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The Significance of Sustainability and Renewable Energy Development in Five North African Countries

Salaheddine Sari-Hassoun [1 *], Hacen Kahwi [2]
[1] University Centre of Maghnia, LEPESSE Laboratory, Algeria
[2] University of Tlemcen, Algeria

أهمية الاستدامة وتنمية الطاقة المتجددة في خمس دول في شمال أفريقيا

د. صلاح الدين صاري حسون[1*]، حسن قهوي[2]
[1] المعهد العلوم الاقتصادية، التسيير والعلوم التجارية، المركز الجامعي مغنية (ولاية تلمسان)، الجزائر
[2] المعهد العلوم الاقتصادية، التسيير والعلوم التجارية، جامعة تلمسان، المدينة، الجزائر

[*]Corresponding author: salah.poldeva08@gmail.com

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Abstract:
In the past ten years, there has been significant progress in two well-known economic concepts: sustainable development and renewable energy. Currently, developing nations are attempting to implement the Sustainable Development Goals by establishing their economies and infrastructure. This article investigates the relationship between adjusted net savings, renewable energy consumption, gross domestic product, and labour force in five North African countries from 2000 to 2022. We demonstrate a positive and significant relationship between REC and ANS, as well as GDP and ANS. On the other hand, LF has a negative and significant effect on ANS. According to this, these countries are ready to invest in RE and create new value-added based on innovative systems, with an emphasis on economic growth and the growth of the primary economic sectors.

Keywords: Sustainable Development, Renewable Energy, Developing Nations, Economic Growth.

الملخص
في السنوات العشر الماضية، أحرز تقدم كبير في مفهومين اقتصاديين معروفين بالتنمية المستدامة والطاقة المتجددة، حيث تحاول الدول النامية تنفيذ أهداف التنمية المستدامة من خلال إنشاء اقتصاداتها وهياكلها الأساسية. في هذه الورقة سوف ندرس العلاقة بين صافي الادخار المعدل (ANS) ، استهلاك الطاقة المتجددة (REC) ، والناتج المحلي الإجمالي(GDP) ، والقوى العاملة (LF) في خمس دول في شمال إفريقيا من عام 2000 إلى عام 2022. أظهرت النتائج بأن هناك علاقة إيجابية ومعنوية بين REC وANS، وكذلك بين GDP و ANS. من ناحية أخرى، فإن LF له تأثير سلبي و معنوي علىANS ووفقاً لذلك، فإن هذه البلدان مستعدة للاستثمار في الطاقات المتجددة وإيجاد قيمة مضافة جديدة تستند إلى نظم مبتكرة، مع التركيز على النمو الاقتصادي ونمو القطاعات الاقتصادية الأولية.

الكلمات المفتاحية: التنمية المستدامة، الطاقة المتجددة، الدول النامية، النمو الاقتصادي.

Introduction
The importance of sustainable development (SD) and renewable energy (RE) is widely acknowledged in research due to their strong correlation with environmental impact, GHG and CO_2 emissions (reducing air and water pollution and mitigating climate change), maintaining energy supply over the long term and safeguarding natural resources for next generations (Sari Hassoun and Ayad, 2020). Energy security, lowering reliance on finite fossil fuels, diversifying energy sources, and boosting national energy independence, particularly in MENA countries,

can all be examined through the economic analysis of RE Sari-Hassoun et al. (2024). It can also demonstrate the path towards generating new employment opportunities in the green energy sector, promoting technological innovation in energy storage and distribution, enhancing energy efficiency technologies, supplying energy to remote areas, generating income in rural areas, improving the stability and flexibility of the energy system, and lessening the susceptibility to supply disruptions (Chica-Olmo et al., 2020).

