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Renewable energy consumption and economic growth: New empirical evidence from a panel of emerging countries

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Résumé

Cette étude a examiné la relation entre la consommation d'énergie renouvelable et la croissance économique dans 21 pays émergents au cours de la période 1980/2018. Compte tenu des séries temporelles limitées, une co-intégration des données de panel et un modèle de correction des erreurs ont été utilisés pour déduire la causalité à l'aide d'un ARDL montrant l'existence d'une relation d'équilibre à long terme entre le revenu réel, la consommation d'énergie renouvelable, la formation totale de capital fixe et le travail, avec des coefficients positifs et statistiquement significatifs. Les résultats de causalité de Granger indiquent qu'il existe une relation causale entre la consommation d'énergie renouvelable et la croissance économique à court et à long terme. Cette causalité s'est avérée varier significativement d'un pays à l'autre. En ce qui concerne notre échantillon de pays émergents, il a été noté qu'il existait une relation unidirectionnelle entre la consommation d'énergie renouvelable et la croissance économique. Ce résultat implique que les gouvernements sont invités à appliquer des politiques efficaces d'économie d'énergie

Mots clés :

Consommation d'énergie renouvelable ; croissance économique ; données de panel ; ARDL.

Abstract

This study examined the relationship between renewable energy consumption and economic growth in 21 emerging countries over the period 1980/2018. Given the limited time series, panel data cointegration and an error correction model were used to infer causality using an ARDL showing the existence of a long-run equilibrium relationship between real income, renewable energy consumption, total fixed capital formation, and labor, with positive and statistically significant coefficients. Granger causality results indicate that there is a causal relationship between renewable energy consumption and economic growth in both the short and long run. This causality was found to vary significantly across countries. For our sample of emerging countries, it was found that there was a unidirectional relationship between renewable energy consumption and economic growth. This result implies that governments are encouraged to implement effective energy conservation policies.

Keywords:

Renewable energy consumption; economic growth; panel data; ARDL.

Introduction

According to the 2009 "World Energy Outlook" published by "The Energy Information Administration", renewable energy is the fastest growing energy source in the world with a 3% yearly increase in its consumption. The increasing attention paid to renewable energy sources can be attributed to several factors. For instance, the recent concerns about the volatility of oil prices, dependence on foreign energy sources, and environmental consequences of carbon emissions are factors that contribute to such interest. Moreover, the emergence of such policies as renewable energy tax credits, reduction on the renewable energy installation costs, renewable portfolio standards, and the establishment of markets for renewable energy certificates, has enhanced the promotion of renewable energy as a viable component of the energy portfolio for several countries (Bowden and Payne, 2010). As mentioned by Kaygusuz et al. (2007), Kaygusuz (2007), Ucan et al. (2014), Kula (2014), Alpera et al. (2016) and Destek (2016), the renewable energy target is not only to deal with the limitations associated with the current energy model and provide much required modernization of the energy sector, but also to encourage the objectives of sustainable development.

Several recent studies have investigated the causal relationship between renewable energy consumption and economic growth (Sadorsky, 2009a, b, 2011, 2012; Apergis and Payne, 2009b, c, 2012; Ucan et al., 2014; Kula, 2014; Alpera et al., 2016; Destek, 2016). In an analysis of the aggregate energy consumption measurement in Turkey over the 1969/1999 period, Sari and Soytas (2004) found that wasteful consumption accounts for 17.3% of the variation of the real GDP forecasting errors, 10.6% of the hydraulic power consumption, an overall 3.5% of the biomass (wood) consumption in terms of renewable energy sources, using a generalized variance decomposition of the forecasting errors. Applying the same approach as that of Sari and Soytas (2004) for the USA on monthly data over the 2001:1-2005:6 period, Ewing et al. (2007) found that, over a 25-month period, hydropower explains in total 1.9% of the variance of the industrial production forecasting errors; 3.8% of solar energy; 10.6% of wasteful energy; 6% of biomass energy (wood); 5.8% of the wind energy; and 2.4% of the total renewable energy consumption. According to Sari et al. (2008), the results show that the industrial production has a positive impact on employment but a negative effect on hydroelectric energy, waste and wind energy consumption. On the other hand, while industrial production has a negative impact on solar energy consumption, employment has a positive effect. Neither of them, however, has a statistically significant impact on wood energy consumption.

