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Article

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The Economic Impact of Renewable Energy on Sustainable Development in Saudi Arabia

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ABSTRACT

This paper studies the asymmetric relationship between renewable energy consumption and economic growth incorporating capital and labor for the case of Saudi Arabia during the period 1990–2019. The nonlinear lagged cointegration (NARDL) model is applied to examine the asymmetric cointegration between the variables. The results indicate that there is an asymmetric relationship between the variables considered. The negative labor shock improves economic growth, while a positive shock reduces (increases) economic growth in the short term. Therefore, policies to promote economic growth, such as the need to improve the quality of financial development and preserve fiscal sustainability, are crucial to improve the renewable energy sector in Saudi Arabia. At the same time, it is essential that the renewable energy sector must also be oriented towards productive development projects.

Keywords: Asymmetry, Economic growth, NARDL, Renewable energy consumption, Shocks
JEL Classifications: Q01, Q43, Q43, Q47

1. INTRODUCTION

This amount includes oil and gas. But the consumption of traditional energy has two problems: first, the problem of import; and second, the problem of the greenhouse effect. For the import, oil is a strategic and very expensive asset. That is why over the years, following an oil shock, economic difficulties have arisen all over the world. Developed countries such as Europe and North America have planned to consume renewable energy, because this energy decreases the dependence of foreign countries and it is safe and healthy (Menegaki, 2011). Renewable energy created 18% of electricity production worldwide in 2007. In Europe-27, energy created by wind is the highest (in renewable energy). After the wind, there is the energy created by the sun and then by biomass which are the most common. But the hydro-based energy had a negative growth in the years 1997-2007. <7% of energy in Europe comes from renewable energy (Menegaki, 2011). Some European countries like Denmark, Germany and the UK increased their energy exports. In other words, renewable energy technologies have found a global market to sell and to create jobs. For example, Germany sold renewable energy instruments worth 21.6 billion euros and created 200,000 jobs in 2006. Denmark created 20,000 jobs in the field of wind energy (Lund, 1999). Currently, the GDP for each country is very important, as it shows the market size and the inhabitants' purchasing power. If there is a significant relationship between the market size and the consumption of renewable energy, countries can apply and develop the consumption of this energy. Therefore, the objective of this article is to study the causal relationship between renewable energy consumption and economic growth. Apergis and Payne (2010), using variables such as capital formation, GDP, labor and renewable energy consumption, showed that in Eurasia there is a bidirectional relationship between economic growth and renewable energy consumption. They reported the same result for OECD countries in 2010. Sadorsky (2009), Wolde-Rufael (2010), and Menegaki (2011) have also studied the relationship between economic growth and renewable energy consumption. Lund (1999) showed that subsidizing renewable energy will increase the number of jobs in Denmark.

Saudi Arabia, aware of the interest of investment in this sector, has given great importance to the subject of renewable energies through the implementation of structural reforms since the 1990s, as part of a general policy of opening the Saudi economy and its insertion in the international market. These strategies also aim to develop the national potential through the privatization of the distribution and refining of petroleum products as well as the transfer of the management of electricity and water distribution to private operators. This model is a strategic choice that allows to strengthen the security of supply and the efficiency of energy resources, in order to optimize the costs of energy services and to protect the environment by reducing greenhouse gas emissions.

Indeed, the Saudi Electricity Company, the national power company, controls 70% of the country's electricity generation with a total installed capacity of 53.4 GW. At the end of 2019, the Kingdom's installed capacity was 76.8 GW, with the electricity mix dominated by gas-fired power plants. With economic development and population growth, the installed electrical power should reach 171 GW in 2030. Renewable energies should represent 34% of the electricity production capacity by this deadline. Increases in electricity tariffs in 2016 and 2018 caused a sharp slowdown in consumption growth (EIA, 2019).

To achieve these objectives, Saudi Arabia plans to increase the volume of investments in this sector by 40 billion dollars by 2030, including 30 billion dollars for renewable energies (OME, 2021). It also aims to modify the structure of the energy consumed by granting a higher share to renewable energies; which would thus rise from 42% in 2020 to 52% in 2030.