Due to its close relationship to GDP, RE, and climate change, SD is currently the subject of a lot of attention. SD is the optimal use of resources to meet current needs without endangering those of the future (Güney, 2019). To guarantee that all people have access to a just, dependable, sustainable, and contemporary energy system, the seventh goal (SDG-7) acknowledges that using RE technology is a suitable means of achieving this objective without depriving future generations of resources. Therefore, several countries have sought to develop RE technology and establish local electrification systems in order to ensure a stable energy transition and to enhance environmental safety. People are also utilising RE technology more and more in order to improve access to energy and meet the growing demand for energy in a sustainable way (Islam et al., 2022). Furthermore, as shown by Sari-Hassoun et al. (2024), less developed regions are expected to surpass more developed regions because they require less initial capital and may have easier access to new technologies (RE technology). in the same vein, developing countries can boost them RE portfolios with solar panels, wind turbines, and other environmentally friendly technologies. As a result, they can put the newest and most efficient RE technologies into practice, which could open the door for decarbonisation technologies.

This study presents ANS as a more appropriate SD variable focused on the overall well-being of the population, in contrast to earlier research that used GDP. If the adoption of environmentally friendly technologies for EC can lead to savings for individuals and regions, then it is reasonable to refer to the outcome as "SD". Therefore, based on the ideas of extended national accounts, several academics (Hamilton, 1994; Hamilton and Clemens, 1999; Pezzey, 2004; Gnégné, 2009; Pezzey and Burke, 2014; Boos, 2015; Dupuy, et al., 2017; Sari Hassoun and Ayad, 2020 and Pezzey 2024) introduce the variable of ANS, also known as genuine saving informally, as a good index to quantify the SD in nations.

We chose five North African nations for our study because they each have a number of unique qualities that set them apart in the context of sustainability and renewable energy research. Lengthy Mediterranean coastline: ideal for wind energy and marine sustainability projects; vast Sahara Desert: enormous solar energy potential; Egypt's Nile River basin: essential for hydropower and water management. In addition, the region boasts one of the best solar radiation levels in the world due to its high solar irradiance and strong, reliable wind patterns in coastal areas. Their energy landscape, which consists of a mix of importers (Morocco, Tunisia) and exporters (Algeria, Libya) and rapidly increasing energy demand as a result of economic development and population growth.

Literature review

This study is a facet of "the green growth," one of the most innovative economic theories. It asserts that economic development and growth can go on as long as the natural environment continues to provide ecosystem services or as long as related negative environmental effects, such as climate change, are lessened. This decoupling occurs (Jacobs, 2013). Additionally, Schumacher (1973) introduced the natural capital theory. Then, the ecological economics theory, which Georgescu-Roegen and his student Daly initially created in 1971 (Schlegel et al., 1973). The majority of empirical research substitutes EG for SD, and there are relatively few that look at how RE and GDP affect ANS, particularly when using a spatial model. Güney (2019) studies during the period of 1990 to 2014, the effect of RE on ANS for 73 underdeveloped and 40 developed nations. He finds that RE has a positive and significant impact on SD in developing and developed economies. Sari Hassoun and Ayad (2020) examine the relationship between RE and ANS for 17 OECD countries between 1990 and 2017 using a panel random effect model and a panel ARDL cointegration model. The results demonstrated that while the REC has a short-term negative and significant impact on the ANS, it has a long-term positive influence on the ANS. Additionally, bidirectional granger causality between the two variables was established. Güney and Kantar (2020) find that RE (biomass) has a positive contribution on ANS in OECD countries covering the period of 1990–2015. Güney (2021) finds that RE and GDP contribute positively and significantly to increase the level of ANS in OECD nations during the period of 1990–2015, while Güney (2022) uses FMOLS and DOLS to analyse the contribution of RE and GDP on ANS in OECD nations during the period of 1990–2015. They find that RE and GDP have a positive and significant impact on ANS. Islam et al. (2022) employ FMOLS, DOLS, and CCR to examine the influence of RE on ANS in ASEAN countries from 1980 to 2018. They find that RE positively influence ANS. Noor et al. (2023) discovered that between 1995 and 2019 and using an ARDL panel, RE impact positively ANS on five South Asian nations. Ahmad et al. (2023) conclude with DOLS that during the years 2000–2015, in 76 chosen countries, RE and GDP had a positive impact on ANS. Zhu et al. (2024) employ MMQR and BSQR to examine how 23 Sub-Saharan African (SSA) nations will fare between 2000 and 2022 in terms of sustainability when it comes to RE. They conclude that SD is negatively impacted by both fintech and RE separately, but, rents with Fintech and RE have a significantly positive combined impact, suggesting that SSA countries may benefit from the well-managed resources through the use of Fintech and RE.

