	1.241731
Total rent	1,903	1.772871	1.111791	.0010669	4.205586
Education	1,406	4.201688	.5013783	1.824122	4.95595
Income	1,89	8.059027	1.087037	5.541656	11.20495
Social dependency	1,911	4.091944	.3038674	2.844863	4.713814
Investment	1,784	3.074166	.3378359	.6933678	4.394709
ICT	1,857	-.0467093	1.060819	-1.429557	2.161941
Governance	1,91	-.0325739	1.267987	-2.409016	2.52058

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Table A2: Correlation matrix between natural resources and research complexity

	Research complexity	Total rent	Education	Income	Social dependency	Investment	ICT	Governance
Research complexity	1.0000							
Total rent	**-0.0764**	1.0000						
Education	0.4126	-0.1329	1.0000					
Income	0.4504	-0.0623	0.7387	1.0000				
Social dependency	-0.2380	0.1988	-0.3508	-0.3765	1.0000			
Investment	0.0668	0.0168	0.1401	0.0981	-0.1391	1.0000		
ICT	0.4335	-0.1429	0.6634	-0.6941	-0.3871	0.1706	1.0000	
Governance	0.4247	-0.2555	0.3848	0.5731	-0.2645	0.1930	0.4574	1.0000

Table A3: List of countries and codes

N0	Country	Code	N0	Country	Code	N0	Country	Code
1	Albania	ALB	20	Costa Rica	CRI	39	Jordan	JOR
2	Algeria	DZA	21	Cote d'Ivoire	CIV	40	Kazakhstan	KAZ
3	Angola	AGO	22	Cuba	CUB	41	Kenya	KEN
4	Argentina	ARG	23	Dominican Republic	DOM	42	Korea, South	KOR
5	Armenia	ARM	24	Ecuador	ECU	43	Kuwait	KWT
6	Azerbaijan	AZE	25	Egypt	EGY	44	Kyrgyzstan	KGZ
7	Bangladesh	BGD	26	El Salvador	SLV	45	Laos	LAO
8	Belarus	BLR	27	Ethiopia	ETH	46	Lebanon	LBN
9	Bolivia	BOL	28	Gabon	GAB	47	Libya	LBY
10	Botswana	BWA	29	Georgia	GEO	48	Madagascar	MDG
11	Brazil	BRA	30	Ghana	GHA	49	Malaysia	MYS

12	Burkina Faso	BFA	31	Guatemala	GTM	50	Mali	MLI
13	Cambodia	KHM	32	Guinea	GIN	51	Mexico	MEX
14	Cameroon	CMR	33	Honduras	HND	52	Moldova	MDA
15	Chile	CHL	34	India	IND	53	Mongolia	MNG
16	China	CHN	35	Indonesia	IDN	54	Morocco	MAR
17	Colombia	COL	36	Iran	IRN	55	Mozambique	MOZ
18	Congo, Dem Republic	COD	37	Iraq	IRQ	56	Namibia	NAM
19	Congo, Republic	COG	38	Jamaica	JAM	57	Nicaragua	NIC

Table A3 (Continued)

N0	Country	Code	N0	Country	Code
58	Niger	NER	75	Sudan	SDN
59	Nigeria	NGA	76	Syria	SYR
60	Oman	OMN	77	Tanzania	TZA
61	Pakistan	PAK	78	Thailand	THA
62	Panama	PAN	79	Togo	TGO
63	Papua New Guinea	PNG	80	Tunisia	TUN
64	Paraguay	PRY	81	Turkey	TUR
65	Peru	PER	82	Uganda	UGA
66	Philippines	PHL	83	Ukraine	UKR
67	Qatar	QAT	84	United Arab Emirates	ARE
68	Romania	ROU	85	Uruguay	URY
69	Russia	RUS	86	Uzbekistan	UZB
70	Saudi Arabia	SAU	87	Venezuela	VEN
71	Senegal	SEN	88	Vietnam	VNM
72	Serbia	SRB	89	Yemen	YEM
73	South Africa	ZAF	90	Zambia	ZMB
74	Sri Lanka	LKA	91	Zimbabwe	ZWE

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