The remainder of the article is organized as follows. The first section is devoted to the analysis of the energy sector in Morocco. The second presents a review of the literature relating to the question studied. The third section consists of empirically examining the impact of the use of renewable energies on economic growth and CO_2 emissions through an econometric model. The fourth and last section is devoted to the conclusion and the formulation of recommendations.

2. LITERATURE REVIEW

A first-generation study based on the VAR method, carried out in 1978 by Kraft and Kraft on the American economy between 1947 and 1974, revealed the existence of a unidirectional causality which shows that in the United States, it is the gross national product that causes energy consumption. This result suggests that it is possible to envisage energy-saving policies without negative effects on economic growth. This analysis will be challenged by several researchers, namely Akarka and Long (1980), who were able to demonstrate that the Kraft and Kraft study was biased due to temporal instability at the sample level of the data used. They therefore resumed the analysis with the same technique, over a more homogeneous period from 1950 to 1968. The test revealed a lack of causality between GDP and energy consumption. Virtually all of the articles that followed were devoted to the American series with very varied results (cf. for example Yu and Hwang (1984), Yu and Choi (1985)).

Over the past few decades, a large empirical literature has developed, focusing on the relationship between energy consumption, including renewable energy, and economic growth. This literature, known as the Energy-Economy-Nexus, emerged in response to the global oil crisis of the 1970s and the ensuing reduction in energy supply.

It is within this literature that (Apergis and Danuletiu, 2014) examined the relationship between renewable energy consumption and economic growth for 80 countries, using the Canning and Pedroni long-term causality test. The two authors showed the existence of a long-term positive causality between renewable energies and real GDP for the whole sample as well as for the different regions. The interdependence between renewable energy consumption and economic growth indicates that renewable energy is not only important for environmental quality but also for economic growth. Along the same lines, (Behname, 2012) examined the long-term as well as the short-term causal relationship between renewable energy consumption and economic growth in Western European countries for the period 1995–2010. The Pedroni test used revealed a long-term relationship between the two variables. It follows that there is a long-term and a short-term bidirectional relationship between economic growth and renewable energy consumption. Another study, by (Lekana, 2019), confirms some of the previous results. This work focused on CEMAC countries for the period 1990 and 2015 and used three panel data error correction models (MG PMG and DFE) and two causality approaches (the Engel and Granger causality and the Dumitrescu and Hurlin causality). The results showed that renewable energy consumption has a positive long-term effect, but has a negative short-term effect on economic growth in these countries.

More recently, (Saidi and Omri, 2020) examined the effectiveness of renewable energy in promoting economic growth and reducing CO_2 emissions in the case of 15 countries, using ordinary least squares and vector error correction model estimation techniques. The results affirm the presence of a bidirectional causal relationship between economic growth and renewable energy in the short and long terms. On the other hand, (Chen et al., 2019) explored the relationships between carbon dioxide emissions, economic growth, renewable and non-renewable energy consumption in three regions in China for the period 1995-–2012. One of the main conclusions obtained in this work is the existence of bidirectional causal relationships in the long term between renewable energy, CO_2 emissions and economic growth in all regions. Finally, we can cite the work of (Bilan et al., 2019). The authors examined the impact of a country's use of renewable energy sources, CO_2 emissions, macroeconomics, and political stability on gross domestic product. For EU countries, RES- like human and capital resources- have an impact on GDP. Furthermore, the results reveal a retraction of the correction when economic growth leads to an increase in renewable energy consumption. Finally, the work reveals that candidate countries and potential candidate countries for EU membership should favor the development of renewable energy. Finally, the work reveals that candidate countries and potential candidate countries for EU membership should promote the development of renewable energy.

Adewuyi and Awodumi (2017) provide a literature review of studies on the energy-growth-emissions relationship over the past two decades. They note that very few studies have combined the analysis of renewable energy, non-renewable energy, and CO_2 emissions in a single model. Beyond the control of the variables' omission bias, the multi-variable models allow to evaluate the relationship between the consumption of renewable energies and sustainable development on the one hand. On the other hand, the level of renewable energy sources aggregation affects the results. A low level of aggregation of the energy sources allows to test the hypotheses on the relationship between the renewable and the non-renewable energy sources. This approach could allow to take into account each country's specificities in terms of renewable energy development strategies (allocation of production sources, economic policies and incentives).

