International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(2), 468-476.

Relationship between Energy and Economic Growth: Evidence from a Panel Nonlinear ARDL Model

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Received: 27 October 2023 **Accepted:** 18 February 2024 **DOI:** https://doi.org/10.32479/ijeep.15513

ABSTRACT

In this article, we study the heterogeneous relationship among energy consumption and economic growth by incorporation gross fixed capital formation, foreign direct investment, international trade and finance development as control variables in a selected sample of 11 countries of the Middle East and North Africa over the period 1980–2020 using a panel nonlinear autoregressive distributed lag model. Empirical results show the presence of an asymmetric long run relationship between energy consumption and economic growth in the group of countries. The Pooled mean Group estimates indicate that positive and negative changes in energy consumption have positive and significant effects on output growth in the long term, whereas both Mean Group and Difference Fixed Effect estimates report that only negative changes in energy consumption have positive and significant effect on long-term economic growth in the selected sample of countries. In addition, the short run individual effects of energy use on economic growth are positive and significant for only three countries (Jordan, Saudi Arabia, and Tunisia). These results are very important for the design of energy policies and sustainable economic growth. Energy-saving policies are suitable for long-run economic growth for the entire sample, while they are only suitable for eight countries out of eleven in the short-run.

Keywords: Energy Use, Economic Growth, Panel Nonlinear Autoregressive Distributed Lag Model, Pooled Mean Group Estimator, MENA
JEL Classifications: C33, O13, Q43

1. INTRODUCTION

Since the second half of the 20th century, energy has played an important role in accelerating global economic growth. This importance has prompted researchers to study the link between energy use and economic growth in almost every country in the world. The Middle East and North Africa (MENA) region is one of the richest sources of energy. Fossil fuels such as oil and gas are an important source of income and wealth creation for many countries in the MENA region. However, since 2011 the majority of MENA countries have been hit by shocks of internal and external political instability. In a context of fragile economic and social balance, these shocks bring many new challenges. In the energy sector, the region is confronting a number of issues. The first issue is the satisfaction of its energy needs. Energy consumption is expected to double over the next 20 years because of fast urbanization, population growth, economic growth and global warming. This will result in higher average temperature and lower precipitation (Ben Saad et al., 2019). Some MENA countries may then be unable to meet their future energy needs. The second issue is the reduction of oil revenues for the net oil-exporting countries. The third issue concerns net oil importing countries such as Jordan, Morocco and Tunisia, which are expected to reduce their dependence on oil price fluctuations, which can undermine their long-term economic growth. For example, Morocco imports all of its oil needs.

As a result, these questions have prompted many empirical studies to analyze the energy-economic growth nexus in the MENA region as a whole or in its countries. However, all of these previous researches have examined the relationship between energy consumption and economic growth in MENA countries using linear models. The linear link between energy consumption and economic growth assumes that the impact of an increase in energy consumption on economic growth is the same in absolute terms for a decrease in energy consumption. Alternatively, it is not evident that this link between both variables is linear but it can be asymmetric (Hamilton, 2003; Richard, 2012; Omay et al., 2014; Raheem and Yusuf, 2015; Bayramoglu and Yildirim, 2017; Ndoricimpa, 2017; Kouton, 2019; Awodumi and Adewuyi, 2020; etc.). The asymmetric responses of a shock on energy are frequent and particularly affect economic growth.

Studies analyzing the impact of energy consumption on economic output have attracted attention since the pioneering article by Kraft and Kraft (1978). Nevertheless, the energy-growth link is still a debate for economists. There is abundant literature on this subject (Belloumi, 2009; Ozturk, 2010; Magazzino, 2014). However, all of these previous studies have examined a linear energy-growth association. They also failed to reach consensus on energy-growth link (Apergis and Tang, 2013). Many explanations were advanced such that the various techniques used, the control variables employed, the periods considered, and country's characteristics (Apergis and Tang, 2013). Recently, some studies have given more attention to the nonlinear relationship between the both variables. Qahtan et al. (2022) studied the asymmetric effects of non-renewable and renewable energy consumption on economic growth in the MENA net oil-exporting and net oil-importing countries using the panel nonlinear autoregressive distributed lag (NARDL) model during the 1990–2019 period. Their results indicated the presence of nonlinear link between nonrenewable energy use and economic growth in both the short and long run for both MENA net oil-exporting and net-oil importing countries. Increased non-renewable energy consumption has a positive impact on economic growth, while lower non-renewable energy consumption has a negative impact on the MENA's net oil exporters in the short and long term. In addition, the impact of renewable energy use on economic growth is similar and negative in the short and long term. In the case of net oil-importing countries, the positive impact of non-renewable energy on economic growth is encouraging it in the long term, but reduces it in the short term; however, there is no impact on the reduced use of non-renewable energy in both short and long run. Furthermore, the long-term impact of renewable energy use is asymmetric but symmetric in the short term; however, none of its effects is significant.

