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Interacting force of foreign direct invest (FDI), natural resource and economic growth in determining environmental performance: A nonlinear autoregressive distributed lag (NARDL) approach

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A R T I C L E I N F O

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A B S T R A C T

Considering the strategic position of Algeria both in the global and regional economic complexities through economic liberalization, much has been said about oil shock and economic performance of Algeria but little has been done towards ascertaining the impact of natural resources and foreign direct investment inflow (FDI) on its environmental performance. For this purpose, we adopt Algeria 1970–2018 data to study its sustainable development with focus on its environmental performance. Nonlinear and long run asymmetric cointegration were utilized for a comprehensive research on this topic. Our findings are as follows: positive and negative shocks to the economic growth and fossil fuels on the Algerian environment increases and reduces carbon emission respectively, positive and negative shocks to FDI and natural resources decrease the carbon emission thereby impacting positively on the environment. Hence, pollution halo hypothesis is confirmed for Algeria meaning FDI is impacting positively on the environment and should be encouraged through policy framing and implementation for the case of Algeria.

1. Introduction

The use of non-renewable energy comes first among the factors that cause negative effects on environmental development. The extraction, production and distribution of non-renewable energy sources can cause environmental damage in many cases. The increase in carbon emissions due to the consumption of fossil fuels causes global warming and climate change, creating an obstacle to regional and global sustainable development. Therefore, the rapid increase in energy demand and the dependence on energy is likely to cause serious problems for all countries in the coming years (Zameer and Wang, 2018). Many countries have reached a consensus to take joint responsibility for combating climate change with the signing of the Paris Agreement (Conference of the Parties-COP21) in 2015 within the scope of the United Nations Framework Convention on Climate Change. In this context, the measures to be taken and regulations to be made have been determined in order to reduce CO2 emissions (Yasmeen et al., 2020).

Algeria has made a commitment to reduce carbon emissions by 7–22% by 2030, under the COP21 contract (Amri, 2017). The total energy consumption of the country increased by 32% between 2010 and 2014 before the contract. According to the Environmental Performance Index, Algeria ranks 84th among 180 countries (EPI, 2020). Therefore, the country must take proactive steps to fulfill its commitment to reduce carbon emissions (Bouznit et al., 2018). At the same time, it is aimed to reduce energy consumption by 9% by 2030 (Amri, 2017). In this context, adopting a national program to increase the share of renewable energy use in total energy consumption can be considered as an important initiative. The sense of responsibility towards mitigating environmental problems on a global scale has not been developed fully due to the current economic conditions of developing countries. In most cases, these countries aim to maximize the use of natural resources to increase their economic performance (Ahmad et al., 2020). The pursuit of high economic growth may lead to ignoring the need to protect the ecosystem (Zameer et al., 2020). Income generated from natural resources in resource-rich countries can determine the direction of economic growth. Oil discovering and production took place in Algeria in 1956. Today, approximately 20% of the country's GDP and 85% of its export revenues come from the resource sectors (OPEC, 2020).

In some resource-rich countries, stricter environmental regulations come to the fore with the effective management of resource revenues,

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while in some resource-rich countries, economic and environmental policies are not sufficiently supported. As a result, developed countries are shifting their investments towards developing countries. It is significant how the flow of investment affects the environmental performances of resource-rich countries that want to gain comparative advantage in the free trade arena. In this regard, if FDIs negatively affect the environmental factors of developing countries, then the " pollution haven" hypothesis (PHH) is valid (Cole, 2004). However, if FDIs affect environmental performance positively, the validity of the "pollution halo" hypothesis is accepted (Zarsky, 1999). Oil resources are one of the main driving forces of FDIs (Oro and Alagidede, 2021). Algeria FDI data show that conventional non-renewable energy resources attract more Investments than any other sector. In the 1980s, FDI was directed only in the hydrocarbon sector, while in 1990s, FDI inflows decreased due to economic and political instability. In 2001, FDI increased as a result of the incentive package and the enactment of investment law, and oil revenues had an increasing effect on investments (Chaib and Siham, 2014). In addition to the frequent changes in economic development and liberalization policies of Algeria over the years, a stable attitude has not been adopted in environmental sustainability until recent years. There was no carbon tax, the effectiveness of overall environmental policies was poor and alternative options could not be created (Mohammed, 2017). It is too soon to make conclusive remarks about whether the commitment to achieving the targets set under COP21 has been demonstrated. Economic and environmental consequences can be analyzed more comprehensively in the coming years. However, analyzing the current dynamics of the country and determining how it affects environmental quality is of critical importance in shaping policy preferences and priorities.

Following the background, the current paper seeks to study the sustainable performance of Algerian environment under the interaction of natural resources, FDI and economic growth. Our study will contribute to the existing literature by incorporating the trio of economic growth, FDI and natural resource with the application of NARDL approach in identifying the best model and policy to foster Algerian sustainable development. The novel of this study will be seen from answering the following questions towards attainment of Algerian sustainable development goals (SDGs): a. Does natural resources in Algeria have a significant effect towards its sustainable development? b. Does FDI has any contribution towards Algerian environment performance? C. Does the country's economic growth has any effect towards its sustainable development? The economic complexity of Algeria is characterized with primary sectors as it anchored on natural resource based. This has paved way for Algerian economy to be among the attracting economies for investors, and this could trigger anti healthy environmental performance due to the unchecked economic operations of foreign investors. Bearing in mind the nexus between the trio (economic growth, FDI and natural resources), our study incorporates FDI to test if the pollution haven hypothesis exist in Algeria. The pollution haven hypothesis was tested within the scope of the effects of FDI flows and trade openness on CO2 emissions. We adopted nonlinear autoregressive distributed lag (NARDL) and long run asymmetric cointegration for in-depth exposition of the interaction of economic growth, FDI and natural resource. This will give a comprehensive exposition of the performance of Algeria environment with the selected variables. Reason is based on the decomposed nature of nonlinear ARDL approach incorporating both the positive and negative impact of the indicator for environment. Our work might not be the first to study the Algerian environmental performance but to our knowledge, this is the only study that seeks to incorporate FDI and natural resources in investigating the environmental performance of Algeria.

The main contributions of this paper are: i) revealing the role of natural resources, FDIs and economic growth in enhancing environmental quality ii) determining the effect of these factors in Algeria iii) providing a scientific source to contribute to the development of effective policies in Algeria and countries with similar economic dynamics.

In the second part of the study, the literature review with different studies is included. Other sections are 3, 4, and 5 for data and methodology, empirical results and discussion, conclusion, and policy suggestions.

2. Literature review

In the natural resource-dependent Algerian economy; the impact of resources, fossil fuel consumption, economic growth and FDI factors are intertwined. These factors have been the subject of our research as the main factors that are expected to affect CO2 emissions. It is possible to categorize the literature, which is examining these factors, under two sections.