To the best of our knowledge, only Pao and Fu (2013) opted for a level of aggregation that allows for successive analysis of wind energy consumption (including biomass), total renewable energy consumption, and total non-renewable energy consumption. In addition, omission bias may remain insofar as the variables considered in the studies may fail to take into account the political and institutional context. Indeed, in North African countries, Komendantova et al., (2012) identify three types of risks that affect foreign direct investment in renewable energy. These risks are regulatory, political and terrorist. The complexity of administrative procedures, corruption, instability of national regulations, lack of guarantee from the national government, lack of involvement of local authorities and political instability are barriers to private investment in solar power projects. These barriers not only increase the cost of new investments but also decrease the quality and efficiency of investments already made.

3. METHODOLOGY

Our objective is to highlight the relationship between renewable energy consumption and sustainable development over the period 1990–2019 in Saudi Arabia. To do so, we use GDP as a proxy for welfare and assume the following relationship:

$$\ln GD_t = \alpha + \beta \ln REN_t + \theta \ln X_t + \varepsilon_t \tag{1}$$

where *InGPt* and *InRent* are respectively the renewable energy consumption and the constant GDP (2010) expressed in natural logarithm. X_t is a vector of control variables including human capital and labor force; ε_t denotes the error term and α, β and θ are the co-integration parameter vectors to be estimated.

In order to account for the asymmetric relationship both in the long and short terms between the two variables, we apply the new co-integration approach of Shin et al., (2014) namely, the nonlinear distributed lag (NARDL) co-integration model. The asymmetric cointegration relationship can be expressed as follows knowing the control variables:

$$\ln GD_t = \alpha + \beta \ln REN_t + \beta^+ REN_t^+ + \beta^- REN_t^- + \mu_t \tag{2}$$

where In GD_t denotes the natural logarithm of GDP and *In* REN_t indicates the logarithm of renewable electricity production. In REN_t^+ as well as In REN_t^- are the partial sum processes associated with negative and positive shocks in In REN_t defined by:

$$\begin{aligned} \ln REN_t^+ &= \sum_{j=1}^{t} \Delta \ln REN_j^+ = \sum_{j=1}^{t} \max(\Delta \ln REN_j, 0) \\ \ln REN_t^- &= \sum_{j=1}^{t} \Delta \ln REN_j^- = \sum_{j=1}^{t} \max(\Delta \ln REN_j, 0) \end{aligned} \tag{3}$$

β^+ and β^- are the associated asymmetric long-term parameters. The extension of the distributed lag model, proposed by Shin et al., (2014) provides the following asymmetric error correction model and knowing the control variables:

$$\begin{aligned} &\Delta \ln GDP_t = \phi + \rho \ln GDP_{t-1} + \beta^+ \ln REN_{t-1}^+ + \beta^- \ln REN_{t-1}^- \\ &+\sum_{i=1}^{p-1} \eta_i \Delta \ln GDP_{t-i} + \sum_{i=0}^{q-1} (\pi_i^+ \Delta \ln REN_{t-i}^+ + \pi_i^- \Delta \ln REN_{t-i}^-) + \varepsilon_t \end{aligned} \tag{4}$$

where the p and q symbols are the number of delays associated with GDP_t and REN_t respectively. The NARDL model expressed in this way has several advantages. Firstly, it allows to estimate by the technique of moments and by the exogenous variable decomposition in positive and negative partial sums. Second, we can test the long-term relationship between the levels of the variables In GDP_t, In REN_t and In EG_t^- (i.e. $\rho = \beta^+ = \beta^- = 0$) by using the *FPSS* statistic suggested by Pesaran et al., (2001) and Shin et al., (2014). The t_{BNEG} statistic proposed by Banerjee et al., (1998) can test the null hypothesis against the alternative hypothesis $\rho < 0$. The estimation can provide valid statistical inferences regardless of whether the exogenous variables are stationary, non-stationary, or a mixture of the two. We can therefore calculate the long-term asymmetric coefficients as follows: In $REN^+ = \beta^+/\rho$ and In REN^- β^-/ρ. Third, the standard Wald statistic can be used to examine long-term symmetry T $\beta = \beta^+ = \beta^-$ as well as the short-term symmetry which could take one of these two following forms: $\pi_i^+ = \pi_i^-$ for every $i = 1, q-1$ where $\sum_{i=0}^{q-1} \pi_i^+ = \sum_{i=0}^{q-1} \pi_i^- = 0$. Finally, the effect of a one percent change in the dynamic asymmetric multipliers respectively REN_{t-1}^+ and REN_{t-1}^- on GDP_t can be expressed as follows:

$$REN_h^+ = \sum_{j=0}^{h} \frac{\partial GDP_{t+j}}{\partial REN_{t-1}^+} \text{ and } REN_h^- = \sum_{j=0}^{h} \frac{\partial GDP_{t+j}}{\partial REN_{t-1}^-} \text{ for}$$

$$h = 0, 1, 2, \ldots \tag{5}$$

If $h \to \infty$, then $REN_h^+ \to L_{REN^+}$ and $REN_h^- \to L_{REN^-}$

In order to test for short-term symmetry, we use the Wald statistic, and if symmetry was not rejected, then the NARDL equation (4) could be simplified by the following asymmetric long-term relationship:

$$\begin{aligned} &\Delta \ln GDP_t = \phi + \rho \ln GDP_{t-1} + \beta^+ \ln REN_{t-1}^+ \\ &+\beta^- \ln REN_{t-1}^- + \sum_{i=1}^{p-1} \eta_i \Delta \ln GDP_{t-i} + \\ &\sum_{i=0}^{q-1} \varphi_i \Delta \ln REN_{t-i} + \varepsilon_t \end{aligned} \tag{6}$$

On the other hand, if long-term symmetry was not rejected, then equation (4) could be simplified to a NARDL with an asymmetric short-term relationship:

$$\Delta \ln GDP_t = \phi + \rho \ln GDP_{t-1} + \beta^+ \ln REN^+_{t-1} + \beta^- \ln REN^-_{t-1} + \sum_{i=1}^{p-1} \eta_i \Delta \ln GDP_{t-i} + \sum_{i=0}^{q-1} (\varphi_i^+ \Delta \ln REN^+_{t-i} + \varphi_i^- \Delta \ln REN^-_{t-i}) + \varepsilon_t \quad (7)$$

4. DESCRIPTIVE STATISTICS AND STATIONARY UNIT ROOT TESTS

We used annual time series for Saudi Arabia during the period 1990-2020. To estimate our empirical model, we used GDP per capita (constant 2010 US$) (GDPP), Renewable energy consumption (% of total final energy consumption) (REC), Gross capital formation in billions (constant 2010 US$) (K) and total labor force in millions (L). The data are sourced from the World Development Indicators (WDI).

Tables 1 and 2 report the descriptive statistics and correlation of variables, respectively. During the period (1990–2016), Table 2 shows that the GDP per capita varies from US$ 16,696.41 to US$ 21,399.11; the range for gross fixed capital formation for capital is from 4.75E+10 to 2.09E+11 US$; the range for total labor force is from 6358516 to 13187031 million and renewable energy consumption ranges from 0.005% to 0.010% of total final energy consumption. This table shows us that GDP is positively linked to the consumption of renewable energy and that this link between these variables is important, which implies that economic growth has a causal impact on renewable energy consumption. This implies that renewable energy consumption is related to GDP (Sharma, 2010). The total labor force (L) and gross fixed capital formation (K) are positive. Therefore, an increase in total labor force and gross fixed capital formation would lead to an increase in the economic growth rate.