Recently, Al-Nawafleh and Alqaralleh (2023) studied the asymmetric influence of energy consumption on economic growth in Jordan by employing the NARDL model over the period 1990–2019. Their findings show that changes in energy consumption have disproportional effects on economic growth. More recently, Rahaman et al. (2023) studied the nonlinear effects of renewable energy use on the economic growth in a selected sample of 10 emerging south and East Asian countries by employing a –NARDL framework over the period 1994-2019. Their main findings report that increases and decreases in renewable energy consumption have positive effects on economic growth. Similarly, Ferhi and Helali (2023) explored the asymmetric influence of renewable energy use on economic growth in a selected sample of 24 organization for economic cooperation and development countries using the non-linear panel threshold and smooth transition models during 1990-2015. The findings of nonlinear panel threshold models showed that renewable energy consumption has a positive effect on economic growth above a threshold value but a negative impact below this threshold value. However, the results of nonlinear panel smooth transition model reported that the transition from low renewable energy consumption regime to higher is instantaneous.

In this study, we attempt to fill this gap by analyzing the asymmetrical impact of energy consumption on economic growth in eleven selected MENA countries using annual data from 1980 to 2020. To achieve this goal, we use a panel NARDL model originally developed by Shin et al. (2014). In particular, the asymmetrical impact of energy consumption on economic growth is determined by estimating positive and negative changes in energy consumption on economic growth. To do this, we determine:

- The existence of an asymmetric relationship between energy consumption and economic growth by employing the symmetric test.
- The impact of the increases and decreases in energy consumption on long-term economic growth for the selected MENA countries using the pooled mean group (PMG), the mean-group (MG), and the difference fixed effect (DFE) estimators for the selected MENA countries.
- The impact of energy consumption on short-term economic growth for the selected MENA countries sample and for each country.
- The direction of causality between energy consumption and economic growth using the Dumitrescu Hurlin panel causality test.

According to Richard (2012), the negative changes in energy consumption are associated with energy conservation policy, while the positive changes in energy use are linked to energy consumption policy. A positive impact of the positive change in energy consumption on economic growth allows validating the energy-led growth hypothesis. A negative impact of an increase in energy use on economic growth allows the validation of the energy recession hypothesis. A positive impact of a decrease in energy use on economic growth permits to validate the energy neutral hypothesis. This implies that a conservation energy policy is important and desirable for economic growth. A negative impact of a decrease in energy use on economic growth permits to validate the energy-led growth hypothesis. This implies that a conservation energy policy is bad for economic growth. The expected results of the different short- and long-term impacts of positive and negative changes in energy consumption on economic growth can be important for decision-makers in selected MENA countries to adopt appropriate policies to manage energy consumption in different economic sectors to achieve the sustainable development goals.

The originally of this study is twofold. Firstly, to my knowledge, this is among the rare studies that estimate the impacts of positive and negative changes in energy consumption on economic growth in MENA countries using a panel NARDL model. Secondly, to control for the omitted variable bias, we introduce four explanatory variables gross fixed capital formation, foreign direct investment inflows, trade openness and finance development. Thirdly, the findings of energy-growth nonlinear link are mixed. Our results should add to the energy economics literature.

The remainder of this paper is organized as follows. Section 2 presents the data and methods used in the study. Section 3 presents the various findings and their interpretation. Finally, in Section 4, we conclude with some conclusions and policy implications.

2. MATERIALS AND METHODS

2.1. Data

The time series and countries studied are carefully selected according to the availability of data and the aim of the study. We use annual data from 1980 to 2020 for eleven selected MENA countries: Algeria, Tunisia, Morocco, Egypt, Jordan, Iran, Syria, Sudan, Bahrain, Oman, and Saudi Arabia. Real GDP per capita (in constant 2015 US dollars) is used as a dependent variable (GDPC). Energy consumption per capita (kg oil equivalent) is used as an independent variable (EU). The variables of gross fixed capital formation as percentage of GDP (GFCF), net inflows of foreign direct investment as share of GDP (FDI), trade openness (TO), and finance development (FD) as control variables in order to prevent the omitted variable bias. The variable trade openness represents the share of exports plus imports to GDP. Finance development is presented by domestic credit to private sector as a share of GDP. The data of the different time series are collected from the World Bank's world development indicators (WDI, 2019). All the variables are transformed to their natural logarithms (LGDPC, LEU, LGFCF, LFDI, LTO, LFD). We apply logarithmic transformation to the variables in order to make patterns in the data more interpretable, to fulfill the different assumptions of inferential statistics and to keep away the problem of heteroscedasticity. Table 1 presents the common sample of descriptive statistics of the logarithms of the variables used in the model. The coefficient of variation is also measured by dividing the standard deviation by the mean for reasons of data heterogeneity. The results indicate that the values of coefficient of variation are less than unity for all the variables, implying the absence of heterogeneity in the data used. In addition, the energy-growth relationship is presented in Figure 1. It is clearly indicated that there is a positive relationship between energy consumption and economic output across the sample.