The relationship between renewable energy consumption and economic growth in newly industrialized countries for the period 1971 - 2011 has also been dealt with in the study of Destek (2016). The results reveal that negative shocks in renewable energy consumption cause positive shocks in real GDP for South Africa and Mexico, but they engender negative shocks in real GDP for India. In addition, the neutrality hypothesis is confirmed for Brazil and Malaysia.

Being aware of this situation, Tunisia has given special importance to the renewable energy sector development aiming at stimulating job creation and increasing the industrial added value. Therefore, the objective of this study is to extend this research trend to identify the extent to which renewable energy consumption affects economic growth in Tunisia. By referring to Ben Jeblia and Ben Youssef (2015), our aim is to examine this option within twenty-one emerging countries, including Tunisia, to find out the extent to which renewable energy consumption impacts economic growth. Because of the limited time series on renewable energy consumption, which reduces the power and size of the unit root and co-integration test properties, the unit root and co-integration approaches on Pedroni's panel data (2004) as well as other tests were used.

The unit root and co-integration tests should provide additional power by combining the cross-sectional data and those of the time series taking into account the heterogeneity between the countries. According to the studies of Bowden and Payne (2010), Apergis and Payne (2009a, 2012) and Ucan et al. (2014), the causal relationship between renewable energy consumption and economic growth are to be conducted within a multivariate framework through the incorporation of capital and work measures to deal with the issue of the biased variables omission.

The remaining of this work is structured as follows. In the second section, the data and the ARDL modeling methodology are presented. The results of this approach are revealed and discussed in the third section. The major conclusions of this research work are the subject of the last section.

1. Methodology: Data, integration tests and estimation methods

The 1980/2018 annual data were obtained from the World Bank development indicators, CD-ROM and the Administration of Energy Information about South Africa, Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Malaysia, Morocco, Mexico, Pakistan, Peru, the Philippines, Portugal, Thailand, Tunisia, Turkey and Venezuela. The multivariate structure includes real GDP (Y) at a constant price of $ 2000, gross fixed capital formation (K) at a constant price of $ 2000, and the labor force (L) in millions. Concerning the renewable energy consumption, as stated by "2009 The World Energy Outlook" published by "The Energy Information Administration", it is assumed to originate from hydroelectric and non-hydroelectric sources. For this reason, the renewable energy (*RE*) consumption is expressed in trillion kilowatt hours in this study. All the variables are used in Neperian logarithm.

Consequently, 819 observations were made with a number of periods (T = 39) exceeding those of the countries (N = 21). The panel data is a particularly valuable statistical source for the analysis of the economic agents' behavior. Currently, they provide rich microeconomic information that avoids temporal aggregation biases and help with the dynamic models estimation and the estimates in sections and in series comparison. These methods specific features require efficient econometric models because of measurement errors, estimation biases and aggregation, which should be taken into account (Arellano, 2003). The panel data regression differs from that of the time series or the individual data model in the way that it has a double value in these variables, where *i* is the individual and *t* is the period, i.e.:

$$y_{it} = \alpha_{it} + \beta^{'} X_{it} + \varepsilon_{it} \qquad \textbf{(1)}$$

where the error term can be specified as $\varepsilon_{it} = \nu_i + \vartheta_{it}$ where ν_i, which represents the unobservable individual specific and invariant effect over time, explains the specific effect not included in the regression. Although these requirements are not flexible, they have their merits in the coefficient common estimation and the improvement of the freedom degree with the potential decrease of the estimated coefficients standard errors. However, the new specifications help vary the constant and / or coefficients through individuals and / or periods.

The main problems of the unit root panel tests lie in the shape of the heterogeneity of the used model to test the unit root, defined as the simplest form which consists in postulating the existence of constants specific to each individual on the one hand, and the probability of the existence of any real correlation between individuals, on the other.

Whether these individual potential inter-dependencies are taken into account or not, has been a controversy opposing two groups of economists. The first group, including Levin, Lin and Chu, 2002 (LLC); Im, Pesaran and Shin, 2003 (IPS); Maddala and Wu, 1999; assume the lack of self correlation residues, because they consider them as nuisance factors. As for the second group that involves Bai and Ng, 2004; Moon and Perron, 2004 among others, they attempted to investigate this alternative because, for them, these co-movements can be used to conduct new tests. The LLC unit root and IPS panel tests on our panel data results are presented in Table 1.