Data and methodology

Data

This paper used annual data for four main variables. ANS, REC, GDP and LF. The annual statistics collected from 5 Nord-Africa nations from 2000 to 2022 are used to generate a balanced panel for the study (Algeria, Egypt, Morocco, Tunisia, and Libya). The corresponding source and measures are displayed in Table 1.

Table 1. Variables description

Variables	Unit	Sources
Adjusted net savings (ANS)	Current US$	WDI
Renewable-Energy Consumption (REC)	Gigajoule	BP
Gross Domestic product (GDP)	Current US$	WDI
Rate of labour force (LF)	Share of total population (%)	UNPD

This research, in contrast to earlier studies, makes use of ANS, which includes particulate emission damage as an SD indicator or sustainability from WB (2024). WB defines ANS as the total of education expenses plus net national savings less the net loss of energy, minerals, forests, and CO2 emission-related particulates. Since the ANS is determined as a percentage of GNI, a high level of sustainability is correlated with a high ANS percentage; on the other hand, a very low or negative percentage indicates that the country is "unsustainable" or has a weak level of sustainability. A more comprehensive view of a country's prosperity and sustainability can be obtained with ANS, which goes beyond traditional economic measures like GDP.

The acronym REC from BP (2024) stands for total energy consumption from renewable sources. Hydroelectric power, solid biofuels, wind, solar, liquid biofuels and biogas, geothermal sources, marine energy, and waste-derived energy are all included in this category.

GDP, which is expressed in consumer prices, indicates the rate of economic growth from WB (2024). The process for calculation involves adding up the gross value added from all domestic producers in the economy, adding any taxes associated with the product, and deducting any subsidies that are not part of the product's cost. Natural asset attenuation and degradation as well as artificial asset depreciation are not included in this computation.

The third exogenous variable is called the labour force (LF), or the currently active population, which is defined as all people who meet the requirements to be classified as either employed (including those in the armed forces) or unemployed. (United Nations Population Division, 2024)

3.2. Methodology

To investigate the effects of REC, EG, and LF on the sustainability term (ANS), the following model is employed and is derived from the neoclassical growth theories of Solow (1956) and Swan (1956). These theories predict a convergence based on the idea that capital accumulation and technological advancements like RE technology drive the EG.

$$lnANS_{it} = a_0 + a_1 lnREC_{i\,t} + a_2 lnGDP_{i\,t} + a_3 lnLF_{i\,t} + v_{it} \quad (1)$$

Where a_0 is the intercept, while a_1, a_2 and $\boldsymbol{a_3}$ are the coefficients of the REC, GDP, and LF, respectively, $\boldsymbol{v_{it}}$ is the error term.

This paper conducts analyses within the scope of the study using panel econometrics examination. First, we study the statistical descriptive and the homogeneity of data between countries known as cross sectional dependence test with Breusch-Pagan (1980) with LM statistic, Pesaran (2004) with scaled LM statistic, Pesaran (2004) CD and Baltagi, Feng, and Kao (2012) with bias-corrected scaled LM. Then, since the first-generation panel unit root test of Maddala and Wu (1999) requires no cross-sectional dependence, we will perform an appropriate panel unit root test based on prior findings. The second-generation panel unit root test, on the other hand, is represented by the Pesaran (2007) CIPS test and requires cross-sectional dependence. After confirming the order of integration of each variable, we move to the panel cointegration test of and panel-dynamic ordinary least-squares estimation of Pedroni (1999, 2004) and Kao (1999). Whether or not the variables are first integrated and cointegrated, the final step is to employ an appropriate estimation. We can create a suitable model for a cointegration relationship if one exists. Examples of such models include canonical cointegration regression (CCR), dynamic ordinary least squares (DOLS), and fully modified ordinary least squares (FMOLS). Based on semi-parametric correction, FMOLS was proposed by Phillips and Hansen (1990) and is advised as a procedure for I(1) co-integrated series (Shaari et al., 2016). The second method, called CCR and created by Park (1992), is closely associated with FMOLS. The final one is DOLS, which Stock and Watson (1993) presented. By removing the correlation between the regressors, this method performs better than FMOLS and CCR (Kao and Chiang, 2001).