2.2. Methods

The research methodology used in this research is based on estimating the panel NARDL model using the annual data of the various time series for 11 MENA countries over the period 1980–2020. This methodology is undertaken in different steps. The first step consists to check the presence of cross-sectional dependence in the time series using the cross-sectional dependence tests such as the Breusch and Pagan (1980) Lagrange multiplier (LM) test, Pesaran (2004) cross-sectional (CD) test, Pesaran (2004) cross sectional dependent-Lagrange multiplier (CD-LM) test and Pesaran et al. (2008) deviating corrected horizontal cross-sectional test. In the second step, we check for the stationarity of the different time series using panel unit root tests. In the case of the absence of cross-sectional dependence in data, we use the first generation of panel unit root tests while in the case of presence of cross-sectional dependence we employ the second generation of panel unit root tests. The first generation of panel unit root tests suppose the assumption of cross-sectional independence (Maddala and Wu, 1999). These unit root tests include those of Im et al. (2003), Levin et al. (2002), Fisher-type (Choi 2001), Breitung (2000) and Hadri (2000). These different tests are unsuitable because they ignore the cross-sectional dependence (Pesaran, 2014). The second generation of panel unit root tests include the cross-sectional augmented DickeyFuller (CADF) test developed by Pesaran (2007) and the Pesaran's cross-sectional augmented Im-Pesaran-Shin (CIPS) unit root test. Both tests take into account the cross-sectional dependence in the time series. In the third step, we test for the existence of panel cointegration relationship between the variables by employing the Pedroni (1999, 2004) and Kao (1999) panel cointegration tests.

Table 1: Common sample descriptive statistics

Variables	LGDPC	LFD	LEU	LFDI	LGFCF	LTO
Mean	8.377	3.406	7.184	4.624	3.124	4.170
Median	8.165	3.621	6.850	4.616	3.172	4.206
Maximum	10.425	4.559	9.356	4.894	3.785	5.526
Minimum	6.588	0.479	5.593	4.458	1.711	2.298
SD	1.001	0.872	1.034	0.030	0.332	0.564
CV	0.119	0.256	0.144	0.006	0.106	0.135
Observations	451	451	451	451	451	451

SD: Standard deviation

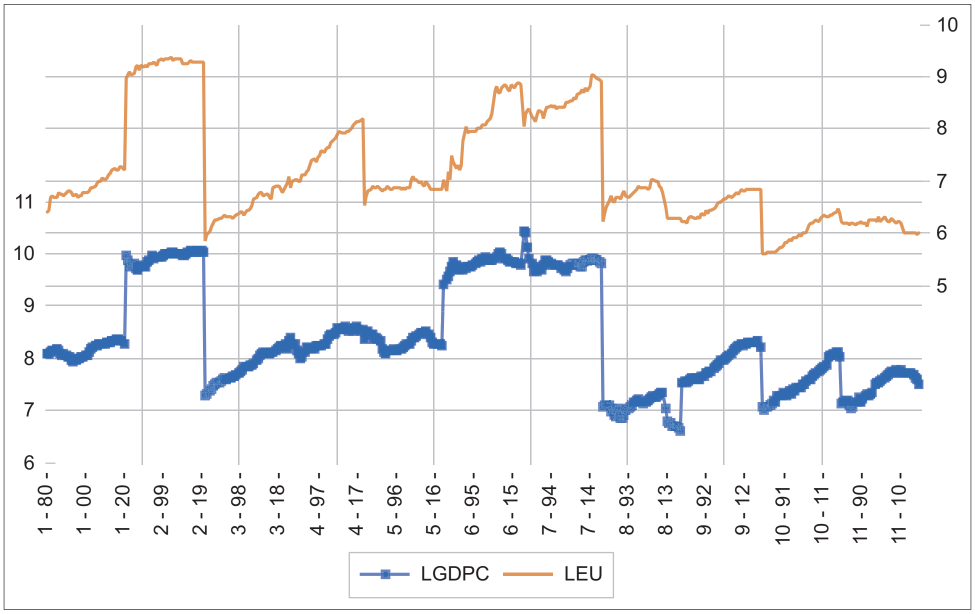
In the fourth step, we estimate the panel NARDL model originally developed by Shin et al. (2014) to detect the short and long run asymmetries between the variables. Before estimating the model, we employ the symmetry test based on Wald statistic to check if the relation between economic growth and energy use is linear or nonlinear in the short run and long run. Then, we perform the Hausman test to choose between the three estimators that can be employed: the PMG, the MG, and the dynamic fixed effect estimators. The PMG estimator allows short-term coefficients to vary across countries, but makes the coefficients homogeneous over the long term. Thus, this estimator is based on a combination of pooling of long run coefficients and averaging of short run coefficients. However, the MG estimator allows short run and long run coefficients to vary across countries and then presents an average of the short run and long run coefficients for the group. In contrast, the DFE estimator allows the coefficients homogeneous over the short and long terms but the intercepts are permitted to vary from country to country. Then, the selected panel linear or nonlinear ARDL model will be estimated to explore the short and long run influence of energy consumption on economic output by taking into account the control variables (gross fixed capital formation, FDI, finance development, and trade openness).