As in the unit root tests, the first in panel co-integration tests (especially those of Pedroni, 2004), rule out not only the existence of any inter-individual co-integration relationship, but also the existence of any dependence between the individuals. Naturally, this inter dependence assumption is not much credible in many empirical applications.

At a 5% risk, the LLC and IPS tests show that the *y*, *k*, and *l* variables are not stationary in level and integrated of order 1, whereas the re variable is stationary in level. The tests reject the unit root null hypothesis, which is therefore integrated of order 0. On the other hand, all the variables are first difference stationary.

Tableau N°1: Unit root test in level and in first difference

		In level				In first difference			
		LLC		IPS		LLC		IPS	
Variables	r_max	Stat.	p-value	Stat.	p-value	Stat.	p-value	Stat.	p-value
y	3	-0.034	0.486	-0.317	0.375	-12.61[a]	0.000	-13.25[a]	0.000
k	2	-1.139	0.127	-2.385[a]	0.009	-12.69[a]	0.000	-12.29[a]	0.000
l	1	-3.291[a]	0.001	4.088	1.000	-7.947[a]	0.000	-9.075[a]	0.000
re	2	-4.557[a]	0.000	-4.731	0.000	-18.89[a]	0.000	-19.50[a]	0.000

Note: *r_max* represents the optimum number of lags where the statistics in the regression is significant, the unit root tests include a constant and a trend (a) which represent the significance at 1% level. y = Ln (Y); k = Ln (K); l = Ln (L); re = Ln (ER). Stat.: Statistics.

Relying on the panel unit root tests results, the heterogeneous panel data co-integration tests developed by Pedroni (2004) are designed to understand the idea of the co-integration null hypothesis absence for both homogeneous and heterogeneous panels. Pedroni's tests take into account the heterogeneity using parameters that may differ between individuals. Moreover, under the alternative hypothesis, there is a co-integration relationship for each individual whose parameters are not necessarily the same as each individual in the panel (Hurlin and Mignon, 2007). To better use these tests, it is necessary to first estimate the long-run relationship:

$$y_{it} = \alpha_i + \delta_i t + \beta_1 k_{it} + \beta_2 l_{it} + \beta_3 re_{it} + \varepsilon_{it} \qquad \textbf{(2)}$$

where $i = 1,...,N$ for each country in the panel and $\varepsilon_{it} = \rho_i \varepsilon_{it} + \omega_{it}$.

Taking into account such heterogeneity is an indisputable advantage since, in practice, seldom are the co-integration vectors identical for all the panel members. In this case, erroneously imposing a homogeneity of the co-integration vectors would result in a non rejection of the null hypothesis of no co-integration ($\rho_i = 1$) while the variables are co-integrated.

Tableau N°2: Pedroni's co-integration test results (2004)

Test	Values	P-values
Statistic panel υ (non parametric) : $Z_{\hat{\upsilon}}^{W}$	8.39	0.0005
Statistic panel ρ (non parametric) : $Z_{\hat{\rho}}^{W}$	-18.56	0.0015
Statistic panel t (non parametric) : Z_{t}^{W}	-6.56	0.0017
Statistic panel t (parametric) : Z_{t}^{*W}	-229.68	0.0000
Group ρ (non parametric) : $\tilde{Z}_{\hat{\rho}}^{B}$	-26.31	0.0000
Group t (non parametric) : $\tilde{Z}_{t}^{B}$	-7.55	0.0000
Group t (parametric) : $\tilde{Z}_{t}^{*B}$	-7.69	0.0000

$\hat{\varepsilon}_{it} = \rho_i \hat{\varepsilon}_{it} + \omega_{it}$. Pedroni proposed seven types of tests that can be classified into two categories, such that the (intra) "*Within*" dimension includes four types, while the (inter) "*Between*" dimension involves only three. These two categories of tests are based on the null hypothesis of the co-integration absence $\rho_i = 1 \ \forall \ i$ where ρ_i indicates the autoregressive term of the residues estimated under the alternative hypothesis $\hat{\varepsilon}_{it} = \rho_i \hat{\varepsilon}_{it} + \omega_{it}$.