Table 1: Description and source of the variables

Variables	Description	Sources
GDP per capita (GDPP)	GDP per capita (constant 2010 US$)	WDI
Renewable energy consumption (REC)	Renewable energy consumption (% of total final energy consumption)	WDI
gross fixed capital formation for capital (K)	gross fixed capital formation in billions of constant 2010 U.S. dollars for capital	WDI
total labor force (L)	total labor force in millions	WDI

Table 2: Summary statistics and correlations

	GDPP	K	L	REC
Mean	19409.09	1.25E+11	9201535	0.007
Median	19315.07	1.34E+11	8812561	0.007
Maximum	21399.11	2.09E+11	13187031	0.010
Minimum	16696.41	4.75E+10	6358516	0.005
SD	1344.880	5.84E+10	2184011	0.001
GDPP	1			
K	0.890	1		
L	0.912	0.963	1	
REC	0.866	0.963	0.925	1

To examine the stationarity of the series, we apply the Augmented Dickey-Fuller (1979) (ADF) and Phillips Perron (1988) (PP) tests. The results presented in Table 3 show that the K and L series are stationary in level while GDP and REN are stationary in first difference, and therefore neither of them is integrated of order 2. This confirms our choice of using the non-linear ARDL.

5. RESULTS

Consistent with the result of the unit root test without the ADF unit root test with structural break and breakpoint, we can use the bounds cointegration test without structural break between the models to demonstrate the long-run association between real GDP, carbon dioxide emissions and renewable energy in Saudi Arabia. According to the table reported by Narayan (2005), the two crucial values are 2.734 and 3.920 at the 5% threshold and are 3.657 and 5.256 at the 1% threshold. The results in Table 4 confirmed the long-term association between the selected variables for all models, as all F-statistics are strongly elevated at 1% threshold.

The results of the estimations are presented in Table 5. The results of the estimations on the short-term relationship are presented in the upper part of the table while the results on the long-term relationship are presented in the lower part. Nonlinear and asymmetry tests are summarized by BDM, PSS statistics. BDM is the statistic proposed by Banerjee et al., (1998) to test the long-term null relationship and PSS is the F statistic proposed by Pesaran et al., (2001) to test the non-cointegration null hypothesis. These two statistics are significant, which confirms a long-term non-linear relationship between per GDP capita and renewable energy consumption, and validates the hypothesis of cointegration of the model's variables. *WLR* (*WSR*) is the Wald statistics that tests the hypothesis of the symmetry of the relationship between the long-term (short-term) series. These tests are significant. They therefore make it possible to reject the hypothesis of a symmetrical long-term and short-term relationship for Saudi Arabia. The short-term and long-term relationship is respectively measured by the coefficient of the variables REN^+_{t-1} or REN^-_{t-1} and L^+_{REN} or L^-_{REN}.

Table 3: Unit root test

Variables	Level	1st difference		
	T–statistic	T-statistic	Time break	Decision
GDP	0.782	–5.842***		I (1)
REN	0.103	–6.457***		I (1)
K	–7.421***	–		I (0)
L	–4.667**	–		I (0)

**P<0.01

Table 4: Bounds cointegration test

Dependent variable	F-Statistic	Prob	Result
GDP	9.028	0.001***	Cointegration
REN	7.354	0.008**	Cointegration

*** and ** denote significance at 1% and 5% thresholds, respectively

Table 5: NARDL estimation results

Dependent variable: Y_t			
Variables	**Coefficients**	**t-Statistic**	**Probability**
		Long-Run	
C	10.574***	5.485	0.000
Y_{t-1}	0.033**	3.156	0.016
REN^{+}_{t-1}	0.215*	3.241	0.058
REN^{-}_{t-1}	–0.110**	–3.615	0.025
K^{+}_{t-1}	–0.075**	–2.894	0.033
K^{-}_{t-1}	0.084	0.571	0.425
L^{+}_{t-1}	0.058*	2.697	0.085
L^{-}_{t-1}	0.062*	2.463	0.066
		Short-Run	
ΔY_{t-1}	0.104	0.722	0.183
ΔY_{t-2}	0.196	1.045	0.156
ΔREN^{+}_{t}	–0.022**	–2.654	0.045
ΔREN^{+}_{t-1}	–0.208***	–6.134	0.000
ΔREN^{+}_{t-2}	–0.155**	–2.157	0.033
ΔREN^{+}_{t}	0.103***	4.071	0.000
ΔREN^{+}_{t-1}	0.277***	5.089	0.000
ΔREN^{+}_{t-2}	0.120***	3.883	0.004
ΔK^{+}_{t}	–0.032	–0.643	0.684
ΔK^{+}_{t-1}	–0.046	–0.447	0.267
ΔK^{-}_{t}	0.039	0.723	0.382
ΔL^{+}_{t}	–12.011**	–2.703	0.022
ΔL^{+}_{t-1}	15.057**	3.041	0.016
		Diagnostic Tests	
R^2	0.880		
$Adj-R^2$	0.961		
DW	2.624		
$W_{LR.REN}$	77.083***	$W_{SR.GE}$	18.462**
$W_{SR.K}$	15.003**	$W_{SR.K}$	9.088*
$W_{LR.L}$	2.658**	$W_{SR.L}$	11.097***
χ^2_{SC}	7.118		
χ^2_{HET}	0.609		
χ^2_{EF}	0.209		
F_{PSS}	9.772***		
T_{BDM}	–10.011***		