Empirical findings

Cross section dependence test

We test the residual from pooled OLS and the cross-sectional dependence of each variable. We see from table 2 that we cannot reject the alternative hypothesis of existence of cross-sectional dependence of residual and the error is homogenously distributed across nations indicated that there is a correlation between error terms across various cross-sectional units in 5 Nord Africa nations, after taking into consideration the effects of explanatory variables.

Table 2. Residual cross-section dependence test:

Test	Statistic	d.f	Prob.
Breusch-Pagan LM	42.999***	10	0.000
Pesaran scaled LM	7.379***		0.000
Pesaran CD	4.9873***		0.000

Note: “***”, ‘**’, ‘*’ refer to the confidence interval at 99%,95%, and 90%.

Table 3 demonstrates that every variable—aside from REC—has a significant p-value. As can be seen, all variables' probability values fall below the 0.05% threshold, with the exception of REC. The results strong refute the null hypothesis, which states that there is "no cross-sectional dependence." This result demonstrates that these five nations not only have neighbouring effects and a spillover effect, but also have similar socioeconomic statuses. Thus, the economic situation may be impacted if a sudden shock occurs in one nation.

Table 3. Cross-sectional dependence test

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
	Statistic (Prob)	Statistic (Prob)	Statistic (Prob)	Statistic (Prob)
ANS	23.395*** (0.009)	2.995*** (0.003)	2.881*** (0.004)	2.509** (0.012)
REC	11.571 (0.315)	0.351 (0.725)	0.238 (0.812)	0.790 (0.43)
GDP	121.539*** (0.000)	24.941*** (0.000)	24.827*** (0.000)	10.704*** (0.000)
LF	55.072*** (0.000)	10.078*** (0.000)	9.965*** (0.000)	6.215*** (0.000)

Note: “***”, ‘**’, ‘*’ refer to the confidence interval at 99%,95%, and 90%.

Panel unit root tests result

The cross-section dependence test indicates that the only variable we have is REC, which is unevenly distributed among the countries of Nord Africa. Therefore, in this instance, we will move on to the Maddala and Wu (1999) test, which is the first-generation panel stationarity test. But after establishing the cross-sectional dependence of ANS, GDP, and LF among the different countries or areas. This brings us to the second-generation panel stationarity test, which takes this situation into account. The Maddala and Wu unit roots for REC are shown in the following table, while the Pesaran panel CSD unity root is shown for the remaining variables.

Table 4. Panel unit root test

	without trend	with trend	
	Zt-bar statistic (p-value)	Zt-bar statistic (p-value)	
ANS	1.097 (0.864)	1.848 (0.968)	I(1)
DANS	-2.117***	-4.192***	

	(0.017)	(0.000)	
REC	15.646 (0.110)	12.514 (0.252)	I(1)
D_REC	34.406*** (0.000)	34.952*** (0.000)	
GDP	2.537 (0.994)	1.738 (0.959)	I(1)
D_GDP	-1.834** (0.033)	-3.427*** (0.000)	
LF	0.223 (0.588)	0.969 (0.834)	I(1)
D_LF	-3.563*** (0.000)	-1.378* (0.084)	

Note: "***", '**', and '*' refer to the confidence interval at 99%,95%, and 90%.

Table 4's results demonstrate that every variable is stationary at the first difference—that is, the first integrated I(1). Put differently, some variables exhibit robust stochastic patterns while others show little or no evidence of such patterns. The findings provide a crucial conclusion for choosing the most effective approach to investigate cointegration relationships. Consequently, a primary focus of our study is the panel cointegration evaluation, which allows for a variable order of integration, especially in cases where the dependent variable exhibits non-stationarity. Generally speaking, though, the FMOLS, DOLS, and CCR yield the most accurate findings.

Cointegration Test

Based on findings from cross-section dependency and unit root analysis, we now investigate whether there is a long-term relationship between the relevant variables. The results of the Pedroni and Kao test are shown in the following tables:

Table 5. Pedroni and Kao panel cointegration.