According to Pedroni, the null hypothesis of co-integration absence can be accepted for a 95 percent significance threshold. Nevertheless, an exception should be made for the parametric statistics of the Z_t^{*W} panel, which shows a possible co-integration.

Just like the previous test, Kao's tests (1999) also rely on the null hypothesis of co-integration absence. Unlike Pedroni, Kao considers a particular case where the co-integration vectors are supposed to be homogenous between individuals. In other words, these tests do not take into account the heterogeneity under the alternative hypothesis and are actually valid only for a bivariate system (i.e. when a single regressor is present in the co-integration relationship). In fact, according to table 3, the tests approve of the co-integration null hypothesis, except for DF_ρ and DF_t which are based on the regressors strict exogeneity hypothesis.

Tableau N°3: Kao's (1999) cointegration test results

Statistics	DF_ρ	DF_t	DF_ρ^*	DF_t^*	ADF	*Lags*
Value	0.147	0.411	-5.429	-1.702	-1.547	1
P-value	0.442	0.341	0.000	0.044	0.061	

Since the variables proved the existence of a unit root based on the tests of LLC (2002) and IPS (2003), we opted for the use of Pesaran's et al. (2001) autoregressive distributed lag (ARDL) model on the panel data to assess the two-dimensional relationship between economic growth and renewable energy consumption. The ARDL model is the most widely used for the variables assessment in a time series context. Unlike Johansen's method (dynamic panel) which is the classic tool to identify long-run relationships and requires that all the variables be integrated of order one, the ARDL is an independent method from the integration order of the different variables.

The ARDL model provides a precise way to cope with the long-run relationships by focusing on a simple equation dynamics where the long-run relationships and the short-run dynamics are estimated together. Furthermore, it allows dealing with the variables that are possibly of a different integration order, particularly I(0) and I(1), and not simply I(1). By deriving Johanson's process, the ARDL cannot emphasize this obligation. All the variables are considered endogenous in the ARDL approach, hence the general formula of this model is written as follows:

$$y_{it} = \alpha_0 + \alpha_1 t + \sum_{j=1}^{p} \lambda_j y_{it-j} + \sum_{m=0}^{q} \delta_k' x_{it-m} + u_{it} \quad \textbf{(3)}$$

where x is the regressors set, assumed to be uncorrelated with the u residue. An equivalent specification might often be found:

$$\Delta y_{it} = \alpha_0 + \alpha_1 t + \phi_i y_{it-1} + \beta_i' x_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{i,t-j} + \sum_{m=0}^{q-1} \delta_{im}^{*'} x_{i,t-m} + u_{it} \quad \textbf{(4)}$$

Separating the equation y from the other x components, with the corresponding partition of the other matrices, the equation Δy can be written in the form of an error correction model, ECM:

$$\Delta y_{it} = \alpha_0 + \alpha_1 t + \pi_{yy} y_{it-1} + \pi_{yx} x_{it} + \sum_{j=1}^{p-1} \Gamma_j \Delta Z_{t-j} + \varepsilon_{it} \quad \textbf{(5)}$$

with $\Pi = \begin{pmatrix} \pi_{yy} & \pi_{yx} \\ \pi_{xy} & \Pi_{xx} \end{pmatrix}$ the variance covariance matrix of $\varepsilon_t = (\varepsilon_{yt}\ \varepsilon_{xt}')$ and $Z_t = (y_t\ x_t')$. If $\phi = \pi_{yy}$

and $\beta = \pi_{yx.x}$ after having redefined the polynomial lag in Z in order so as to get the contemporary value of x in the equal part, which leads to Pesaran's ARDL approach equation:

$$\Delta y_{it} = \alpha_0 + \alpha_1 t + \pi_{yy} y_{it-1} + \pi_{yx.x} x_{it-1} + \sum_{j=1}^{p-1} \widetilde{\psi}_j^{'} \Delta Z_{it-j} + \omega^{'} \Delta x_{it} + \varepsilon_{it} \qquad \textbf{(6)}$$

where $\pi_{yx.x} = \pi_{yx} - \omega^{'} \Pi_{xx}$ (1 x m matrix) ; $\omega = \Omega_{xx}^{-1} \omega_{xy}$, $\Omega = \begin{pmatrix} \omega_{yy} & \omega_{yx} \\ \omega_{xy} & \Omega_{xx} \end{pmatrix}$ the variance covariance matrix of ε_t and $u_t = \varepsilon_{yt} - \omega_{yx} \Omega_{xx}^{-1} \varepsilon_{xt}$.