2.1. The nexus of energy use, economic growth and CO2 emissions

Studies analyzing the linkage between energy consumption and economic growth have been included. According to the findings obtained from the studies of Rahman and Velayutham (2020) examining the effects of energy use on economic growth in South Asian countries, the use of both renewable and non-renewable energy affects economic growth positively. Yasmeen et al. (2021) also explained that renewable and non-renewable energy consumption encourages economic growth. In the study analyzing the Algeria's data from 1970 to 2013 using the ARDL model, an inverted N-shape relationship was found between electricity consumption and GDP. As income levels increase, the use of efficient devices may increase, so growth can be encouraged to reduce electricity consumption (Bouznit et al., 2018).

There are various studies that show that economic growth is directly related to the increase in CO2 emissions and causes environmental problems (Zhang et al., 2018). Wei et al. (2017) pointed to rapid economic growth as a significant contributor to carbon emissions growth. Yao et al. (2015) determined that economic growth is the main factor of increasing CO2 emissions, according to the results of their studies using the data of the G-20 countries for the period 1971–2010. Yasmeen et al. (2019), in their study that they used the LMDI factor decomposition analysis with the data of 1972–2016 in Pakistan, showed that the main driving force that increases per capita carbon emissions is economic development. Lacheheb et al. (2015) showed that income and population in Algeria in the period 1971–2009 had a significant impact on CO2 emissions. In another study conducted on Algeria, the linkage between carbon emission, GDP and energy consumption types was analyzed by using the ARDL model for the data of the period 1980–2011 (Amri, 2017). Zameer et al. (2020), in their study examining natural resources, financial development and ecological efficiency in China for the period of 2006–2018, found that regions with lower economic development are more dependent on natural resources. On the other hand, regarding the relationship between economic growth and carbon emissions, Shahbaz et al. (2020) determined the validity of the EKC hypothesis and suggested that economic growth can produce solutions to environmental problems in the long run.

2.2. The nexus of economic growth, FDI and CO2 emissions

In the second section, studies that reveal the relationship between economic growth, FDI and environment are included. Yasmeen et al. (2021) argued that financial openness affects economic growth positively. Shahbaz et al. (2018) highlighted the role of financial development as one of the factors that reduces CO2 emissions. The increasing scale of economic activities as a result of reduced trade barriers affects environmental performance by causing changes in production techniques and production composition (Grossmann and Kruger, 1991). As the technology level increases, the composite effect, in which economic and environmental factors are carried out together, emerges as the last phase (Cole and Elliot, 2003). Therefore, the economic growth dynamics of countries have been analyzed in different studies in the literature as a comprehensive factor that activates the environmental regulation motivation.

In this context, Bakhsh et al. (2017), using Pakistan's 1980–2014 data, stated that economic growth and FDIs triggered an increase in carbon emissions. Shahbaz et al. (2020), in their study, concluded that FDIs increased carbon emission and affected environmental quality negatively. Findings show that energy investments of public-private partnerships hinder the improvement of environmental performance.

Zhang (2011), in his study on the impact of China's financial development on carbon emissions, concluded that foreign capital investments increased carbon emissions between 1980 and 2009. In a study covering the period of 1980–2003 for India, Acharyya (2009) found that investments had negative impacts on environmental quality. In a study on Turkey, it was concluded that the pollution haven hypothesis was valid for the period of 1974–2013 (Kılıçarslan and). Shahbaz et al. (2015) revealed the existence of long term EKC in their analysis which they examined the 99 low, medium and high-income countries covering the period 1975–2012. As a result of another research on China, India, Indonesia, Iran and South Africa, the validity of the pollution haven hypothesis was confirmed (Sarkodie and Strezov, 2019). While Mike and Kardaşlar, 2018 in their findings support the pollution haven hypothesis for low-income countries, they confirm the existence of the pollution halo hypothesis for low-middle, upper-middle and high-income groups.

Kivyiro and Arminen (2014) examined the relationship between energy consumption, development, FDI and CO2 emissions in their study on six Sub-Saharan African countries and EKC hypothesis is valid for the Democratic Republic of the Congo, Kenya and Zimbabwe, the pollution haven hypothesis has been observed in Kenya and Zimbabwe, and the pollution halo hypothesis has been observed in the Democratic Republic of the Congo and South Africa. Munir and Ameer (2020), in their study in which they analyzed the effects of FDI and economic growth on environmental performance with the Pakistan's data of 1975–2016, found that economic growth and increase in FDI increased CO2 emissions.

On the other hand, studies revealing that FDIs contribute to the improvement of environmental factors for some countries and should be encouraged have also taken place in the literature. Öztürk and Öz (2016) examined the relationship between FDIs, income, energy consumption and CO2 emissions in Turkey for the years between 1974 and 2011 and found As a result of the analysis, it was found that the variables are related in the long term. It has been determined that the EKC hypothesis and the pollution halo hypothesis are valid for Turkey. Waqih et al. (2019) concluded that there is an inverse U relationship between FDIs and CO2 emissions, FDIs cause CO2 emissions up to a certain investment level, and emissions begin to decrease after the investment level reaches the threshold value.

In addition to the factors discussed, it would be meaningful to examine the basic elements that were found to affect the environmental quality positively. Shahbaz et al. (2018) emphasized that the increase in energy innovations reduces carbon emissions. Increasing investments in energy innovations can affect environmental quality positively by reducing CO2 emissions. Studies revealing that the use of renewable energy and innovations in the energy sector reduce CO2 emissions support the encouragement of relevant policies (Álvarez-Herránz et al., 2017; Ganda, 2018; Shahbaz et al., 2018). In order to achieve global sustainable development, it is recommended to act with the goal of a green economy to reduce the consumption of fossil fuels. (Lixin and Zhenghao, 2019).

When the literature is reviewed, there is no study found examining the environmental performance of Algeria in terms of natural resources, economic growth and FDIs. It is aimed to contribute to the literature in this direction.

3. Data and variable

The current study adopts Algeria annual time series data of 1970–2018. Algeria is considered in this study because of its economic complexities which is rooted in resource generated income, more specifically oil resource. Algeria is among the oil resources based economies in the North Africa and strategic in defining the environmental management and performance within the region. Following the argument from Anyanwu (2012), resource endowment is identified as among the strong forces of attracting FDI, and FDI history in Algeria is such an interesting trend which is pointed towards determining the social economic operations of the country. FDI was only accepted in the hydrocarbon sector in the 1980s but the inflow decreased in the 1990s due to economic and political instabilities. However, the trend was upturned to a more positive trend due to the incentive package and investment law enacted in 2001. The oil resource revenues had an increasing effect on investments, but later investments tended towards upturning again due to the regulations and high transaction costs in the following periods (Chaib and Siham, 2014). Nexus between FDI and resources in determining the economic performance of oil rich countries have drawn much attention in the research world but little has been done in the same regards to environmental performance.