Pedroni test		
With Trend and Intercept		
	Statistic (Prob)	Statistic (Prob)
Panel v-Statistic	0.374 (0.3542)	0.519 (0.302)
Panel rho-Statistic	0.615 (0.7306)	0.827 (0.796)
Panel PP-Statistic	-4.013*** (0.000)	-2.448*** (0.007)
Panel ADF-Statistic	-3.479*** (0.000)	-2.474*** (0.007)
	Statistics (Prob)	
Group rho-Statistic	1.630 (0.9484)	
Group PP-Statistic	-3.634*** (0.000)	
Group ADF-Statistic	-2.435*** (0.007)	
With Intercept only		
	Statistic (Prob)	Statistic (Prob)
Panel v-Statistic	-0.913 (0.819)	0.172 (0.432)
Panel rho-Statistic	-1.0853 (0.139)	-1.093 (0.137)
Panel PP-Statistic	-2.882*** (0.002)	-3.100*** (0.001)
Panel ADF-Statistic	-2.561*** (0.005)	-3.072*** (0.001)
	Statistic (Prob)	
Group rho-Statistic	-0.053 (0.479)	

Group PP-Statistic	-4.337*** (0.000)
Group ADF-Statistic	-3.441*** (0.000)
Kao test	
ADF	t-Statistic (Prob)
	-2.917***(0.002)

Note: "***", '**', '*' refer to the confidence interval at 99%,95%, and 90%.

The results of Table 5 show that, in a model with trend and intercept term, there is a long-term association between the variables. These results also demonstrate the cointegration of the independent variables and the exogenous variables, which results in strong cross-country cointegration relationships between the variables. We can now focus on the FMOLS, DOLS, and CCR models since cointegration has been proven.

Long run estimation and discussion

Numerous intriguing findings from the long-run estimation analysis are compiled in Table 6 as follows:

Table 6. Long-run results.

Variables	FMOLS	DOLS	CCR
	Coefficient (Prob)	Coefficient (Prob)	Coefficient (Prob)
REC	1.083** (0.020)	0.443 (0.434)	0.360*** (0.000)
GDP	0.199*** (0.000)	0.561*** (0.000)	0.123*** (0.000)
LF	-7.073 (0.9308)	-55.731 (0.4983)	-335.263 (0.981)
R^2	0.446	0.904	0.480

Note: "***", '**', '*' refers to the confidence interval at 99%,95%, and 90% level.

Table 6 shows the long run estimation of the three exogenous variables. REC is positive and significant at the level of 5% and 1% with FMOLS and CCR, respectively, while it is insignificant with DOLS technic. This suggests that in order to expedite the process of mobilising resources, these countries ought to leverage the abundance of underutilised RE resources. Local private companies, public initiatives, and donor funding could assist RE technologies, which are widely used in developing nations to lower the cost of services for rural households. While RE is allowed to contribute to SDGs, its high cost of operation necessitates the development of new business models, funding and clients for privately held energy producers, market facilitation to expand sustainable markets, transfer of technological expertise, and impressive subsidies to guarantee socio-economic benefits through income generation and savings encouragement. In rural and impoverished areas, such as these five countries in North Africa, where it is difficult to produce energy from conventional fossil fuels, RE can operate most effectively. Furthermore, RE might be less susceptible to fluctuations in value and price that affect users of non-renewables like oil and petrol, this might increase ANS's value. This finding is consistent with the findings of Güney and Kantar (2020), Güney (2019, 2021, 2022), Islam et al. (2022), and Ahmad et al. (2023), who noted that a significant barrier to achieving desired operation levels and the ability of RE technologies to ensure sustainability is the cost of RE.