It is worth mentioning that the ARDL model is introduced to ensure that all the Z components are I(1) as required by the VECM specifications. If $\phi \neq 0$, Π reduces the rank to $r+1$ ($r \leq m$, the variables number in Z), the long-run relationship can be written as follows, with y_t as an endogenous variable:

$$y_{it} = \theta_0 + \theta_1 t - \frac{\beta_i^{'}}{\phi_i} x_{it} + v_{it} \qquad \textbf{(7)}$$

If $\theta = -\beta/\phi$, the long-run relationship is non-degenerate, and if $\beta = 0$, the long-run conditional vector parameters on x is non null (or equivalent).

In our case, to test the renewable energy consumption (*re*) impact on economic growth (*y*), the general form of the ARDL model is represented as follows:

$$\begin{aligned} \Delta y_{it} &= \alpha_0 + \alpha_1 t + \delta_0 y_{it-1} + \delta_1 x_{1it-1} + \delta_2 x_{2it-1} + \delta_3 x_{3it-1} \\ &+ \sum_{r=1}^{p} \lambda_i \Delta y_{it-r} + \sum_{j=0}^{q_1} \beta_j \Delta x_{1i,t-j} + \sum_{m=0}^{q_2} \gamma_m \Delta x_{2i,t-m} \sum_{s=0}^{q_3} \varphi_s \Delta x_{3i,t-s} + \zeta_{it} \end{aligned} \qquad \textbf{(8)}$$

We first briefly present a discussion of the ARDL co-integration approach through the implementation of two steps to make it very efficient in the co-integration procedure. Therefore, it is important to test the existence of a long-run relationship between the variables of the system. Consequently, the null hypothesis of having neither integration nor a long run relationship between the variables $H_0 : \delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$ is tested against the alternative hypothesis $H_1 : \delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq 0$. The "Bounds tests" procedure is based on Fishers statistics "F". This statistics used for this procedure has a non standard distribution because the variables in the system are I(0) or I(1). Therefore, two sets of critical values are calculated by Pesaran et al. (2001, p.300), for a given level of significance. The first set assumes that all the variables are I(0) while the second assumes that they are all I(1). If the calculated "F" statistics exceeds the upper bound of the critical values, then, H_0 is rejected. Moreover, if the calculated "F" statistics falls between two landmarks, then, nothing can be concluded for this test. However, if the calculated "F" statistics is below the lower limit of the critical values, it implies no co-integration relationship.

The second stage assumes an established long-run relationship, then, the long-run estimates of the errors correction model (ECM) and the ARDL model can be obtained from equation (8). The ARDL model estimation is supposed, first of all, to identify the number of lags to be introduced. The Akaike (AIC) and Schwarz (SBC) information criteria are often used. A general representation of equation (8) ECM is formulated as follows:

$$\Delta y_{it} = \alpha_0 + \alpha_1 t + \delta\, EC_{it-1} + \sum_{r=1}^{p} \lambda_i \Delta y_{it-r} + \sum_{j=0}^{q_1} \beta_j\, \Delta x_{1it-j} + \sum_{m=0}^{q_2} \gamma_m\, \Delta x_{2it-m} \sum_{s=0}^{q_3} \varphi_s\, \Delta x_{3it-s} + \zeta_{it} \qquad \textbf{(9)}$$

where δ is the adjustment parameter speed and EC the obtained residues from the estimation of the co-integration model of equation (8). Since the used observations are annual, up to 3 lags were tested on the first difference of each variable, and then, the F statistics was calculated for the joint significance of the levels of the variables lags in equation (8). The long-run conditional model, which can be obtained from the solution of the reduced form of (8), can be written as follows:

$$y_{it} = \theta_0 + \theta_1 x_{1it} + \theta_2 x_{2it} + \theta_{3it} x_{3it} + \mu_{it} \qquad \textbf{(10)}$$

with $\theta_0 = -\frac{\alpha_0}{\delta_0}$, $\theta_1 = -\frac{\delta_1}{\delta_0}$, $\theta_2 = -\frac{\delta_2}{\delta_0}$ and $\theta_3 = -\frac{\delta_3}{\delta_0}$.

