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RESEARCH ARTICLE

Empirical analysis into the nexus between energy consumption, economic growth, and natural resources in D-8 bloc: evidence from panel causality analysis

Mahmut Sami Duran[1] · Seyma Bozkaya[2] · Festus Victor Bekun[3,4]

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Abstract

THe importance of the impact of natural resources on economic growth is an important issue with a long history in the energy and environment literature. It is seen that the studies conducted in this field are generally shaped by the "resource curse hypothesis," a hypothesis that highlights the trade-off between economic growth and resource abundance in the growth literature. However, the extant literature have presented inconclusive results. This study aims to examine the direction of causality between capital, energy use, energy imports, exchange rate, natural resources, and per capita income in countries that are rich in natural resources and consist of developing countries (D-8). In this context, first of all, the existence of CD test was determined, and then the stationarity of the variables was determined with the CADF unit root test. Then, whether the slope coefficients of the variables were homogeneous or not, it was decided that they were heterogeneous. Finally, the direction of causality between the variables was examined with the Dumitrescu-Hurlin panel causality test applied to heterogeneous panels. The empirical analysis results show a unidirectional causal relationship from capital to GDP per capita and from GDP per capita to energy use. In addition, while a two-way causality relationship was determined between the exchange rate and GDP per capita, no causal relationship was found between energy imports, natural resources, and per capita income. These results have macroeconomic implications and spillover effects on the energy mix of D-8 economies. In addition, no causal relationship was found between natural resources and GDP per capita in this country group and within the scope of the analysis period. Policy recommendations are highlighted in the conclusion.

Keywords Natural resource curse · Clean economy · Economic growth · Exchange rate · Dumitrescu-Hurlin panel causality test · Developing economies

JEL Classification N50 · O47 · Q49 · C10

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✉ Festus Victor Bekun
fbekun@gelisim.edu.tr

Mahmut Sami Duran
msduran@selcuk.edu.tr

Seyma Bozkaya
seymabozkaya@hotmail.com

1 Finance, Banking and Insurance Department, Yunak Vocational School, Selcuk University, Konya, Turkey

2 Economics PhD Program, Social Sciences Institute, Nevşehir Hacı Bektaş Veli University, Nevşehir, Turkey

3 Faculty of Economics Administrative and Social Sciences, Department of International Logistics and Transportation, Istanbul Gelisim University, Istanbul, Turkey

4 Adnan Kassar School of Business, Department of Economics, Lebanese American University, Beirut, Lebanon

Abbreviations

D-8	Bangladesh, Indonesia, Iran, Malaysia, Egypt, Nigeria, Pakistan, and Turkey
GDP	Gross domestic product
R&D	Research and development
GHG	Greenhouse gas emissions
COP	Climate Change Conference
CO_2	Carbon emissions
GCC	Gulf Cooperation Countries
CS-ARDL	Cross-sectional autoregressive distributed lag
E7	China, India, Brazil, Turkey, Russia, Mexico, and Indonesia
SDGs-8	Sustainable development goals
LM	Lagrange multiplier
CADF	Cross-sectionally augmented Dickey Fuller
CD	Cross-section dependency
AIC	Akaike information criterion

Introduction

Economic growth, which is expressed as an increase in the general production level of an economy, is one of the most important goals that countries want to achieve. Many factors such as social savings tendency (capital accumulation), R&D, innovation, and population growth are accepted as the main factors that drive economic growth and ensure its continuity (Kaldor 1957). When viewed from this angle, studies investigating the factors affecting economic growth using different variables cover a wide area in the extant literature. Basic growth models also include the factors that determine economic growth, such as natural resources, capital accumulation, technological development, labor, human capital, energy consumption, and human capital, which argues that it depends on many factors. However, as the economies grow, the world is also exposed to increasing environmental degradation, which is becoming more and more threatening to the ecosystem. Thus, increased greenhouse gas (GHG) emissions are a result of increased economic growth and development (Jiang et al. 2022; Ferreira et al. 2022; Wang et al. 2022). As a result, policymakers and governments often worry less about the environment and strive to increase total production in pursuit of more growth. For this reason, politicians fall into the dilemma of making concessions from economic growth and development in order to provide a more livable environment. This situation leads to a gradual shift away from a sustainable environmental policy (Akadiri et al. 2022a, b; Zhang et al. 2022; Wu et al. 2022; Dabbous and Tarhini 2021; Syed and Bouri 2021). The United Nations Climate Change Conference (COP) is organized in order to ensure unity in the world and implement common policies on this issue. The conference, held for the twenty-sixth most recent (COP26), includes policy discussions at international, regional, and national levels.