Data utilized in this study are gotten from both World Development Index (WDI) and British Petroleum (BP) Statistical Review of World Energy. Centered on the objective of this study, that is determining the impact of resources and FDI in determining the quality of Algeria environment which is a pointer to its contribution towards mitigating climate change. Selection of the right variable is very crucial in effective research for better insight to the defined objective. Algeria is a resource (oil) based country, and by the implication of the economic complexities of the country FDI is likely to be attracted to the economy. FDI has been researched (Udemba, 2019a,b; Udemba, 2020a,b; Aizenman et al., 2013; Blonigen and Piger, 2014) as a channel to boost economic performance either directly (revenue generation and economies of scale) or indirectly (spillover effect such as technology and knowledge transfer to other firms), and evidences were derived with mixed results. Hence, natural resource and FDI are among the crucial variables adopted in this current study. The natural resources is proxy with "Total natural resources rents (% of GDP)" which is the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents. This is considered a comprehensive measure of natural resource which will expose the environmental implication of the totality of the natural resources in the country instead of utilizing oil rent or any other single variable with lopsided impact. Total natural resources rent (% of GDP) is sourced from the 2018 updated world development indicator (WDI). Foreign direct investment (FDI), inflow is measured with foreign direct investment, net inflows (% of GDP) and it is sourced from 2018 updated world development indicator (WDI). Economic growth and fossil fuel are the control variables adopted in this study. Complexities of Algeria economic operations as it connects to the utilization of energy in promoting the economic activities have made it possible for this current study to adopt economic growth and fossil fuel to ascertain the economic performance of the country. Economic growth is measured with GDP per capita (constant 2010 US$), while the fossil fuel is the summation of non-renewable energy sources (oil, gas and coal) measured in million tonnes of carbon dioxide. Many scholars (Udemba, 2019a, 2020a; Dergiades, 2016; Vehmas, 2007; Shahbaz et al., 2013; Farhani et al., 2014; Al-Mulali et al., 2013; Chen, 2008 and Stern, 2004) have extensively discussed the interaction between the economic growth, energy use (fossil fuels) and the environmental performance with different approaches with mixed evidences. The variables (GDP per capita (constant 2010 US$) and fossil fuel) are sourced from the updated 2018 world development indicator (WDI) and 2019 British Petroleum (BP) statistical review energy world respectively. With focus on the performance of Algeria environment, we adopted carbon emissions (CO_2) variable as better proxy to the environment. The choice of CO_2 is based on the tendency of emitting excess emission in the process of utilizing fossil fuel in executing economic operations and even in harnessing or exploration of the natural resources such as oil and flaring of gas etc. Carbon dioxide emissions is measured in million tonnes of carbon dioxide and it is sourced from 2019 British Petroleum (BP) statistical review energy. The summary of the variables with the sources of data is put in Table 1 below.

4. Methodology and modelling

We adopt different methodologies in this study for clear and insightful analysis of the chosen topic. Scientific approaches such as unit root tests with traditional and structural break tests, descriptive statistics, and nonlinear with asymmetric cointegration version of autoregressive distributed lag (ARDL) are all adopted in this study. Conventional approaches such as Dickey Fuller (DF, 1979); Philip-perron (PP, 1990) and Kwiatkowski Philips-Schmidt-Shin (KPSS, 1992) and Zivot Andrew (1992) structural break methods were applied in this study for the test of unit root. The nonlinear and asymmetric cointegration tests as developed by Shin et al. (2014) and Hatemi-j (2012) is applied in ascertaining the cointegration and long run relationship between the explanatory (GDP, FDI, fossil fuels and natural resource) variables and the dependent(CO_2) variable. The nonlinear ARDL is considered in this study over other approaches like vector error correction model (VECM) or Engel and Johansen cointegration because of its advantage over them. There are no spectacular criteria like the mentioned approaches demands before considering them appropriate for the cointegration estimates. Before the introduction nonlinear version of ARDL by Shin et al. (2014), it has been the fundamental to confirm the integration order of series at 1st difference, i.e. at I(1) before the adoption of either Engel and Johansen cointegration or nonlinear threshold VECM. Nonlinear ARDL approach of cointegration does not need a special order of integration before being utilized for cointegration analysis. The only condition that needed to be in place is the non-application of series that integrated at order I(2), but a mixed order of integration I(0) and I(1) could be applied in nonlinear ARDL approach. Also, problem of multicollinearity is avoided by selecting appropriate lag order for the included variables (Shin et al., 2014).

Our study is modelled after Shin et al. (2014) nonlinear autoregressive distributed lag (NARDL) with asymmetric error correction

Table 1
Summary of literature review.

Author(s)	Country	Period	Methodology	Results
Energy use, economic growth and CO2 emissions				
Lacheheb et al. (2015)	Algeria	1971–2009	ARDL	Absence of the EKC hypothesis
Yao et al. (2015)	G-20 countries	1971–2010	Index decomposition analysis	Positive effect of economic growth on CO2 emissions
Wei et al. (2017)	China	2000–2010	Input–output analysis	Positive effect of economic growth on CO2 emissions
Amri (2017)	Algeria	1980–2011	ARDL	Positive effect of non-renewable energy use on CO2 emissions
Bouznit et al. (2018)	Algeria	1970–2013	ARDL	Inverted N-shape relationship between energy consumption and GDP
Yasmeen et al. (2019)	Pakistan	1972–2016	LMDI	Positive effect of economic development on CO2 emissions
Shahbaz et al. (2020)	China	1984–2018	ADF tests, BARDL model	Existence of EKC hypothesis
Rahman and Velayutham (2020)	5 South Asian countries	1990–2014	Pedroni and Kao tests Panel FMOLS and DOLS Panel causality test	Positive effect of renewable & non-renewable energy consumption on economic growth
Yasmeen et al. (2021)	Pakistan	1990Q1-2018Q4	SEM technique	Existence of resource curse hypothesis Positive effect of renewable & non-renewable energy use on economic growth
Economic growth, FDI and CO2 emissions				
Acharyya (2009)	India	1980–2003	ADF tests	Positive effect of economic growth and FDI on environmental pollution Existence of the pollution haven hypothesis
Zhang (2011)	China	1980–2009	Cointegration, Granger causality test	Positive effect of FDI on CO2 emissions Existence of the pollution haven hypothesis
Kivyiro and Arminen (2014)	6 Sub-Saharan African countries	1971–2009	Granger causality test, ARDL	Existence of the pollution haven hypothesis for Kenya and Zimbabwe Existence of the pollution halo hypothesis for the Democratic Republic of the Congo and South Africa
Shahbaz et al. (2015)	99 high, middle, and low-income countries	1975–2012	Cointegration and causality tests, FMOLS	Positive effect of FDI on CO2 emissions Existence of the pollution haven hypothesis
Oztürk and Oz (2016)	Turkey	1974–2011	Cointegration and Granger causality tests	Negative effect of FDI on CO2 emissions Existence of the pollution halo hypothesis
Bakhsh et al. (2017)	Pakistan	1980–2014	3SLS model	Positive effect of economic growth and FDI on environmental pollution
Kılıçarslan and Dumrul (2017)	Turkey	1974–2013	Cointegration test, Vector error correction model	Positive effect of FDI on CO2 emissions Existence of the pollution haven hypothesis
Mike and Kardaşlar (2018)	102 countries	2000–2015	Dynamic panel data analysis	Existence of the pollution haven hypothesis for low income countries Existence of the pollution halo hypothesis for low-middle, upper-middle and high-income groups
Shahbaz et al. (2018)	France	1955–2016	SOR test	Positive effect of FDI on CO2 emissions Existence of the pollution haven hypothesis Negative effect energy research innovations on CO2 emissions Negative effect financial development on CO2 emissions Positive effect of energy consumption on CO2 emissions
Sarkodie and Strezov (2019)	China, India, Iran, Indonesia and South Africa		Panel data regression	Existence of the pollution haven hypothesis
Waqih et al. (2019)	SAARC region	1986–2014	ARDL and FMOLS	Existence of the pollution haven hypothesis in the short-run Absence of the pollution haven hypothesis in the long-run
Munir and Ameer (2020)	Pakistan	1975–2016	NARDL Granger causality test	Positive effect of FDI on CO2 emissions Positive effect of economic growth on CO2 emissions