GDP contribute positively and significantly to ANS at the significance level of 1% with FMOLS, DOLS and CCR, demonstrating how SD is supported by growing economic infrastructure. This result is noteworthy because it shows that EG is not always associated with environmental deterioration and that it is moving in the right direction to support SD. By the way, while some business and political leaders believe that environmental damage is a necessary condition for economic growth, others reject the idea that environmental pollution can result from economic growth. This finding does not support a growth reduction strategy to combat environmental pollution because insufficient and ineffective environmental policies to reduce GHG have a greater impact on climate change and global warming than does EG. Instead, it makes the case that the emphasis ought to be on figuring out what exactly causes environmental pollution. Additionally, it encourages people and the government to invest more money in fields like RE and education. Therefore, nations can promote a future that values inclusivity and sustainability for the present and future generations by prioritising sustainable investments. Our findings confirm earlier studies by Ahmad et al. (2023), Güney (2019, 2021, 2022), Güney and Kantar (2020), Noor et al. (2023),

and Zhu et al. (2024), showing that advancement towards SDG 8 is indicated by a positive correlation between GDP and ANS.
Additionally, LF has a negative and insignificant effect on ANS, proving that the labour force cannot serve as a sustainable engine. As a result, these countries lack both sustainable practices and cutting-edge green technology. A workforce with limited knowledge is more likely to misunderstand and be unfavourable to sustainable practices, which hinders economic growth and could even lead to less funding for sustainable initiatives. These nations must, nevertheless, transition to a sustainable economy, which not only reduces poverty and ensures social stability but also creates new jobs in the RE and circular economy sectors. Moreover, large labour forces and industries, particularly in cities, may also be a factor in increased transportation-related emissions and unfavourable environmental effects. Furthermore, excessive working hours can lead to health and social issues, which can be detrimental to the sustainability of society (Dembe et al., 2005; Bannai and Tamakoshi, 2014; Kivimäki et al., 2015). The findings of Røpke (1999), Schor (2005), Hayden and Shandra (2009), Victor (2012), Knight et al. (2013), and Fitzgerald et al. (2015) are all in agreement with this one.

Conclusions

In this article, we examine the effects of GDP, REC, and LF on ANS in five countries in North Africa between 2000 and 2022. We prove that REC and ANS, as well as GDP and ANS, have a positive and significant relationship. However, the impact of LF on ANS is insignificant and negative. This suggests that these nations, with a focus on EG and the expansion of the main economic sectors, are prepared to invest in RE and develop new value added based on creative systems.
Fortunately, the results show that raising RE will raise SD outcomes, demonstrating the significance of RE for development and growth. The encouraging results lead us to believe that increasing RE will not only enable us to meet the 2050 targets outlined in the Paris Agreement but will also enable us to power economies without releasing any pollution into the atmosphere. The GDP figures are also significant because they demonstrate that the economy is expanding in a way that will support SD without posing a threat to the environment. Therefore, in this instance, slowing economic growth through policy is ineffective.
It is crucial to promote clean energy policies and put an emphasis on energy efficiency. It is imperative that governments prioritise the energy transition by passing legislation in favour of it, making infrastructure investments, and providing financial incentives for clean technology. A solid foundation for developing a comprehensive plan to transition to RE sources and expand national energy portfolios is provided by accurate and well-written regulations. Furthermore, by providing a clear path for the growth of the energy sector, these regulations can foster innovation and facilitate the advancement of cutting-edge technologies. This makes it possible to create and enact progressive laws with clear goals for increasing the proportion of renewable energy, cutting emissions, and improving energy efficiency.
However, considering sustainability, economic diversification, and the energy transition is a difficult task for policymakers, especially when dealing with middle-income nations that produce gas and oil. Significant job and economic opportunities can also arise from growing the clean energy sector, but it will be crucial to ascertain whether these can be pursued in the same areas where the use of fossil fuels is declining.
In addition to the economics of the areas and communities that are likely to be impacted by the transition, policymakers also need to understand the size and scope of who will be most impacted by filling in data gaps about the skills, wages, and demographics of oil and gas workers. Nigeria is present in our analysis and it formed an alliance between the Environmental Rights Action-Friends of the Earth Nigeria and the Nigerian Labour Congress, one of the biggest trade unions in Africa, aims to inform employers and the government about the need for a fair RE and economic diversification for workers in the agriculture and petroleum industries. Policymakers must comprehend the extent and makeup of those most affected by the transition in addition to the economics of the regions and localities that are anticipated to be affected. This can be done by completing data gaps regarding the education, employment, and demographics of the oil and gas workforce.

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