The model linking energy consumption to economic output takes the following form:

$$GDPC = f(EU, GFCF, FDI, FD, TO) \qquad (1)$$

Where GDPC is the real GDP per capita, EU is energy use per capita, GFCF is the gross fixed capital formation, FDI is the net inflows of foreign direct investment, FD is finance development, and TO is trade openness.

Figure 1: The relation between energy use per capita and real GDP per capita



Eq. (1) can be rewritten in logarithmic form with a time series specification on panel data, such as:

$$LGDPC_{it}=\alpha_0+\alpha_1\ LEU_{it}+\alpha_2\ LGFCF_{it}+\alpha_3\ LFDI_{it}+\alpha_4\ LFD_{it}+\alpha_5\ LTO_{it}+\mu_i+\varepsilon_{it} \quad (2)$$

where the index i (i = 1,…, 11) indicates the country i of the selected sample, t (t = 1980,…, 2020) indicates the period. In the case that all the variables are stationary and they are not cointegrated, the first difference or system GMM estimators can produce consistent estimates. However, when some of the variables are not stationary at their levels (I[0]) but stationary on their first differences (I[1]), the panel ARDL model is more consistent and convenient.

The estimated model then takes the form of the following panel linear ARDL model (p, q) originally developed by Pesaran and Smith (1995) and Pesaran et al. (1999):

$$LGDPC_{it} = \alpha_0 + \sum_{j=1}^{p} \alpha_j LGDPC_{i,t-j} + \sum_{j=0}^{q} \delta_{1j} LEU_{i,t-j} + \sum_{j=0}^{q} \delta_{2j} LGFCF_{i,t-j} + \sum_{j=0}^{q} \delta_{3j} LFDI_{i,t-j} + \sum_{j=0}^{q} \delta_{4j} LFD_{i,t-j} + \sum_{j=0}^{q} \delta_{5j} LTO_{i,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

By transforming eq. (3), we obtain the panel ARDL(p, q) error correction model:

$$\Delta LGDPC_{it} = \alpha_0 + \$_i \begin{pmatrix} LGDPC_{i,t-1} - \rho_{1i} LEU_{i,t} - \rho_{2i} LGFCF_{i,t} \\ -\rho_{3i} LFDI_{i,t} - \rho_{4i} LFD_{i,t} - \rho_{5i} LTO_{i,t} \end{pmatrix} + \sum_{j=1}^{p-1} \alpha_{ij} \Delta LGDPC_{i,t-j} + \sum_{j=0}^{q-1} \delta_{1ij} \Delta LEU_{i,t-j} + \sum_{j=0}^{q-1} \delta_{2ij} \Delta LGFCF_{i,t-j} + \sum_{j=0}^{q-1} \delta_{3ij} \Delta LFDI_{i,t-j} + \sum_{j=0}^{q-1} \delta_{4ij} \Delta LFD_{i,t-j} + \sum_{j=0}^{q-1} \delta_{5ij} \Delta LTO_{i,t-j} + \mu_i + \varepsilon_{it} \quad (4)$$

Where is the group-specific coefficient of speed of adjustment (Φ_i<0); ρ_1, ρ_2, ρ_3, ρ_4 and ρ_5 represent the coefficients that measure the long-run effects of energy consumption and the control variables on economic output. The variable, ECT=[($LGDPC_{i,t-1}-\rho_{1i}$ $LEU_{i,t}-\rho_{2i}$ $LGFCF_{i,t}-\rho_{3i}$ $LFDI_{i,t}-\rho_{4i}$ $LFD_{i,t}-\rho_{5i}$ $LTO_{i,t}$)] is the error correction term; δ_{1ij}, δ_{2ij}, δ_{3ij}, δ_{4ij} and δ_{5ij} are the coefficients of short-run dynamics; p is the optimal lag for the dependent variable; q is the optimal lag orders for the regressors; μ_i is the country specific effects; and ε_{it} are the random error terms.

Nevertheless, it is not convenient to estimate a panel linear ARDL model when we obtain an asymmetric impact of energy use on economic growth. In this context, we estimate the panel NARDL model developed by Shin et al. (2014). This model permits for asymmetric responses of economic output to energy consumption. In this context, the energy consumption variable is decomposed into two partial sums: $EUPOS_{it}$ is the positive partial sum expected to capture the upward fluctuations of energy consumption, while $EUNEG_{it}$ is the negative partial sum expected to capture the negative changes of energy consumption. The main idea behind this is that positive and negative shocks to energy use are expected to have different effects on economic growth.