***, **, and * represent significance at 1%, 5%, and 10% thresholds, respectively

The diagnostic test statistics are presented in Table 5. These tests are summarized by the statistics $\chi^2_{SC}, \chi^2_{HET}$ *and* F_{PSS}. Among these results, we note that there is no serial correlation χ^2_{SC} and no homoscedasticity χ^2_{HET}. In addition, the F_{PSS} statistic confirms the asymmetrical co-integration between economic growth, renewable energy consumption, capital and labor force. W_{LR} (W_{LR}) is the Wald statistic that tests the symmetry relationship hypothesis between the variables in the long (short) run. Both statistics are significant, thus rejecting the symmetric relationship hypothesis in the long and short run. Therefore, the model passes all the tests that indicate a correct estimation by the NARDL model.

The long-run NARDL results presented in Table 5 confirm that an increase in renewable energy consumption would boost economic growth (coefficient of 0.215), showing that a 1% increase in renewable energy consumption improves economic growth by 21.5%. In contrast, a negative shock to renewable energy consumption has a significant and negative effect on long-term economic growth. The negative coefficient (0.110) shows that any decrease in renewable energy consumption harms economic growth. Our results corroborate those of Olaoye et al., (2020) and Shi et al., (2017). These results indicate that negative shocks in renewable energy consumption will stimulate economic growth. The above results suggest that increased renewable energy consumption is beneficial, as an increased renewable energy promotes infrastructure development and employment opportunities; creates a peaceful environment for investment opportunities; and also contributes to the optimal use of resources and capital stock (Alptekin et al., 2012).

Indeed, a negative relationship was noted between positive capital shocks and economic growth, while a positive relationship was noted in negative shocks. These results confirm that an increase in capital investment hinders economic growth, while a decrease in capital stimulates economic growth. Similar results were noted by Benkraiem et al., (2019) for the relationship between capital and economic growth. Indeed, policymakers must respect capital investments. In the long run, a positive and significant effect was evident between labor and economic growth in both positive and negative shocks. Our results contradict those of Amna et al., (2020), who found that the labor force productivity weakens Asian countries' economic growth model. In other words, the lack of diversification of economies that are heavily dependent on the primary sector contributes to accentuating this phenomenon. Moreover, the positive coefficients show that the policy concerning labor employment stimulates economic growth in Tunisia.

In contrast, in the short run, a negative change in renewable energy consumption was negatively correlated with economic growth (coefficient 0.022). Moreover, a negative change is negatively associated with one-period lagged economic growth (with a coefficient of 0.208). These results are consistent with the results of Eid (2020). They indicate that a small decrease in government expenditure will boost economic growth at lag 0 while government expenditure decreases at lag 1. This reduction in government expenditure will disrupt production activities and dampen short-term economic growth in Tunisia.

Furthermore, a negative impact is verified between capital and economic growth for positive shocks in the short run (at lag 0 and 1), while a positive impact for negative shocks is presented (at lag 0). Our results were consistent with Shahbaz et al., (2017) in India, who argue that gross capital formation is detrimental to economic growth. These results highlight the importance of capital in the short run regarding economic development, since a positive shock in capital weakens economic growth. However, positive shocks to labor have a negative impact on economic growth (at lag 0), while a positive coefficient at lag 1. These results contradict those of Shahbaz et al., (2017) for India, where they found that employment is an economic growth driver. Therefore, in the short run, the government and policymakers should be cautious when designing policy regarding capital investment and employment.