The same procedure would be applied if we handled it the other way round, i.e. the impact of economic growth on renewable energy consumption.

2. Estimations and interpretations

The calculated F statistics for each lag order are given in table 5 for the endogenous variable *y*. This table shows that all the F statistics are significant at 99% at least. Therefore, these results show that the null hypothesis of the lack of a long-run relationship is strongly rejected. As a result, it is clear that there is a long-run relationship between the variables in the model. Therefore, we can move on to the next step of the analysis where a maximum number of lags equal to p = 1 is chosen.

Tableau N°4: F-statistics of the renewable energy consumption long-run effect on economic growth

Order of lags	Without trend		With trend	
	F Statistics	p-values	F Statistics	p-values
1	**$F(4,555) = 24.78^{***}$**	**0.000**	$F(4,554) = 24.71^{***}$	0.000
2	$F(4,530) = 15.27^{***}$	0.000	$F(4,529) = 15.24^{***}$	0.000
3	$F(4,505) = 10.77^{***}$	0.000	$F(4,504) = 10.75^{***}$	0.000

Note: The critical values are obtained from the CI (*iii*) table, case III (unrestricted intercept and no trend; with three explanatory variables m = 3) in Pesaran et al. (2001, p.300). There are 2.72 - 3.77 at 90% level, 3.23 - 4.35 at 95% level, and 4.29 - 5.61 at 99% level. *** indicates that the F-statistics is above the upper bound at 99%.

To find out the optimal order of the long-run variables levels, we chose two criteria, the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC). In table 6, the results of these criteria are presented as $(p;q_1;q_2;q_3)$ for the different ARDL models. In fact, 16 possible combinations were achieved to find out the appropriate model. A close examination of table 6 shows that the most appropriate model is represented by an ARDL (1;0;0;0). Table 7 presents the results of the short-run estimation of the ARDL model (1;0;0;0). These results show that, in the short-run, all the variables are statistically significant at 1%. Renewable energy shows, in particular, a positive and significant effect on economic growth.

Tableau N°5: Choice of the ARDL$(p;q_1;q_2;q_3)$ model

Criterion /Models	(1;0;0;0)	(1;0;0;1)	(1;1;1;1)
AIC	**-7.423**	-7.419	-7.421
SIC	**-7.354**	-7.343	-7.331

In order to achieve the stability test on the preferred representation of the error correction model of the ARDL approach, the ECM-ARDL represented by equation (9) is also represented in table 7. The results indicate that the error correction term is statistically significant and negative, which proves that there is a co-integration relationship between the variables in the model. More precisely, the estimated value of EC_{t-1} is -0.191 implying that the long-run balance adjustment speed as a response to the imbalance caused by the short-run shocks of the previous period is 19.1%.

Tableau N°6: Short-run estimation results of the renewable energy effect on economic growth

Variables	ARDL(1;0;0;0)	ECM-ARDL(1;0;0;0)
Constant	0.134^{***}	0.021^{***}
$y_{i,t-1}$	-0.036^{***}	-
$x_{1i,t-1}$	0.028^{***}	-
$x_{2i,t-1}$	0.006^{***}	-
$x_{3i,t-1}$	0.002^{*}	-
$\Delta y_{i,t-1}$	0.085^{***}	0.291^{***}
$\Delta x_{1i,t}$	0.194^{***}	0.188^{***}
$\Delta x_{2i,t}$	-0.071	-0.051
$\Delta x_{3i,t}$	0.011^{***}	0.014^{***}
$EC_{i,t-1}$	-	-0.191^{***}

Note: *, **, *** Significance at 10%, 5%, 1%.

The long-run results show that the renewable energy coefficient is significant and has a good positive sign as expected. This means that there is a long-run positive relationship between the renewable energy consumption increase and economic growth in this sample of 21 emerging countries. This relationship can be written as follows:

$$\underset{(t\_stat.)}{Ln\,\hat{Y}_{it}} = \underset{(0.00)}{3.76} + \underset{(15.4)}{0.81}\,Ln\,K_{it} + \underset{(3.65)}{0.16}\,Ln\,L_{it} + \underset{(2.12)}{0.05}\,Ln\,RE_{it}$$

Taking the example of Tunisia particularly and referring to the above long-run equation, renewable energy seems to be an indicator of effective growth which helps reduce high production costs.