The positive shock of energy use (EUPOS) is decomposed from energy use per capita as follows:

$$EUPOS_{it} = \sum_{j=1}^{t} \Delta EUPOS_{ij} = \sum_{j=1}^{t} \max(\Delta EU_{ij}, 0) \quad (5)$$

The negative shock of energy use (EUNEG) is decomposed from energy use per capita as follows:

$$EUNEG_{it} = \sum_{j=1}^{t} \Delta EUNEG_{ij} = \sum_{j=1}^{t} \min(\Delta EU_{ij}, 0) \quad (6)$$

The panel NARDL model estimated has the same form as the panel ARDL model given by eq. (4) with the variable energy use

(EU) is replaced by the positive changes (EUPOS) and negative changes (EUNEG) in energy use.

Finally, in the last fifth step, we use causality tests to detect the direction of causality between economic growth and the different independent variables. In the case of cross sectional independence, the Granger (1969) causality test is used for the stationary variables while the Dumitrescu and Hurlin (2012) causality test would be employed in the case of presence of cross-sectional dependence in panels.

3. RESULTS AND DISCUSSION

3.1. Results of Cross-Sectional Dependency Tests (CSD)

Before estimating the model, we begin the empirical study by checking the CSD in the data by employing the Breusch and Pagan LM test, the Pesaran scaled LM test, the Bias-corrected scaled LM test and the Pesaran CD test. The results of these tests are reported in Table 2. It is shown that the null hypothesis indicating the absence of cross-section dependence is rejected by the four tests at 1% level of significance which means the presence of cross-section dependence in the panels. These findings imply that there is significant evidence of cross dependence in all the series across the 11 MENA countries. These results can consolidate the idea of that the economies of the MENA countries are linked due to many reasons of culture and integration. Thus, any shock on energy use affecting economic growth of one country may also affect economic growth in other MENA countries.

3.2. Results of Second Generation Panel Unit Root Test

As all panels present cross-section dependence, we cannot use conventional panel unit root tests because they are weak in the presence cross-section dependence. Therefore, we employ the Pesaran (2007) CIPS panel unit root test that takes into account cross-section dependence. The results of this test for all the variables at their levels and first differences are reported in Table 3. It is shown that LFDI is stationary at its level whereas LGDPC, LFD, LEU, LGFCF, and LFDI are stationary at their first differences. Hence, the panel is a mixture of I(0) and I(1), which opens the way for the use of the panel ARDL model that considers heterogeneity and non-stationarity in panel data series.

3.3. Results of Panel Cointegration Tests

As none of the variables are integrated of order two, we use the panel cointegration tests to check the existence of long run relationship between energy use, gross fixed capital formation, FDI, finance development, trade openness and economic growth. The cointegration is checked using the Pedroni panel test (Pedroni, 1999, 2004) and Kao (1999) panel test. The results of both panel cointegration tests are presented in Table 4.

The Pedroni cointegration test results indicate that panel PP-Statistic, the panel ADF-Statistic, the Group PP-Statistic and the Group ADF-Statistic are significant at 1% level. Therefore, we reject the null hypothesis of absence of cointegration between the variables. Moreover, the ADF statistic of Kao test is significant at 5% significance level. Therefore, we can conclude that there is long run relationship between energy use and economic growth in the presence of control variables. This finding indicate that any shock on energy use will have a permanent effect on economy. Thus, we estimate a nonlinear panel ARDL model using the PMG estimator.

3.4. Results of Estimation of Panel NARDL Model

Before estimating the model, we employ the symmetry test to check if energy use has symmetric or asymmetric impact on economic growth. The results of this test are reported in Table 5. From these results, we conclude that we reject the null hypothesis of linear relationship between energy use and economic growth in the long run at a level of significance 1%. It is shown that energy use has an asymmetric long run impact on economic growth in the selected sample of 11 MENA countries. Therefore, we estimate a panel nonlinear ARDL model by considering that the influence of energy use is asymmetric in the long run. Then, we undertake the Hausman test to choose between the PMG, MG and DFE estimators. The results of this test are inconclusive because the differences of covariance are not positive definite. The results of PMG estimator, MG estimator, and DFE estimator are presented in Tables 6-8, respectively. The specificities of the short run equilibrium by country of the PMG estimator are also shown in Table 9. The results are presented for the long run and short run equilibrium for the entire sample. The results of PMG method indicate that all variables have positive and significant impact on economic growth at 1% in the long run except gross fixed capital formation. Results of the overall PMG-ARDL model indicate that both positive and negative changes in energy use have positive long run effects on economic growth in the selected sample of MENA countries. In fact, both increases and decreases in energy use have positive and significant effects at 1% level of significance on economic growth in the long run for the whole sample. This implies that both increases and decreases in energy use could lead to an increase in economic growth for the selected MENA countries. However, the results of MG and DFE estimators are similar but they are slightly different from PMG estimates. They indicate that only a decrease in energy use has a positive and significant impact on economic growth in the long run.