Finally, we applied several dynamic adjustments. The results are shown in Figure 1, which plots the cumulative dynamic multipliers. These multipliers show the pattern of adjustment of economic growth to its new long-run equilibrium following a negative or positive shock in renewable energy consumption, labor and capital, respectively. The asymmetric curve (solid red line) reflects the difference between the dynamic multipliers associated with positive and negative shocks, i.e., $m_h^+ - m_h^-$. This curve is displayed with its lower and upper bands (dotted red lines) at a 95% confidence interval to provide a measure of the statistical significance of the asymmetry at any horizon h.

Figure 2 confirms the existence of an overall positive relationship between renewable energy consumption and economic growth. We see that the effect of a positive shock on renewable energy consumption outweighs that of a negative shock. Moreover, a significant asymmetric response to renewable energy consumption shocks is observed. In addition, there is an overall positive relationship between labor and economic growth, as negative shocks to labor have dominant positive effects on economic growth. However, a positive shock to capital dominates its negative shock. This result confirms the previous result, where a negative shock to capital has an insignificant impact on economic growth.

The last step in the NARDL estimation is to check the stability of the parameters in the long and short terms. The CUSUM techniques based on the cumulative sum of the recursive residuals and the CUSUMQ based on the cumulative sum of the square of the recursive residuals are applied (Figure 1). The results show that the graph of CUSUM and CUSUMQ statistics remain within the interval of critical values at the 5% threshold, implying that the model coefficients are stable.

Figure 1: CUSUM and CUSUMQ

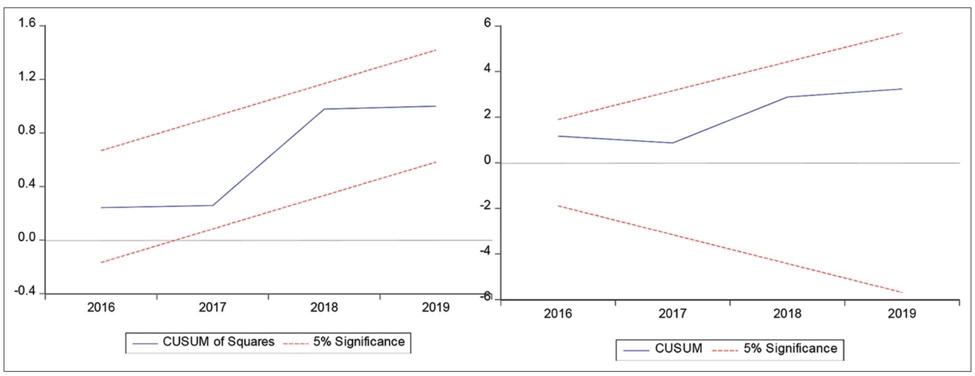
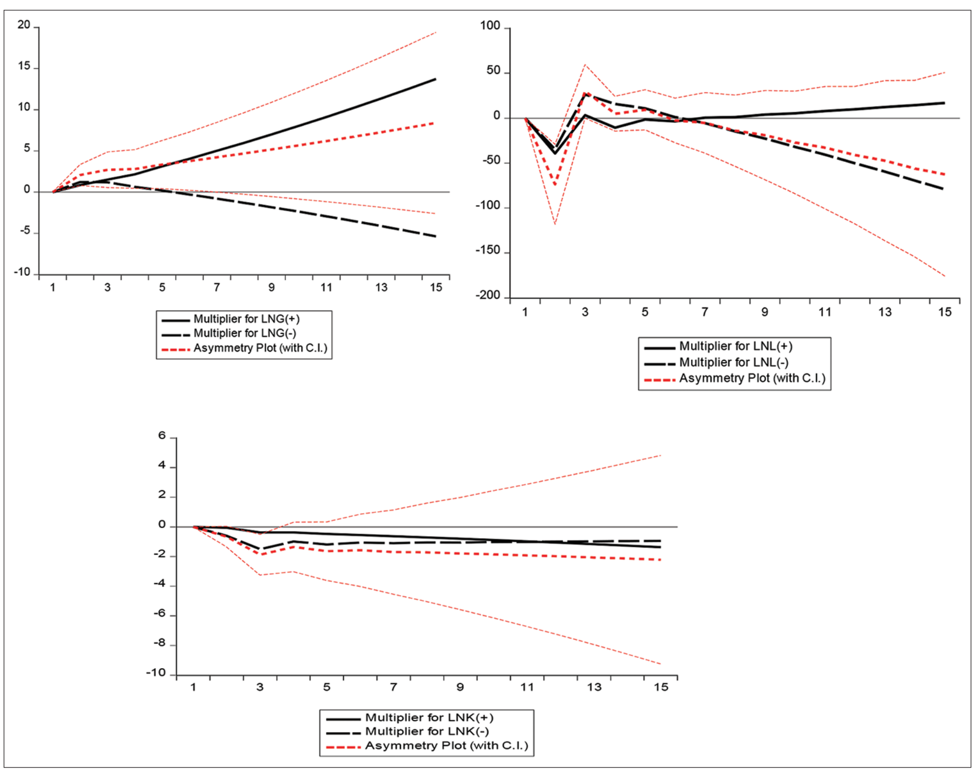