Policymakers at COP26 draw attention to the serious impacts of global warming on the peaceful coexistence of humans and the sustainability of the environment for present and future generations (Ibrahim 2022a). The decisions taken at COP26 aim to keep the global warming of 2° in the current era below a reference limit of 1.5°. If this cannot be achieved, it is seen that the global economy will face a big problem in the near future (İbrahim 2022b). Therefore, striking the balance between further growth and protecting the environment is a vital decision for our safety and the lives of future generations.

However, the literature generally focuses on the thesis that countries with natural resources achieve much lower growth rates. According to this thesis put forward by Sach and Warner (1995) and Auty (1993), they posited that the income generated as a result of the exploration and exploitation of natural resources comes with its consequences on the country's economy and that this would cause a slowdown in economic growth and based this on historical examples and real data (Bekun et al. 2019; Ulucak and Ozcan 2020). Atkinson and Hamilton (2003) argued that if rich natural resources are not managed or re-invested appropriately, it can have negative consequences in terms of economic performance and spillover implications for environmental sustainability (Ulucak and Ozcan 2020; Eslami et al. 2021; Anwar et al. 2022; Hu et al. 2022; Mirza et al. 2022). The extant literature on resource curses hold the position that many of the countries rich in natural resources cannot have rapid and expected growth rates that have taken a remarkable situation in the last five decades. Despite this negative relationship between natural resources and growth, natural resources are very important for national economies. In this context, recent studies investigating the effect of natural resources on growth contribute to the literature. If we give an example of current studies on this subject, Moshiri and Hayati (2017) concluded that natural resource wealth had a positive effect on GDP growth between 1996 and 2010 over a large sample group of 149 countries. Bekun et al. (2019) study examines the relationship between CO_2 emissions, resource rent, and renewable and non-renewable energies in 16 EU countries between 1996 and 2014. According to empirical findings, non-renewable energy consumption and economic growth increase carbon emissions. On the other hand, renewable energy consumption reduces CO_2 emissions.

Majeed et al. (2021) investigated the impact of natural resource abundance, globalization, and unbundled energy consumption on environmental quality in GCC countries, taking into account urbanization and economic growth, between 1990 and 2018. Findings from the CS-ARDL estimator showed that natural resource abundance significantly improves environmental quality and economic globalization, and renewable energy consumption reduces emission levels in GCC economies. Adebayo et al. (2021), using data covering the period from 1965 to 2019, examined the relationship between CO_2 emissions, gross capital formation, energy use, and economic growth in South Korea. Empirical evidence has confirmed that CO_2 emissions trigger economic growth and support the energy-driven growth hypothesis. Also, a unidirectional causality running from energy consumption to GDP was found in South Korea.

Destek et al. (2022) investigated the validity of a potential inverted *U*-shaped relationship between natural resource dependence and economic growth in 28 countries using the 1990–2017 data set. Their findings show that the current level of resource dependency does not appear to be a barrier to economic growth in 17 of 28 countries, but appears to be a curse for sustainable development in 9 out of 17, among 11 other countries. Gyamfi and Adebayo (2022) examined the effects of renewable energy, resource volatility, and fossil fuels on economic performance and CO_2 emissions in E7 countries between 1990 and 2018. They concluded that all variables have a significant and positive relationship on economic performance. Akadiri et al. (2022a, b) examined the effect of financial globalization and natural resource rent on the load capacity factor in the Indian economy. Their results show that only renewable energy consumption reduces the load capacity factor, economic growth and financial globalization are positively related to the load capacity factor, and natural resource rent is insignificant in the short run. On the other hand, while only economic growth has a negative relationship with the load capacity factor in the long run, other variables affect the load capacity factor positively.