Table 2: Results of cross-section dependence tests

Tests	Breusch-Pagan LM		Pesaran scaled LM		Bias-corrected scaled LM		Pesaran CD	
	Statistic	P	Statistic	P	Statistic	P	Statistic	P-value
LGDPC	780.26	0.00	69.15	0.00	69.01	0.00	18.94	0.00
LDCPS	702.56	0.00	61.74	0.00	61.60	0.00	16.45	0.00
LGFCF	377.02	0.00	30.70	0.00	30.56	0.00	7.410	0.00
LFDI	331.24	0.00	26.33	0.00	26.20	0.00	14.86	0.00
LEU	1106.5	0.00	100.2	0.00	100.12	0.00	21.45	0.00
LTO	473.65	0.00	39.91	0.00	39.77	0.00	15.40	0.00

Null hypothesis (H_0): Absence of cross-section dependence

Table 3: Results of Pesaran (2007) cross-sectional augmented im-pesaran-shin panel unit root test

Tests	Levels		First difference		Order of integration
	Statistic	P	Statistic	P	
LGDPC	–1.418	≥0.10	−3.25	<0.01	I (1)
LFD	–1.43	≥0.10	−3.83	<0.01	I (1)
LGFCF	–0.91	≥0.10	−5.60	<0.01	I (1)
LFDI	–2.88	<0.01	−8.06	<0.01	I (0)
LEU	–1.97	≥0.10	−4.77	<0.01	I (1)
LTO	–2.15	≥0.10	−5.70	<0.01	I (1)

Null hypothesis (H_0): Absence of cross-section dependence

Table 4: Results of Pedroni and Kao panel cointegration tests

Pedroni residual cointegration test				
Alternative hypothesis: common AR coefficient (within-dimension)				
Tests	Statistic	P-value	Weighted statistic	P-value
Panel v-statistic	0.003	0.498	–0.337	0.632
Panel rho-statistic	−0.346	0.364	–0.190	0.424
Panel PP-statistic	–3.009***	0.001	–2.501***	0.006
Panel ADF-statistic	–3.213***	0.000	–2.612***	0.004
Alternative hypothesis: Individual AR coefficient (between-dimension)				
Tests	Statistic		P-value	
Group rho-statistic	0.665		0.747	
Group PP-statistic	–3.049***		0.001	
Group ADF-statistic	–3.564***		0.000	
Kao residual cointegration test				
Test	t–statistic		P-value	
ADF	–1.962**		0.024	

***P<0.01, **P<0.05, *P<0.10. Null hypothesis is no cointegration; Level of significance. ADF: Augmented Dickey Fuller

Table 5: Results of symmetry test

Variable	Statistic	Value	P-value
Long-run			
LEU	F-statistic	10.32***	0.001
	χ^2	10.32***	0.001

Level of significance: ***P<0.01, **P<0.05, *P<0.10; Null hypothesis: Coefficient is symmetric. The model selection method used is the Akaike information criterion

Therefore, these results can validate the energy neutral hypothesis, which implies that a conservation energy policy is important and desirable for economic growth in the selected sample of MENA countries in the long term.

Short run dynamics modelling provides information on how adjustments are made between different model variables to restore long run equilibrium. The long run relationship is captured by the error correction term (ECT). The coefficient of this term indicates the speed of adjustment at which the system returns to equilibrium after a shock. The existence of a long run relationship can be assumed if the coefficient sign of the error correction term is negative and significant. Looking at Tables 6-8, we can see that the estimated coefficient for the ECT is negative and significant at the 1% or 5% levels for the three estimates (PMG, MG and DFE), confirming the existence of an asymmetric long run relationship between energy use and economic growth for the selected sample of MENA countries. It is also reported that short run coefficient

Table 6: PMG-ARDL long run and short run estimates

Dependent variable: D (LGDPC)				
Variable	Coefficient	SE	t-statistic	P-value
Long-run (pooled) coefficients				
LGFCF	0.059	0.051	1.145	0.252
LTO	0.298***	0.070	4.232	0.000
LFDI	1.088***	0.407569	2.670708	0.007
LDCPS	0.238***	0.045	5.242	0.000
EUPOS	0.489***	0.089	5.468	0. 000
EUNEG	0.946***	0.131	7.184	0. 000
Short-run (mean-group) coefficients				
COINTEQ	−0.135**	0.061	−2.203	0.028
D (LTO)	−0.018	0.025	−0.715	0.474
D (LTO(-1))	−0.026	0.041	−0.632	0.527
D (LTO(-2))	−0.022	0.025	−0.891	0.373
D (LFDI)	−0.729	0.768	−0.949	0.343
D (LFDI(-1))	−1.124	1.066	−1.054	0.292
D (LDCPS)	−0.128**	0.053	−2.420	0.015
D (LDCPS(-1))	−0.006	0.036	−0.175	0.860
D (LEU)	0.034	0.092	0.376	0.706
D (LEU(-1))	0.051	0.071	0.719	0.472
C	0.187*	0.100	1.867	0.062