Figure 2: Cumulative effect of independent variables on the dependent variable



6. CONCLUSION AND POLICY IMPLICATIONS

This study aims to investigate the asymmetric impacts of renewable energy, capital and labor on economic growth in Saudi Arabia during the period 1990-–2019 based on a non-linear ARDL model both in the long and short terms. The results indicate that there is an asymmetric relationship between the variables considered. The positive shock of renewable energy consumption has a positive impact on GDP in the long run. In the long run, a positive and significant effect is evident between labor and economic growth in both the positive and negative shocks. However, in the short run, positive shocks to labor have a negative impact on economic growth (at lag 0), while a positive coefficient at lag 1.

In general, it is important for Saudi Arabia to increase its renewable energy consumption by focusing on fixed capital formation and labor at the expense of its operating expenditure, which has limited growth potential. This recommendation is in line with the objectives set out in Tunisia's Growth and Employment Strategy Paper (GESP), which is to raise the investment rate to at least 13.3% of GDP. To achieve this goal, Saudi Arabia should implement policies aimed at reducing current account and fiscal deficits. All this requires a structural transformation of countries' economies. It is time to move from a rentier to a transformation economy. To increase its added value, raw materials should be transformed into semi-finished or finished products. For this transformation policy to be successful, foreign investors must be brought in. The aim is to promote the relocation to developed countries of the production chains of companies that operate in these different sectors. This relocation should promote technology transfer for the benefit of local small and medium-sized enterprises which, in the medium and long terms, could become real industries. However, it would be essential for SMEs to migrate from the informal to the formal sector. Saudi Arabia should improve its companies' competitiveness by filling the infrastructure deficit in terms of quality and quantity. These are mainly transport infrastructure and energy infrastructure. This goal can easily be achieved through the development of public-private partnerships through concession agreements. This strategy increases the consumption of renewable energy, reduces public deficits and at the same time allows companies to achieve economies of scale. They will now be more competitive and more profitable in order to better contribute to budget revenues. The public-private partnership admits, however, a constraint related to the fact that the country obtains the debt under the conditions of those who finance the implementation of the various projects. Thus, capacity building would enable state actors to better negotiate within this partnership. In Saudi Arabia, successful disarmament operations should continue in order to end conflicts and allow the state to control the entire country. The growth sectors of the economy should be developed to generate significant revenues in the medium term in order to improve budget deficits and better meet social obligations. It is important to note that these strategies can produce relevant results only in a climate of peace, socio-political stability, good governance and security. In other words, the prevention and effective management of conflicts that rock the countries of the African region and the establishment of peace and security would boost economic growth and development in the subregion countries. It is in this context that, under the leadership of Asian countries, special emphasis should be placed on combating unemployment and poverty in Saudi Arabia.

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