model. The model presents the empirical equation in a decomposed way accommodating both positive and negative shocks and interactions of the explanatory variables with the depended variables. The Shin et al. (2014) model of NARDLwith the asymmetric error correction is as follows:

$$\Delta CO_{2t} = +\beta_0 + \beta_1 CO_{2t-1} + \beta_2^+ GDP_{t-1}^+ + \beta_3^- GDP_{t-1}^- + \beta_4^+ FDI_{t-1}^+ + \beta_5^- FDI_{t-1}^- + \beta_6^+ FF_{t-1}^+ + \beta_7^- FF_{t-1}^- + \beta_8^+ NR_{t-1}^+ + \alpha_9^- NR_{t-1}^- + \sum_{i=0}^{\rho} a_1 \Delta CO_{2t-i} + \sum_{i=0}^{\rho} a_2 \Delta GDP_{t-i}^+ + \sum_{i=0}^{\rho} a_3 \Delta GDP_{t-i}^- + \sum_{i=0}^{\rho} a_4 \Delta FDI_{t-i}^+ + \sum_{i=0}^{\rho} a_5 \Delta FDI_{t-i}^- + \sum_{i=0}^{\rho} a_6 \Delta FF_{t-i}^+ + \sum_{i=0}^{\rho} a_7 \Delta FF_{t-i}^- + \sum_{i=0}^{\rho} a_8 \Delta NR_{t-i}^+ + \sum_{i=0}^{\rho} a_9 \Delta NR_{t-i}^- + \mu_t \tag{1}$$

In Equation (1), β_i and a_i ($i = 1 \ldots \ldots 9$) represent long run and short run coefficients. The short run and long run analysis deal with the immediate effect of independent variables shock on the dependent variable, and assessment of the disequilibrium and speed of bouncing back to the equilibrium level respectively. CO_2, GDP, FDI, FF and NR represent carbon emission, economic growth, foreign direct investment and natural resources respectively. P and q are the optimal lags for the explained and explanatory variables. The lags are selected by the Akaike Information Criterion (AIC). Long ($\beta = \beta^+ = \beta^-$) and short ($a = a^+ = a^-$) term asymmetries for the variables are checked with Wald test. The impact of the shock of independent variables broken into positive and negative effects on the dependent variable. The decomposition of the shocks of the independent variables into positive and negative effects are shown with partial sums for increases and decreases as follows: $\varnothing_t^+ = \sum_{j=1}^{t} \Delta\varnothing_j^+ = \sum_{j=1}^{t} max(\Delta x_j, 0)$ *and* $\varnothing_t^- = \sum_{j=1}^{t} \Delta\varnothing_j^- = \sum_{j=1}^{t} max(\Delta x_j, 0)$, where $\varnothing_t$ represents the explanatory variables (*GDP,FDI, FF and NR*). A test of cointegration is done bound test with F-stats and t-stats of Pesaran et al. (2001) and Banerjee et al. (1998). This is drawn from Shin et al. (2014) emphasis on bound test which is done jointly with all the lagged levels of the independent variables for the asymmetric long run cointegration. The bound cointegration test is estimated in a hypothetical manner by stating the null and alternative hypothesis against or for the statement of there is cointegration. Hence, null hypothesis for F-stats is expressed as $\beta = \beta^+ = \beta^- = 0$ stating there is no cointegration against the alternative $\beta = \beta^+ = \beta^- \neq 0$ stating there is cointegration, while for t-stats, the null hypothesis is expressed as $\beta = 0$ stating there is no cointegration against the alternative $\beta \neq 0$ stating there is cointegration. The decision in support or against the null hypothesis is rooted in comparing the F-stats and t-stats with the critical values of the upper bound tests. If the values of the tests (F and –stats) are greater than the critical values of bounds tests, the null hypothesis is rejected, and vice versa. But if the values of the F and t-stats are in between the upper and lower bounds, the findings is termed inconclusive.

Again, the calculation of long term asymmetric coefficients are based on $L_{mi} = \alpha^+/\rho$ and $L_{mi} = \alpha^-/\rho$. This measures the relationship between the variables (dependent and independent) with a view of separating them into positive and negative shocks of the independent variables in the long run equilibrium. Also, the asymmetric dynamic multiplier effects are accommodated in this analysis and can be expressed as follows:

$$m_\partial^+ = \sum_{j=0}^{\partial} \frac{\partial CO_{2t+j}}{GDP_t^+}, m_\partial^- = \sum_{j=0}^{\partial} \frac{\partial CO_{2t+j}}{GDP_t^-}, m_\partial^+ = \sum_{j=0}^{\partial} \frac{\partial CO_{2t+j}}{FDI_t^+}, m_\partial^- = \sum_{j=0}^{\partial} \frac{\partial CO_{2t+j}}{FDI_t^-}, m_\partial^+ = \sum_{j=0}^{\partial} \frac{\partial CO_{2t+j}}{FF_t^+}, m_\partial^- = \sum_{j=0}^{\partial} \frac{\partial CO_{2t+j}}{FF_t^-}, m_\partial^+ = \sum_{j=0}^{\partial} \frac{\partial = CO_{2t+j}}{NR_t^+}, m_\partial^- = \sum_{j=0}^{\partial} \frac{\partial CO_{2t+j}}{NR_t^-}, \quad for \ \partial = 0, 1, 2, \ldots$$

where, if $\partial \rightarrow \infty$, then $m_\partial^+ \rightarrow L_{mi^+}$ and $m_\partial^- \rightarrow L_{mi^-}$. As remarked above, the asymmetric responses of the dependent variable to positive and negative shocks in the independent variables is represented with dynamic multipliers. From the calculated multipliers, the dynamic adjustment is noticed from the initial equilibrium to the new equilibrium between the system variable sequel to the variations that affects the system.

5. Empirical results and discussions

We will present and discuss the findings from the adopted methods mentioned in the previous sections. Results from descriptive statistics, unit root tests, structural break tests and the nonlinear NARDL and asymmetric cointegration will be presented and discussed according to the findings. The presentation and discussion of the findings will be based on real situation of the economy and comparison with the previous studies on the performance of the countries and other studies.

5.1. Descriptive statistics and uni root tests

Results of descriptive statistics results are presented in Table 2. With the outcomes from the descriptive statistics, we find GDP per capita the most volatile variable among the selected variables of this study. From the probability of Jarq-Bera, apart from FDI, outputs of other variable depict a normally distributed model with no significant outcome.