The model selection method used is the Akaike information criterion (AIC; the model selected is DFE ARDL (1,0,3,2,2,2); Level of significance: ***P-value<0.01, **P value<0.05, *P-value<0.10

Table 7: MG-ARDL long run and short run estimates

Dependent variable: D (LGDPC)				
Variable	Coefficient	SE	t-statistic	P-value
Long-run coefficients				
LGFCF	0.098	0.060	1.627	0.104
LFDI	−0.371	1.656	−0.224	0.822
LTO	0.345***	0.104	3.310	0.001
LDCPS	−0.230	0.171	−1.342	0.180
EUPOS	−0.132	0.476	−0.279	0.780
EUNEG	0.973*	0.548	1.774	0.076
Short-run coefficients				
COINTEQ	−0.417***	0.070	−5.969	0.000
D (LFDI)	−0.688	0.775	−0.887	0.375
D (LFDI(−1))	−0.791	0.858	−0.922	0.356
D (LTO)	−0.075*	0.040	−1.838	0.066
D (LTO(−1))	−0.073**	0.035	−2.070	0.039
D (LTO(−2))	−0.079***	0.026	−3.030	0.002
D (LDCPS)	−0.045	0.039	−1.133	0.257
D (LDCPS(−1))	0.003	0.039	0.082	0.934
D (LEU)	−0.097	0.080	−1.216	0.224
D (LEU(−1))	0.004	0.050	0.093	0.925
C	2.549	1.644	1.550	0.121

The model selection method used is the Akaike information criterion (AIC; the model selected is DFE ARDL (1,0,3,2,2,2); Level of significance: ***P-value<0.01, **P value<0.05, *P-value<0.10

of energy use is positive but not significant in the case of the three estimators PMG, MG and DFE. This implies that energy consumption does not affect economic growth in the short run for the selected MENA countries. This result implies the neutrality hypothesis in the short run, which means that overall; the selected MENA countries could reduce energy consumption in the short run without affecting economic growth.

We turn down now to the country-specific short run estimates shown in Table 9. It is shown that the short run impact of energy use on economic growth is positive and significant for the case

Table 8: DFE-ARDL long run and short run estimates

Dependent Variable: D (LGDPC)				
Variable	Coefficient	SE	t-statistic	P-value
	Long-run coefficients			
LGFCF	0.034	0.075	0.460	0.645
LFDI	1.219	0.824	1.479	0.139
LTO	0.299***	0.109	2.745	0.006
LDCPS	−0.069	0.043	−1.580	0.114
EUPOS	−0.062	0.095	–0.655	0.512
EUNEG	1.176***	0.186	6.319	0.000
	Short−run coefficients			
COINTEQ	−0.135***	0.019	−6.965	0.000
D (LFDI)	−0.092	0.107	−0.864	0.387
D (LFDI(-1))	−0.132	0.093	−1.418	0.156
D (LTO)	0.010	0.018	0.590	0.555
D (LTO(-1))	0.021	0.018	1.165	0.244
D (LTO(-2))	0.002	0.018	0.110	0.912
D (LDCPS)	−0.012	0.015	−0.807	0.419
D (LDCPS(-1))	0.012	0.015	0.848	0.396
D (LEU)	0.035	0.034	1.038	0.299
D (LEU(-1))	0.081**	0.032	2.501	0.012
C	0.204	0.516	0.396	0.691

The model selection method used is the Akaike information criterion (AIC; the model selected is DFE ARDL (1,0,3,2,2,2); Level of significance: ***P-value<0.01, **P value<0.05, *P-value<0.10

of three countries (Jordan, Saudi Arabia, and Tunisia). These findings support the energy-led growth hypothesis in the short run for these countries. This implies that for Jordan, Saudi Arabia and Tunisia any decrease in energy use could lead to an economic recession in the short run. Any policy based on energy conservation is not appropriate for economic growth in the short run the three countries. However, for the case of Bahrain, Iran and Oman, the short run impact of energy use on economic growth is negative and significant. This implies the validation of the energy recession hypothesis in the short run for these countries. For the rest of countries (Algeria, Egypt, Morocco, Syria, and Sudan), we observe that energy use does not affect economic growth in the short run. Therefore, for these countries, an energy conservation policy is preferable for their economic growth in the short run. In particular, a decrease in energy use could lead to reduce their energy dependence and hence release much more money accorded to the importation of oil to other productive sectors that can boost economic growth.