The relationship between natural resources, energy consumption, urbanization, capital, and economic growth in the BRICS countries for the period 1990–2016 was examined by panel data analysis (Bozkaya and Duran 2022). According to their findings, it was found that energy consumption has a positive effect on economic growth. Contrary to expectations, the impact of natural resources is negative. Therefore, it has been observed that the "curse of natural resources" is valid for this group of countries. Although the impact of natural resources on growth is very important, the literature mostly focuses on the effect of energy consumption on economic growth. The relationship between energy and growth is a critical issue that should be emphasized for the sustainable development goals of economies. This preposition aligns with the United Nations demand for decent and sustainable economic growth outlined in UNSDGs-8. On the other hand, although natural resources have been neglected due to the energy crisis, a lot of work has been done recently as a factor affecting growth. In this context, this study aims to investigate the impact of natural resources on economic growth in D-8 countries such as Bangladesh, Nigeria, Pakistan, Iran, Indonesia, Egypt, Malaysia, and Turkey between 1981 and 2016. In this country group, which has a rich structure in terms of natural resources, the causality relationship between natural resources and growth is the primary aim of this study. In addition, the causality relationship of energy consumption, energy imports, exchange rate, and capital with the economic growth of this country group constitutes the secondary objective.

In order to explain this effect between variables, Dumitrescu and Hurlin heterogeneous panel causality test is applied (Fig. 1). In addition to studies focusing on the relationship between energy and growth, the study contributes to the empirical literature by examining the relationship between capital accumulation, energy imports, and exchange rates, which are policy-determining indicators for these economies, and per capita income in developing countries that are rich in natural resources. In this context, the study consists of three parts. While the "Introduction" section is the introduction, the "Data, methodology, and empirical application" section explains the methodological method used in the study. In the "Concluding remarks" section, the results of the analysis are given and a comprehensive evaluation is made. Finally the "Policy suggestions" section presents the policy suggestions for the studied bloc.

Data, methodology, and empirical application

The sample used in the study consists of D-8 (Bangladesh, Nigeria, Pakistan, Iran, Indonesia, Egypt, Malaysia, Turkey) countries. D-8 was established on June 15, 1997 at the Heads of State and Government Summit held in Istanbul. Countries that are members of the D-8 Economic Cooperation Organization have an important position in their regions due to their natural resources, dense population, and potential markets. The developments in this economic cooperation, which is a developing country group, are also important for the world economy. The study includes annual data for the