5.2. Unit root tests

The output displayed in Tables 3 and 4 are the results of unit root estimated with the traditional methods and structural break test. We applied traditional methods of estimating unit root such as Augmented Dickey-Fuller tests, (ADF, 1979); Philip-perron, (PP, 1990), and Kwiatkowiski Philips-Schmidt-Shin (KPSS, 1992), and Zivot Andrew (1992) structural break in revealing the stationarity and order of integration among the series. Time series data are known with instability because of

Table 2
Summary of the selected variables with their measurements.

Variables	Short Form	Measurements	Sources
Economic growth	GDP (Y)	GDP per capita (constant 2010 US$)	2018 updated World Development Indicator (WDI)
Total natural resources rent	N.R	Total natural resources rents (% of GDP)	Worldwide Governance Indicator (WGI),
Foreign Direct Investment	FDI	Foreign direct investment, net outflows (% of GDP)	2018 updated World Development Indicator (WDI)
Carbon emission	CO_2	million tonnes of carbon dioxide	2019 British Petroleum (BP) Statistical Review of World Energy.
Non-renewable energy consumption	Fossil fuels (FF)	million tonnes oil equivalent	2019 British Petroleum (BP) Statistical Review of World Energy

Source: Authors' Compilation

Table 3
Summary of descriptive statistics.

Variables	CO2	GDPPC	FDI	FOSSIL	N_RESOUR
Mean	65.54943	3775.781	0.057147	26.43009	20.60008
Median	64.89479	3642.513	0.025026	26.45858	18.95766
Maximum	135.5305	4828.626	0.501505	56.54885	39.34579
Minimum	8.264425	2335.032	−0.129574	3.013228	7.853010
Std. Dev.	33.95005	602.0596	0.101312	14.00276	8.111167
Skewness	0.157573	0.063190	2.277712	0.212301	0.366177
Kurtosis	2.598606	2.386963	9.681971	2.679579	2.244751
Jarque-Bera	0.531721	0.799897	130.8012	0.577702	2.259604
Probability	0.766546	0.670355	0.000000	0.749124	0.323097
Sum	3211.922	185013.3	2.743064	1295.074	1009.404
Sum Sq. Dev.	55325.07	17398834	0.482413	9411.707	3157.970
Observations	49	49	48	49	49

Source: Authors computation

Table 4
Unit root test with ADF, PP and KPSS.

Variables	Level			1st Diff	
	Intercept	Intercept & trend	Intercept	Intercept & trend	Order
			ADF		
LCO_2	0.226	−1.197	−3.940***	−3.959**	I (1)
LGDP	−2.077	−2.008	−7.902***	−7.924***	I (1)
FDI	−4.289***	−4.7697***	−4.469***	−4.239***	MIXED
LFF	1.116	−0.268	−4.381***	−4.447**	I (1)
LNR	−2.721[a]	−2.585	−7.069***	−7.064***	MIXED
			PP		
LCO_2	0.288	−1.166	−3.954***	−3.981**	I (1)
LGDP	−1.001	−1.678	−7.769***	−7.767***	I (1)
FDI	−4.417***	−4.770***	−8.044***	−8.135***	MIXED
LFF	0.568	−0.979	−4.348***	−4.426***	I (1)
LNR	−2.704	−2.604	−7.147***	−7.119***	I (1)
			KPSS		
LCO_2	0.842***	0.115	0.174	0.141[a]	MIXED
LGDP	0.693***	0.122[a]	0.123	0.126[a]	MIXED
FDI	0.386[a]	0.099	0.292	0.088	I (1)
LFF	0.850***	0.116	0.206	0.153**	MIXED
LNR	0.196	0.080	0.102	0.075	MIXED

Note: Null hypothesis is non-stationary for ADF&PP, and stationary for KPSS. The signs depict ([a]) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant.

[a] *MacKinnon (1996) one-sided p-values.*

Source: Authors computation

some macroeconomic and structural occurrences including policies that are likely to affect the stability of the variables in determining a specific phenomenon in the economy. Macroeconomic and structural changes such as unemployment, inflation, and natural disaster cum health challenges like pandemic and COVID-19 are likely going to cause a shock to the economy which is capable of leaving a permanent impact on the economy. These are capable of impacting the stability of the data for any study in that country. Most times, conventional methods does not capture such shocks and often account them as stationary. This is more reason of adopting a structural break test to expose date of occurrences of such shocks. From the estimate, we find a mixed order of integration i. e. I(0) and I(1) among the series which confirms unit root and mixed order of stationarity (both at level and 1st difference). The break dates are 1984 and 2011 for CO_2, 1995 and 2002 for GDP, 1980 and 1996 for FDI, 1984 and 1993 for fossil, 1981 and 1987 for natural resources. Most of the shocks to Algerian economy has their roots from the oil shock which accommodate both oil price and financial shock that affect both energy and economic growth of the country. As remarked from the methodology section, nonlinear NARDL does not command any rigid form of integration before utilizing in any study. We needed to ascertain the structural break date through structural tests in case of any surprises encountered in subsequent findings in this study. Hence, we adopt nonlinear ARDL and asymmetric approach which follows immediately after unit root tests.

5.3. Nonlinear ARDL (NARDL) and asymmetric cointegration

Results from the estimates of nonlinear asymmetric cointegration are shown in Table 5 with the following findings established from the estimates: Goodness of fit of the model is confirmed with R^2 (0.9998) and adjusted R^2 (0.9997) which is the evidence of dependent variable (carbon emission) explained by the independent variables (*GDP, FDI, FOSSIL FUELS, NATURAL RESOURCES*) at 99.9 percent. The remaining variation in dependent is explained by the error term in the model. The cointegration result gotten from bound test estimate confirmed the existence of cointegration with the values of F-stats (4.6035) greater than the critical bound(upper) (3.77) at 1 percent significant value. This equally confirms the likelihood of long term relationship between the variables. Some diagnostics tests were performed to ascertain that the model is free from some econometrics problems such as multicollinearity, autocorrelation and serial correlation, heteroscedasticity are all confirmed absence from the model and estimations. Autocorrelation, serial correlation and heteroscedasticity are confirmed absence from this analysis with the values of Durbin Watson (DW) and LM at 2.22, 1.255 [0.359] and 20.01 [0.332] respectively. Error correction term (ECT) was established at (−0.50807) 51 percent at 1 percent significant level which confirms the ability of the short run disequilibrium to adjust at long run equilibrium thereby establishing long run relationship between the selected variables. The nonlinear relationship between the shocks to the independent variables and the dependent variables are as follows: from the long run perspective, positive and negative shocks to the economic growth will amount to increase and decrease in emission in Algeria at 0.005 and −0.001 respectively. While the positive shock is significant at 1 percent, the negative shock is not significant. This means that at the increase of economic growth the environment performance of Algeria is distorted while the slow in economic growth improves the Algeria environment through the reduction of emission. Evidence of initial economic growth impacting negatively on the environment of countries especially the developing countries have been established by (Burke et al., 2015; Sheldon, 2017; York, 2012). The crude economic complexity of most developing countries has permitted the penetration of the economies by the external economic agents in form of investors and producers who exploit the laxity in their regulations and policies and engage in operations unfriendly to the quality of environment. The activities that involve excess utilization of fossil fuel are all interwoven with the economic operations that lead to economic growth. This process will most likely trigger carbon emission into the environment and this will impact negatively on the quality of environment. The same trend is established in the short run between the shock to the economic growth and the environment. Surprisingly,

Table 5
Zivot- Andrew break test.