Let us check now the other way round. One may wonder whether economic growth may cause renewable energy consumption. Using the above described approach, the ARDL approach was applied by replacing the position of the $x_{3,it}$ variable in equation (8) with that of y_{it}. Thus, we started by estimating the existence of a long-run relationship between the considered variables knowing that the variable $x_3 = Ln\ RE$ plays the endogenous variable role in the model. The calculated F-statistics for each order of lags are given in Table 8.

Tableau N°7: F statistics of the economic growth long-run effect on renewable energy consumption

Order of lags	Without trend		With trend	
	F-statistics	p-values	F-statistics	p-values
1	F(4,555) = 1.27	0.281	F(4,554) = 1.25	0.290
2	F(4,530) = 1.12	0.348	F(4,529) = 1.10	0.356
3	F(4,505) = 1.40	0.232	F(4,504) = 1.40	0.234

Table 7 indicates that all the F statistics are not significant even at the 90% level. Therefore, these results show that the null hypothesis of the lack of long-run relationship cannot be rejected. It is clear, then, that there is no long-run relationship between the variables in the model and that we cannot proceed to the next step of the analysis.

Following the co-integration test results and those of the ARDL model, a Vector Error Correction Model (VECM) in panel was estimated to test Engle and Granger (1987) causality and check the previous results. Therefore, a two-step procedure was adopted by estimating first of all the long-term model to get the residues.

$$Ln\,Y_{it} = \alpha_{it} + \delta_i t + \beta_K\,Ln\,K_{it} + \beta_L\,Ln\,L_{it} + \beta_E\,Ln\,ER_{it} + \varepsilon_{it} \quad \textbf{(11)}$$

The lagged value of these residues was introduced as an error correction term of the VECM. The following error correction dynamic model was estimated:

$$\begin{cases} \Delta Ln\,Y_{it} = \alpha_{iY} + \sum_{j=1}^{q}\theta_{11ij}\Delta Ln\,Y_{i,t-j} + \sum_{j=1}^{q}\theta_{12ij}\Delta Ln\,K_{i,t-j} + \sum_{j=1}^{q}\theta_{13ij}\Delta Ln\,L_{i,t-j}\sum_{j=1}^{q}\theta_{14ij}\Delta Ln\,ER_{i,t-j} + \lambda_{1i}\varepsilon_{it} + u_{1i,t} \\ \Delta Ln\,K_{it} = \alpha_{iK} + \sum_{j=1}^{q}\theta_{21ij}\Delta Ln\,Y_{i,t-j} + \sum_{j=1}^{q}\theta_{22ij}\Delta Ln\,K_{i,t-j} + \sum_{j=1}^{q}\theta_{23ij}\Delta Ln\,L_{i,t-j}\sum_{j=1}^{q}\theta_{24ij}\Delta Ln\,ER_{i,t-j} + \lambda_{2i}\varepsilon_{it} + u_{2i,t} \\ \Delta Ln\,L_{it} = \alpha_{iL} + \sum_{j=1}^{q}\theta_{31ij}\Delta Ln\,Y_{i,t-j} + \sum_{j=1}^{q}\theta_{32ij}\Delta Ln\,K_{i,t-j} + \sum_{j=1}^{q}\theta_{33ij}\Delta Ln\,L_{i,t-j}\sum_{j=1}^{q}\theta_{34ij}\Delta Ln\,ER_{i,t-j} + \lambda_{3i}\varepsilon_{it} + u_{3i,t} \\ \Delta Ln\,ER_{it} = \alpha_{iER} + \sum_{j=1}^{q}\theta_{41ij}\Delta Ln\,Y_{i,t-j} + \sum_{j=1}^{q}\theta_{42ij}\Delta Ln\,K_{i,t-j} + \sum_{j=1}^{q}\theta_{43ij}\Delta Ln\,L_{i,t-j}\sum_{j=1}^{q}\theta_{44ij}\Delta Ln\,ER_{i,t-j} + \lambda_{4i}\varepsilon_{it} + u_{4i,t} \end{cases} \quad \textbf{(12)}$$

where q is the number of lags that can be determined by the two-step procedure suggested by Abdalla and Murinde (1997). According to these authors, it is the optimal number of lags that maximizes the R-squared value, with u as the error term.