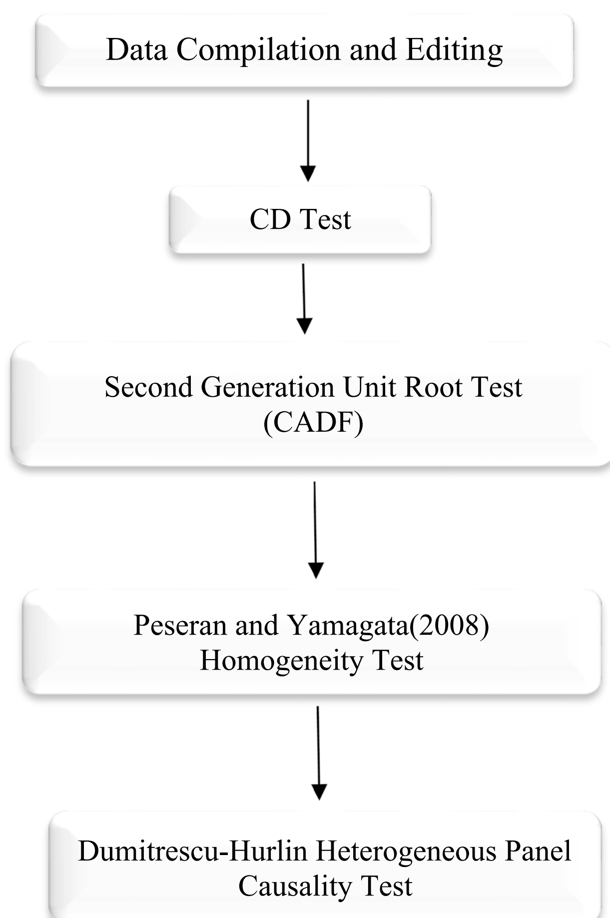

Fig. 1 Model research framework. *Sources*: Created by the authors

period 1981–2016. Due to the data constraints of some countries, the limits of the study were determined in this way. In the empirical analysis, variables affecting the economic performance of these countries were selected. GDP per capita was used as the growth variable. In addition, variables such as capital, energy use, energy imports, natural resources, and exchange rates have been determined as the variables that are effective on growth for these countries. In this context, the variables, definitions, and databases used in the study are given in Table 1.

Initially, diagnostic tests were performed when embarking on empirical practice. First, the cross-section dependency test was applied to examine whether there was an interaction between the countries, which is a common effect check; this is necessary to avoid spurious inferences among the study bloc investigated. Considering that countries are in close relations with each other in the global economic order, the importance of this test emerges. Panel data analysis is very important and gives consistent results since it takes these relationships between the series into account and tests accordingly. In addition, this test result helps to decide on the methods to be used to determine the unit root, cointegration, and long-term coefficients to be used in the study. Table 2 shows the CD test result.

When the results in Table 2 are evaluated, the individual results of the variables and the *P* probability values of the group results are taken as basis. Since the probability value of the LM (Peseran 2004) test statistic, which is based on $T > \mathrm{N}$ ($T = 35 > N = 8$) according to the time and cross-section values used in our model, is less than 0.05, the null hypothesis of H_0: there is no cross-section dependency is rejected and it is accepted that there is a horizontal section between the series. Therefore, based on this result, it was decided that the unit root test to be used in the study would be second generation. Table 3 shows the CADF test results, which is the second-generation unit root test. Unit root test results for all variables become stationary at $I(1)$ level.

After the unit root test, the necessity of applying the homogeneity test, which helps to determine the model required for determining the long-term coefficients, arises. The homogenic test, which was first developed by Swamy (1970), is used by Pesaran and Yamagata (2008) by expanding it as Delta (Δ) test (Peseran et al. 2008, pp. 54–55). According to this new test developed, in the cointegration equation of the form $Y_{it} = \alpha + \beta_{it} X_{it} + \varepsilon_{it}$, β_i represents the slope coefficient. The hypotheses used to test the Δ test are as follows:

H_0: $\beta_i = \beta$,
H_1: $\beta \neq \beta_j$,

In addition, Pesaran and Yamagata (2008) developed the equations in Eqs. (1) and (2) for wide panel and short panels in order to test the above hypotheses with this method they developed.

$$\text{To use in more observations, } \hat{\Delta} = \sqrt{N}\left(\frac{N^{-1}\hat{S} - k}{\sqrt{2k}}\right. \tag{1}$$

$$\text{For use on smaller samples, } \tilde{\Delta}_{\mathrm{adj}} = \sqrt{N}\left(\frac{N^{-1}\hat{S} - k}{\sqrt{2k}}\right. \tag{2}$$

Table 1 Variable definitions and source databases

Variable	Broad definition of variable	Source
GDPpc	GDP per capita (current US$)	WDI
Capital	Gross capital formation (% of GDP)	WDI
Energy use	Energy use (kg of oil equivalent per capita)	WDI
Energy ımp	Energy imports, net (% of energy use)	WDI
Natural resources	Total natural resources rents (% of GDP)	WDI
Exchange rate	Official exchange rate (LCU per US$, period average)	WDI

Source: Authors' compilation

Table 2 Cross-section dependency (CD test) test results

Variable	*GDPpc*	*Cap*	*Eu*	*Eımp*	*Natr*	*Exrate*
P-value	0.000***	0.046**	0.000***	0.000***	0.000***	0.000***
Group results						
			LM	LM_{adj}	LM_{CD}	
Statistics			51.95	7.86	3.183	
P-value			0.0039**	0.0000***	0.0015**	

*** and ** indicate the significance levels at 1% and 5%, respectively. Related test statistics were obtained with the "Stata 15" package program