3.5. Results of Dumitrescu Hurlin Panel Causality Tests

In order to investigate the causal relationship between the dependent variable represented by economic growth and the independent variables (energy use, gross fixed capital formation, FDI, finance development and trade openness), we employ the panel causality test developed Dumitrescu and Hurlin (2012). The Dumitrescu Hurlin (DH) panel causality test is considered as an advanced form of Granger causality test. Therefore, it was accepted that the causality analysis in the Dumitrescu Hurlin panel has some advantages over Granger causality analysis. For example, the DH panel causality test is more successful at analyzing data in the presence of sectional dependence between countries. The main prerequisite for such an analysis is that we consider the variables at their levels if they are stationary and their first differences if they are integrated of order one. The results of this test are reported in Table 10. The findings indicate the presence of bidirectional

Table 9: Country-specific PMG-ARDL short run estimates

Countries	ECT	DLENU
Algeria	0.073*** (0.004)	0.141 (0.168)
Bahrain	−0.068 (0.422)	−0.345** (0.029)
Egypt	−0.068** (0.022)	−0.015 (0.770)
Iran	−0.412*** (0.001)	−0.374*** (0.007)
Jordan	−0.199*** (0.000)	0.477*** (0.000)
Oman	−0.354*** (0.001)	−0.116** (0.049)
Saudi Arabia	−0.119 (0.140)	0.222* (0.077)
Syria	−0.436*** (0.000)	−0.196 (0.281)
Tunisia	0.152 (0.311)	0.532*** (0.005)
Morocco	−0.168** (0.028)	0.191 (0.242)
Sudan	0.109** (0.037)	−0.134 (0.425)

Level of significance: *** P value<0.10, **P value<0.05, *P value<0.01

Table 10: Pairwise Dumitrescu Hurlin panel causality test results

Null hypothesis	W-Statistic	Zbar-Statistic	P-value
DLGFCF does not homogeneously cause DLGDP	3.029	−0.213	0.830
DLGDP does not homogeneously cause LGFCF	4.416	1.391	0.164
DLTO does not homogeneously cause DLGDP	4.667	1.681	0.092
DLGDP does not homogeneously cause DLTO	3.290	0.088	0.929
LFDI does not homogeneously cause DLGDP	2.913	−0.348	0.727
DLGDP does not homogeneously cause LFDI	4.021	0.934	0.350
DLEU does not homogeneously cause DLGDP	5.982	3.203	0.001
DLGDP does not homogeneously cause DLEU	4.976	2.039	0.041
DLFD does not homogeneously cause DLGDP	5.559	2.714	0.006
DLGDP does not homogeneously cause DLFD	2.721	−0.570	0.568

causality between energy consumption and economic growth in the selected sample of MENA countries. In addition, there is unidirectional causality running from finance development and trade openness to economic growth. These results confirm those of PMG estimates that energy consumption, finance development and trade openness play a role in promoting economic growth in MENA countries.

4. CONCLUSIONS

This study examines the asymmetric impact of energy use on economic growth in selected sample of eleven MENA countries over the period 1980-2020 by estimating a panel NARDL model using the PMG, MG and DFE estimators. The results of this study are four-folds. Firstly, the second generation of panel unit root tests (the Pesaran (2007) CIPS panel unit root test) that the variables investigated are integrated of order 0 or 1. Moreover, the Pedroni and Kao panel cointegration tests sugget the presence of cointegration between the variables. Secondly, the results of PMG, MG and DFE estimators indicate that negative shocks on energy use have positive and significant effect on economic growth in the long run for the whole sample while only the findings of PMG estimates report that positive shocks have positive and significant impact on economic growth for the whole sample. From these findings, we conclude the validity of neutrality hypothesis in the long run for the whole sample. Thirdly, the results of the three estimators indicate that energy consumption does not affect economic growth in the short run for the selected sample of MENA countries. This result implies the validity of neutrality hypothesis in the short run, which means that the selected MENA countries could reduce energy consumption in the short run without affecting economic growth.

Finally, when considering the country-specific short run estimates, we obtain that the energy use has symmetric positive and significant impact on economic growth for only three countries out of eleven countries. These results confirm the previous findings and they imply that short run and long run energy policies should be based on energy conservation. Therefore, energy conservation policies fit better for the selected MENA countries.

At the end of our study, it is important to draw the attention of the competent authorities to the various appropriate policies to be implemented to reduce the energy use in the selected MENA countries to reduce the CO2 emissions, as energy conservation measures are appropriate for the whole sample in both the short and long run. Moreover, MENA countries should invest mainly in renewable energy resources such as solar and wind energies to meet the various needs in energy of their populations in the near future and resolving the environmental problems. Moreover, energy resources can play an important role in achieving sustainable economic growth in MENA countries and thus inclusive development by reducing the different socioeconomic problems.

5. ACKNOWLEDGEMENT

The authors are thankful to the Deanship of Graduate Studies and Scientific Research at Najran University for funding this work under the General Research Funding program grant code NU/NRP/SEHRC/12/20.

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