Variables	Ziv-A	Prob.	Lg	Break period	CV@ (1%)	CV@ (5%)
LCO_2	−2.560	0.008***	4	2011	−5.57	−5.08
LGDP	−4.486	0.0016***	4	2002	−5.57	−5.08
FDI	−3.432	0.017***	4	1996	−5.57	−5.08
LFF	−2.025	0.063*	4	1993	−5.57	−5.08
LNR	−3.479	0.062*	4	1981	−5.57	−5.08
D LCO_2	−5.750	0.008***	4	1984	−5.57	−5.08
DLGDP	−13.4***	0.000***	4	1995	−5.57	−5.08
DFDI	−7.402	0.175	4	1980	−5.57	−5.08
DLFF	−6.303	0.006*	4	1984	−5.57	−5.08
DNR	−3.654	0.026**	4	1987	−5.57	−5.08

The signs depict (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant.

* MacKinnon (1996) one-sided p-values.

Source: Authors computation

positive and negative shocks to the FDI tend to reduce carbon emission respectively. This means that acceptance of FDI into the Algerian economy will improve the quality of environment while the limiting of FDI will also tend toward good environmental performance. This is surprising and a good trend for Algeria if maintained. It means that both the positive and negative shocks to the FDI impact the Algerian environmental performance by reducing carbon emission by 3.733 (−3.733) and 2.741. The same pattern is established in the short run. Also, a positive and negative shocks to the fossil fuels were discovered increasing and decreasing carbon emission by 2.689 and 1.784 at 1 percent significant level respectively. This confirms the implication of non-renewable energy consumption in productive and manufacturing activities in Algeria. Many studies have found energy (fossil fuels) use impacting negatively on the environmental performance of many developing countries. This is because of little or no much incentive in diversifying the energy sector into more renewable sources like solar, hydro and wind. The pattern of positive and negative interactions of the independent variables with the dependent variables in the case of fossil is replicated in short run output. Moreover, positive and negative shocks to the total natural resources is confirmed decreasing carbon emission by −0.035 and 0.034 respectively. This result actually toe the pattern of FDI that seems to impact environment positively. The only difference is that while finding on FDI is significant, the result on natural resources are not significant.

We equally adopted Wald test to estimate the long run asymmetric interaction and significance (see Fig. 1). The Wald test output is shown in Table 6 with evidence of significant long run asymmetric relationship among the variables at 5 percent for fossil fuel and 10 percent for GDP and FDI respectively. No significant long run asymmetric relationship for the case natural resources. This attests to the finding from the nonlinear dynamic ARDL estimates. This finding equally acts like robust check to both the cointegration and error correction term by given credence to their findings. The stability of the model applied in this study is tested and established by CUSUM and CUSUMSQ in Figs. 2 and 3 immediately after Table 6 (see Table 7).

5.4. Comparison of our findings with previous studies

Our findings exposes the implications of the selected variables (economic growth, FDI, fossil fuels and natural resource) towards decarburization of Algeria and antecedents of fostering sustainable development goals of the country. Indeed, our work is not the first in this line of research on Algeria but contributes in the literature by considering the environmental aspect of sustainable development of the country instead of focusing on the economic growth like other studies. It is worth comparing our findings with other studies which will help expose the possibility of the Algerian authorities in achieving SDGs. Hence, we find interesting response of Algerian environment development to its economic growth as positive and negative shocks to the economic growth will amount to increase and decrease in emission in

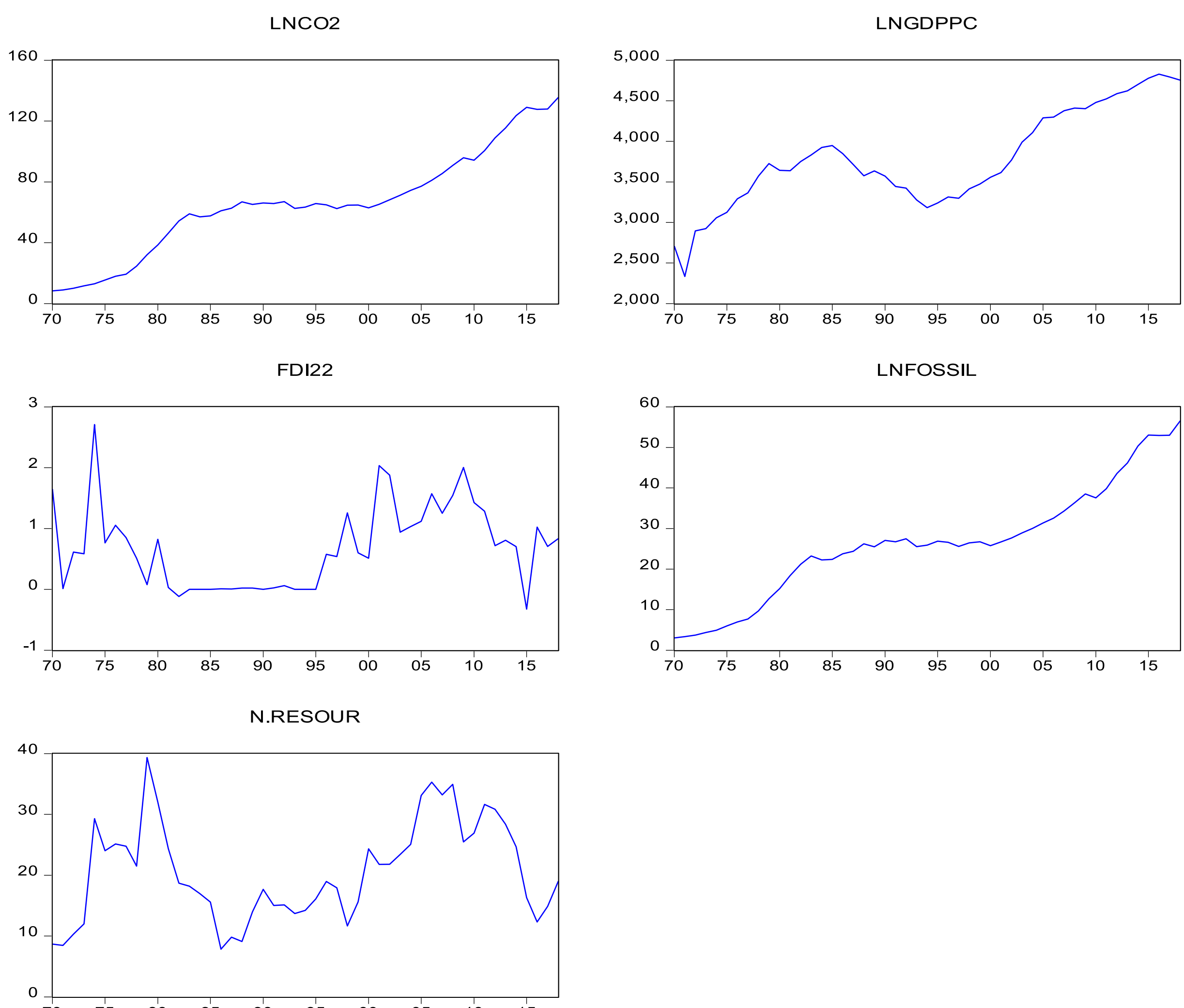

Fig. 1. Trends in GDP per capita, total natural resources rent, FDI, carbon emission, fossil fuels in Algeria from 1970 to 2018.
Source: Authors compilation

Table 6
Non-linear ARDL long and short-run results.