Table 3 CADF unit root test

Variables	CADF *P*-value	CADF *Z* (*t*-bar)	CADF Results
d.GDPpc	0.004**	−2.623	*I*(1)
Capital	0.674	0.452	-
d.capital	0.000***	−4.781	*I*(1)
Euse	0.284	−0.570	-
d.euse	0.000***	−4.382	*I*(1)
Eımp	0.292	−0.548	-
d.eımp	0.000***	−3.669	*I*(1)
Natr	0.372	−0.327	-
d.natr	0.000***	−4.295	*I*(1)
Exrate	0.953	1.671	-
d.exrate	0.043**	−1.712	*I*(1)

*** and ** indicate the significance levels at 1% and 5%, respectively. Fixed option is used. Relevant test statistics were obtained with "Stata 15"

In the equations, N represents the cross section, S represents the Swamy test statistic, and k represents the number of explanatory variables (Peseran et al. 2008, pp. 52–57). In line with these explanations, Table 4 shows the homogeneity test result. In the homogeneity test performed for the overall panel, it is concluded that the *Delta* and $Delta_{adj}$ test statistics are heterogeneous for the panel as a whole, according to their probability values.

After the homogeneity test, the cointegration test was applied, but no long-term relationship was found between the series. Therefore, the necessity of estimating the long-term cointegration coefficients has been eliminated. In this context, starting from the unit root test results, all of the variables become stationary at the $I(1)$ level. Based on the heterogeneity of the panel according to the homogeneity test results, it was decided to apply the Dumitrescu and Hurlin (2012) panel causality test applied to heterogeneous panels in order to learn the direction of the causality relationship between the study variables under consideration. In addition, there is a prerequisite for all the variables to be $I(0)$ in order to apply this test. Therefore, in our study, the difference of all the variables that were $I(1)$ was converted into $I(0)$.

Dumitrescu and Hurlin (2012) is an extended version of the Granger causality test so that it can be applied to heterogeneous panels. The main hypothesis of this causality test is it is expressed as "all β_i s are equal to zero." It also means that there is no causality from X to Y for the entire panel; that is, there is no homogeneous panel causality. While the basic hypothesis of the method is homogeneity, the alternative hypothesis is that the model is heterogeneous. If the basic hypothesis is not rejected, it means that the variable X is not the cause of Y for all units of the panel. When the basic hypothesis is not rejected, the variable X represents the cause of Y for the entire panel. Therefore, a homogeneous panel is obtained as a result of causality (Dumitrescu and Hurlin 2012).

Table 4 Homogeneity test results

	Group results	
	Delta	*P*-value
	16.960	0.000***
Adj.	18.896	0.000***

*** and ** denote the statistical rejection levels at 0.01 and 0.05%, respectively

In order to test the main hypothesis of the method, Wald test statistics are taken into account. In the Dumitrescu-Hurlin method, the causality test in each unit is made by taking the average of the Wald test statistics. This situation is shown in the figure below:

$$\overline{W}_{N,T} = \frac{1}{N} \sum_{i=1}^{N} W_{i,T} \tag{3}$$

where $W_{i,T}$ expresses the unit-specific Wald test statistic in order to test the $H_0 = \beta_i = 0$ hypothesis of the unit. In the light of these explanations, the results of the causality test results according to different models are shown below. Table 5 shows the direction of the causal relationship between GDP per capita and capital.

When interpretation is made according to the test statistics in Table 5, the causality relationship from GDP per capita to capital is accepted as H_0 according to the probability value. Therefore, there is no causal relationship from GDP per capita to capital. In the second part of the table, the direction of causality between capital and GDP per capita is tested. Since the P-value is less than 0.05, the H_0 hypothesis is rejected. In this context, the existence of a causal relationship from capital to GDP per capita has been determined. Table 6 shows the test statistics examining the direction of the causal relationship between the second model, energy use, and GDP per capita.

According to the test statistics, the existence of causality from per capita income to energy use has been determined in the first row of the table. Since the P probability value is less than 0.05, the H_0 hypothesis is rejected. Therefore, it is accepted that there is a causality running from per capita income to energy use. On the other hand, H_0 cannot be rejected since the statistical value testing the causality from energy use to per capita income is greater than 0.05. In this context, it is determined that there is no causality from energy use to per capita income. Table 7 shows the results that determine the direction of the causal relationship between natural resource rents and per capita income.