Tableau N°8: The panel Granger causality test

Dependent variable	*ΔLn Y*	*ΔLn K*	*ΔLn L*	*ΔLn RE*	SIC	Lag	Adjusted R^2	ECT
ΔLn Y	0.499^{***}	-0.042^{***}	0.206^{*}	**-0.008^{**}**	-6.435	1	0.156	-0.003
ΔLn K	1.512^{***}	-0.130	-0.282	-0.017	-3.769	2	0.132	**-0.168^{***}**
ΔLn L	-0.006	-0.002	0.735^{***}	0.007^{*}	-8.838	3	0.361	$-0.7\ e^{-4}$
ΔLn RE	**0.194**	-0.019	-0.502	-0.196^{***}	-2.69	1	0.042	**-0.018^{*}**

Note: *, **, *** Significance at 10%, 5%, and 1%. ECT: Error correction term, SBC: Schwarz Bayesian Criterion.

According to the results in the Granger sense reported in table 8, there is a short-run one-way causality between the GDP growth and renewable energy consumption (*RE* causes *Y*). On the other hand, there is no causality between renewable energy consumption, GDP growth and the factors of the capital and labor production.

Over the long run, for the country-specific results, renewable energy consumption was found to have a positive and significant impact on the national income in all the studied countries. A 1% increase in renewable energy consumption causes 0.1% rise in the income according to the VECM results.

Furthermore, the GDP has a positive and significant impact on renewable energy consumption, which negatively and significantly affects the capital. As a result, the long-run neutrality hypothesis between the variables for all the countries is not valid. The more these countries depend on new sources of energy, the more they are impacted, which helps improve the business conditions.

Tableau N°9: Long-run relationship

Dependent variable	*Ln Y*	*Ln K*	*Ln L*	*Ln RE*	Constant	Trend	Adjusted R^2
Ln Y	-	0.841^{***}	-0.059^{***}	0.100^{***}	5.339^{***}	0.001	0.938
Ln K	0.921^{***}	-	0.151^{***}	-0.052^{***}	-1.631^{***}	0.004^{***}	0.939
Ln L	-0.564^{***}	1.328^{***}	-	0.181^{***}	-1.969^{*}	-0.018^{***}	0.665
Ln RE	2.117^{***}	-1.008^{***}	0.397^{***}	-	-27.02^{***}	-0.008	0.641

Note: *, **, *** Significance at 10%, 5%, and 1%.

In short, it is clearly noticeable (table 9) that there is a dependency relationship between renewable energy consumption and production factors in all the countries, especially, in Tunisia which is planning to implement innovative funding tools. For this purpose, some suggestions were made for the establishment of funding mechanisms devoted to energy efficiency founded on the National Energy Savings Fund.

Furthermore, the 11th Plan has seriously promoted fair energy prices in its main objectives. Despite the difficulty of applying this objective owing to the involved social and economic issues, its achievement will probably be a decisive factor for the success of the energy management policy.

Conclusion

The countries' growth dependency on fossil fuels due to a weak energy infrastructure and a lack of development of some initiatives in this field has urged a lot of researchers to study in depth new alternatives such as the renewable sources of energy and their general impact on the economy.

In this context our study achieved some relatively interesting results. In fact and over the short-run, the panel co-integration estimates show that there is a unidirectional causality between renewable energy consumption and GDP growth for the whole panel. In fact, the increase of renewable energy consumption has a positive and statistically significant impact on the real income. However, there is no causality between the capital and renewable energy consumption.

Our results also proved that, in the long run, a 1% increase of renewable energy consumption has resulted in a 4.9% rise of the real income for the selected emerging economies. Then, the study moved to emphasize the complementarity relationship between renewable energy consumption and production factors over the short and long runs.

On the basis of these results, some economic policy recommendations can be formulated. The global concerns related to the issue of energy access and security and the climate changes make Africa and Europe's energy future, in particular, more and more interdependent. Therefore, the authorities are urged to promote policies that target the promotion of the renewable sources of energy. This can not be achieved without a serious encouragement of an adequate Foreign Direct Investment policy in the field. Besides, energy infrastructure and the difficult access to electricity and to transport fuels have to be taken into account as they are a major obstacle to a sustainable development in Africa, in particular. Such an objective would be of great interest to be studied theoretically and empirically in a future potential perspective.

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