Variables	Long-Run Estimation				Short-Run Estimation				
	Coeff	Std Error	t-stat	P-value	Variables	Coeff	Std Error	t-stat	P-value
GDP^{+}	0.005***	0.001	3.611	0.001	GDP^{+}	0.005***	0.001	3.611	0.001
GDP^{-}	−0.001	0.002	−0.208	0.837	GDP^{-}	−0.001	0.002	−0.272	0.788
FDI^{+}	−3.733**	1.670	−2.236	0.034	FDI^{+}	−3.733***	1.032	−3.617	0.001
FDI^{-}	2.741	2.401	1.142	0.266	FDI^{-}	2.741	1.664	1.647	0.111
FF^{+}	2.689***	0.188	14.29	0.000	FF^{+}	2.689	0.088	30.38	0.000
FF^{-}	1.784***	0.286	6.235	0.000	FF^{-}	1.784	0.179	9.975	0.000
NR^{+}	−0.035	0.030	−1.160	0.256	NR^{+}	−0.035	0.030	−1.160	0.256
NR^{-}	0.034	0.054	0.634	0.531	NR^{-}	0.034	0.030	1.118	0.273
C	2.617***	1.189	2.200	0.037	ECT(−)	−0.508071	0.065	−7.835	0.000
Diagnostic Tests									
R^2	0.9998								
$AdjR^2$	0.9997								
DW Stats	2.22								
F-Stats	9535.9 [0.000]								
Bound test	F = 4.6035***K = 8			,@ 1%	I(0) = 2.62	I(1) = 3.77			
χ^2 *LM*	1.255 [0.359]								
$\chi2$ *HET*	20.01 [0.332]								

Note: *, ** and *** mirror 10%, 5% and 1% significance level, respectively.
Source: Authors computation.

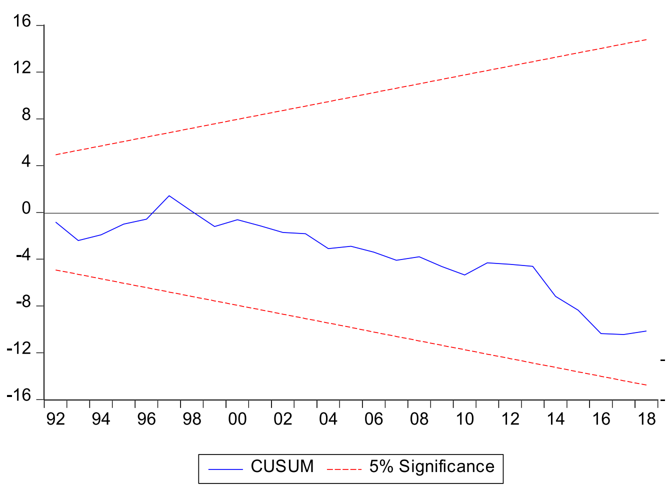

Fig. 2. Plot of Cumulative sum of recursive residuals. The blue line is the solid line while the red lines that bounded the blue line are the critical bounds at 0.5. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

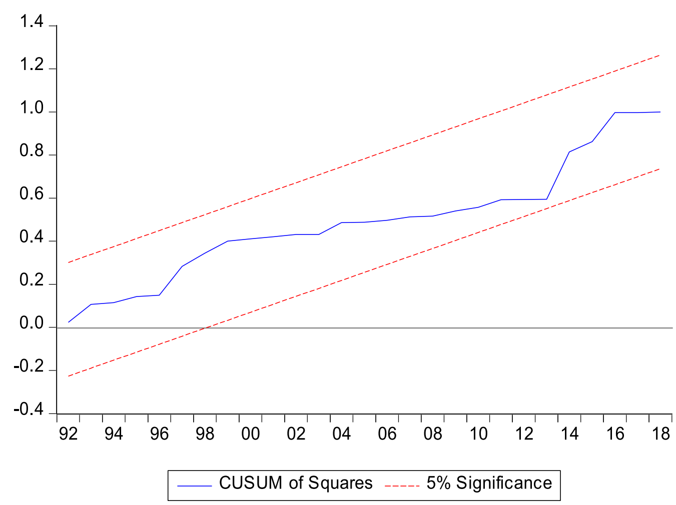

Fig. 3. Plot of Cumulative sum square of recursive residuals. The blue line is the solid line while the red lines that bounded the blue line are the critical bounds at 0.5. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)
Source: Authors computation

Algeria. This compliment authors expectations as developing economies have always shown more effort in their economic growth at the initial stage than their environmental developmental. Evidence of initial economic growth impacting negatively on the environment of countries especially the developing countries have been established by (Burke et al., 2015; Sheldon, 2017; York, 2012). Also, Yasmeen et al., (2019) found the economic development factor as the main driving force for the increase of per capita carbon emissions for Pakistan. Again, positive and negative shocks to the FDI tend to reduce carbon emission respectively. This means that acceptance of FDI into the Algerian economy will improve the quality of environment. This finding confirms pollution halo for Algeria and supports the finding from Udemba et al. (2019) for Indonesia; Mike and Kardaşlar (2018); Balsalobre-Lorente et al. (2018). However, our findings differ from the findings of Adeel-Farooq et al. (2021) for the developing countries. Also, a positive and negative shocks to the fossil fuels were discovered increasing and decreasing carbon emission. This finding is in agreement with the findings of Shahbaz et al. (2013); Al-mulali and Tang (2013); Udemba (2019) for China; Udemba et al. (2019) for Indonesia and Udemba (2020) for Turkey: Alola and Kirikkaleli, 2019 . Moreover, positive and negative shocks to the total natural resources is confirmed decreasing carbon emission. This finding supports the finding by (Balsalobre-Lorente et al., 2018; Shahabadi and Feyzi, 2016).

Table 7
Long-run asymmetries (WALD test).

Variables	x^2Chi-Square [Prob]	Decision
GDP(Y)	2.936* [0.087]	Yes
FDI	3.390* [0.065]	Yes
FF	5.25** [0.022]	Yes
NR	0.661* [0.319]	No

Note: *, ** and *** indicate 1%, 5% and 10% significance level.
Source: Authors computation

Lastly, apart from confirming the adjustment to equilibrium in the long run after the short run disequilibrium with error correction term, NARDL multipliers was also applied to illustrate the adjustment to new equilibrium equation after the shocks (positive and negative). The NARDL multipliers is shown below in Fig. 4. The asymmetries adjustments of CO_2 to negative and positive shocks are shown with black dotted and solid black lines, while the red dotted lines are the asymmetric pattern that show the difference between positive and negative shocks.