In this model, no causal relationship could be detected from both natural source to per capita income and from per capita income to natural source. According to the P

Table 5 *Model 1* Dumitrescu and Hurlin heterogeneous causality test

H_0 hypothesis	*W*-bar	*Z*-bar	*P*-value
GDPpc → Capital	1.4680	0.9359	0.3493
Capital → GDPpc	2.6623	3.3246	0.009**

These are our own calculations. The lag length was determined according to the information criterion to AIC and was chosen as 1 for the first model and 9 for the second model. *** indicates 5% significance level

Table 6 *Model 2* Dumitrescu and Hurlin heterogeneous causality test

H_0 hypothesis	*W*-bar	*Z*-bar	*P*-value
GDPpc → Energy use	15.0802	4.0535	0.000***
Energy use → GDPpc	0.8412	– 0.3175	0.7508

These are our own calculations. The lag length was determined according to the information criterion to AIC and was chosen as 9 for the first model and 1 for the second model. *** indicates 1% significance level

Table 7 *Model 3* Dumitrescu and Hurlin heterogeneous causality test

H_0 hypothesis	*W*-bar	*Z*-bar	*P*-value
GDPpc → NatR	0.5134	– 0.9731	0.3305
NatR → GDPpc	0.7714	– 0.5264	0.6490

These are our own calculations. The lag length was determined according to the information criterion to AIC and was chosen as 1 for both models

probability value, H_0 for both cases, the hypothesis that *X is not the cause of Y* was accepted. Table 8 shows the causality relationship between per capita GDP and energy imports for model 4.

Considering the probability values for this model, the *P*-values are valid both from per capita income to energy imports and from energy imports to per capita income. It led to the acceptance of the H_0 hypothesis. In this context, no causal relationship was found between energy imports and per capita income. Table 9 shows the causal relationship between the latest model, per capita income, and exchange rate.

According to Table 9, which shows the results for the last model, there is a causal relationship from income per capita to exchange rate. Likewise, the H_0 hypothesis is rejected since it is less than 0.05 according to the *P*-value. Therefore, it is accepted that there is a causality running from the exchange rate to the per capita income. In this context, it has been determined that there is a bidirectional causality between per capita income and exchange rate.

Figure 2 schematizes the results of the Dumitrescu and Hurlin causality test. It is seen in the figure that there is a one-way causality relationship from capital to per capita income, and a one-way causality relationship from per capita income to energy use. In addition, it has been shown that there is a bidirectional causality between per capita income and exchange rate.

Table 8 *Model 4* Dumitrescu and Hurlin heterogeneous causality test

H_0 hypothesis	*W*-bar	*Z*-bar	*P*-value
GDPpc → Eimp	0.7214	– 0.5571	0.5775
Eimp → GDPpc	1.4923	0.9847	0.3248

These are our own calculations. The lag length was determined according to the information criterion to AIC and was chosen as 1 for both models

Table 9 *Model 5* Dumitrescu and Hurlin heterogeneous causality test

H_0 hypothesis	*W*-bar	*Z*-bar	*P*-value
GDPpc → Exrate	9.9952	11.3069	0.000***
Exrate → GDPpc	2.5055	3.0109	0.002**

Our own calculations. The lag length was determined according to the information criterion to AIC and was chosen as 2 for the first model and 1 for the second model. *** and ** indicate the significance levels at 1% and 5%, respectively

Concluding remarks

In the context of developing countries (D-8 countries), per capita income tests the causality relationship between capital, energy use, energy imports, exchange rate, and natural resource. In this context, Dumitrescu-Hurlin panel causality test applied to heterogeneous panels was used. The results of the analysis identify a causal relationship from capital to GDP per capita and from GDP per capita to energy use. In addition, there is a bidirectional causality relationship between exchange rate and GDP per capita. On the other hand, no causal relationship was found between energy imports and natural resource per capita income.

The results of the application and the results to be drawn from the literature can be evaluated as follows: one of the most important factors on economic growth is capital accumulation. Countries can increase their capital accumulation and use it for investments and benefit for long-term growth. Developing countries should develop policies in order to attract foreign capital to increase their capital accumulation. With policies that will encourage foreign investors and internal stability, they can achieve an effective growth by ensuring that this capital is permanent. Therefore, developing countries can develop their own economic structures and provide a suitable basis for foreign capital. In addition, with the existence of abundant and cheap labor force, which is a problem of developing countries, they can evaluate this

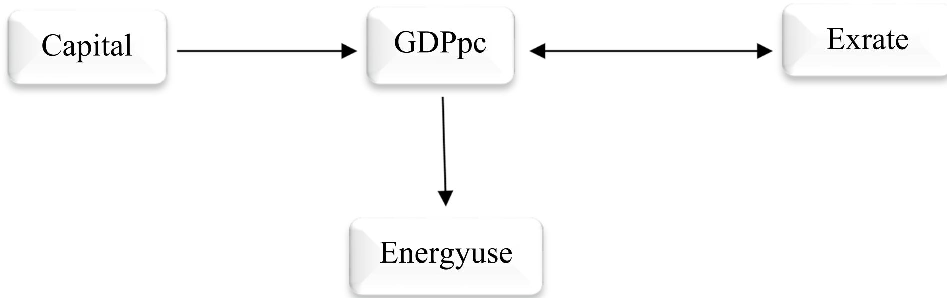

Fig. 2 Schematic representation of the causality relationship. *Sources*: Created by the authors

potential as a contribution to foreign capital. In this context, they can increase employment opportunities and increase per capita income. National economies should attach importance to investments in this direction.

The energy factor has spread to all areas of the economy and is very important in terms of being used as an input at every stage of production. Therefore, energy use is of vital importance. As an important input, in order to get maximum efficiency from this factor and reduce energy costs, countries should focus on policies that will increase energy efficiency. In addition, it seems possible to be effective on growth by making incentives in this direction and reducing costs through legal regulations. Therefore, it is important for national economies to work in this direction.

Energy imports, which constitute a major expenditure item as a significant loss of foreign currency in developing countries, should be carefully examined. These countries seem to be condemned to importing energy, which has many different uses such as being able to produce and heat. This necessity causes countries to borrow in foreign currency. In this context, in order to minimize foreign dependency in energy, reduce the fragility of the country, and prevent foreign exchange loss, increasing energy investments in the country and promoting efficiency should be among the primary measures.

Policy suggestions

From a policy standpoint, the D-8 countries, which host countries rich in natural resources, need to contribute to growth by incorporating these resources into production with the right management. Otherwise, it seems inevitable that the natural resource curse will be valid. Exchange rate is very important on the basis of developing countries. Because these countries are dependent on foreign sources for many inputs in order to produce. Therefore, fluctuations in exchange rates significantly affect input costs and reduce predictability. In countries where the national currency is ineffective and foreign dependency is significant, fragility increases. Any development that takes place abroad greatly increases the economies of this country. Developing countries must first effectively manage their domestic economic policies in order to increase predictability, reduce fragility, and ensure a certain stability. Effective policies, incentives, necessary investments, and legal regulations should be made to ensure stability, which is more important than growth.

In the light of empirical application, conclusions, and evaluations, it is pointed out that it is an important issue for future studies to focus on the effective management of natural resources. It will be significant in terms of paving the way for developing countries rich in natural resources to benefit from their existing resources with these studies and effective management.

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Author contribution The first author Mahmut Sami Duran was responsible for the conceptual construction of the study's idea, the data gathering, and preliminary analysis. Second author Seyma Bozkaya handled the literature section, and third author Festus Victor Bekun managed the proofreading and manuscript editing.

Data availability The data for this present study are sourced from WDI as outlined in the "Data, methodology, and empirical application" section.

Code availability All codes for the analysis are available in STATA and E-views statistical software.

Declarations

Ethical approval Authors mentioned in the manuscript have agreed for authorship read and approved the manuscript and given consent for submission and subsequent publication of the manuscript.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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