6. Conclusion and policy recommendation

Our work is a research into determining the state of Algeria environment with the interaction of economic growth (GDP per capita), foreign direct information (FDI) and natural resources. Algeria is highly endowed with natural resource which place it as among the top oil exporting countries of the world. Considering its place in natural resources which is among the attracting forces of FDI (Anyanwu, 2012) and its economic complexity as a developing countries, the country is poised as a good case study on how to mitigate environmental damage. Also, most times economic activities such as oil exploration, gas flaring and excessive utilization of fossil fuels in the oil rich nations tend to trigger poor environmental performance. For in-depth study and finding, we adopt a more comprehensive approach, nonlinear ARDL and long run asymmetric cointegration in this current study. This approach shows a two-way (positive and negative) finding and explanation of the analysis. From the estimates, our finding confirmed the negative implications of economic growth and excessive use of fossil fuels to the environmental performance. Hence, positive and negative shocks to the economic growth and fossil fuels tend to increase and decrease carbon emission which will negatively affect the quality of the environment because positive is significant. Interestingly, positive and negative shocks to FDI and natural resources tend to decrease and increase carbon emission which will positively impact on the environment because the positive shocks are significant.

However, from the findings, FDI and natural resources variables are confirmed impacting Algerian environment positively in both ways (positive and negative shocks). Also, our findings give credence to the best ways of achieving sustainable development in Algeria by answering the following questions which were raised in the introduction section of this study towards attainment of its sustainable development goals (SDGs): a. Does natural resources in Algeria have a significant effect towards its sustainable development? b. Does FDI has any contribution towards Algerian environment performance? C. Does the country's economic growth has any effect towards its sustainable development? Therefore, policy framing should be towards promotion of foreign direct investment, with strict monitoring. Policy that will allow the efficient and effective exploration of natural resources by the foreign investors should be pursued through the institutions saddled with the trade and commerce. There should be a collaboration of different institutions in charge of different sectors for maintenance of both good economic and environment performance. This will enhance sustainable development

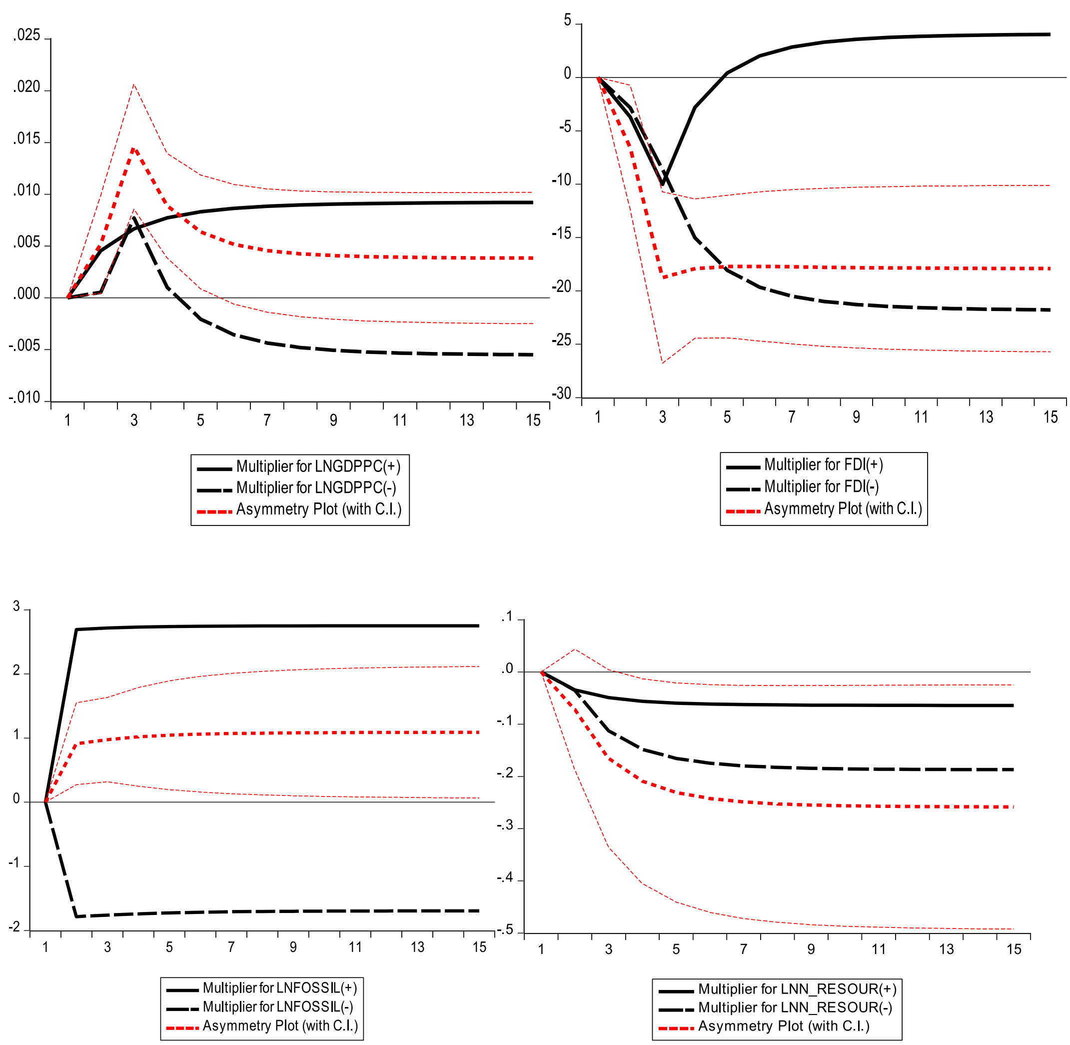

Fig. 4. Multiplier for GDP, FDI, Fossil fuels and Total natural resource rent.
Source: Authors computation

of Algeria and push towards achieving United Nation's sustainable development goals (SDGs 5–12). The over utilization of fossil fuels in economic operation may responsible for negative impacts on Algeria environment from duo (fossil fuels and economic growth). Hence, there is a need for deregulation in energy sector which will allow diversification of energy sources and encourage a shift from non-renewable and carbon intensive sources of energy to a more renewable energy sources. A need to invest into renewable sources like solar, wind and hydro power generation is encouraged. Also, subsidies like tax cut and price control policy should be considered on the industries that specialize in production and assembling of renewable energy sources. This will enable them to increase their production which will make the products available and affordable for public and private interests. At the same time, there should be implementation of different tax policies for carbon intensive industries. Ceiling should be placed on the level of carbon emission by the industries where higher tax is placed on any level higher than the accepted level. This should be placed. The regulation of carbon emission through these energy policies will aid in decarburizing Algeria. General awareness and sensitization through public education on the need for green practices and friendly environmental activities will get the masses involved in the promotion of good environment quality.

Conclusively, this study will serve as blue print for other resource based and developing economies. This topic is not saturated in research world, other variables and indicators such as institutional quality can be utilized in researching this same topic.

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Compliance with ethical standards

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Declaration of competing interest

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