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The Effects of Environmental Quality, Technological Progress and Aggregate Risk on Green Growth in the Mena Region

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ABSTRACT

Green growth (GG) or environmentally adjusted multifactor productivity growth is essential to achieve the dual objectives of economic development and pollution reduction. In this context, very little work has addressed the issue of sustainable development in the MENA region. Therefore, our work studies the impacts of environmental quality, technological progress and aggregate risk on green growth of this region in the aggregate level. Using the autoregressive distributed lag (ARDL) model over the period 1996-2020, the results demonstrate that GG is positively related to R&D expenditure and natural resource rents but inversely associated with aggregate (economic, financial, and political) risks. In the long run, a 1% increase in total risk decreases GG by 0.7%. In contrast, a 1% increase in profits from fossil fuel exports and innovation increases GG by 0.8% and 0.3%, respectively. The impact of renewable energy consumption is positive but not significant on GG. These findings are also confirmed by alternative regressions and offer several policy recommendations.

Keywords: Green Growth, Aggregate Risk, Renewable Energy, Research and Development, Natural Resources Rents, MENA Region
JEL Classifications: O32, O44, Q20, Q34

1. INTRODUCTION

To combat global warming, most developed and developing countries have signed the Paris Agreement. The latter aims to lower the global temperature below 2°C and try to reach the limit of around 1.5°C. In this context, the Middle East and North Africa (MENA) countries should reduce their greenhouse gas (GHG) emissions (Tagliapietra, 2019; Awijen et al., 2022). These emissions threaten environmental quality and the climate, through increasing levels of drought and flooding, melting glaciers, worsening extreme weather phenomena, and rising sea levels. Alternatively, the 2030 Sustainable Development Goals (SDGs) agenda proposed by the United Nations highlights issues of green growth and environmental sustainability (He et al., 2022; Xu et al., 2022; Murshed, 2024). The concept of green growth (GG) assumes that gross domestic product (GDP) should decouple from damages caused by carbon emissions and resource use (Hickel and Kallis, 2020; Wang et al., 2023). This is why many studies have employed adjusted net savings (ANS) to measure sustainable growth (Spaiser et al., 2019; Wei and Huang, 2022; Ahmad et al., 2023). With temperatures rising twice as fast as the global average, the MENA region has seen record drought cycles, wildfires, floods and land degradation. Therefore, we decided to investigate factors that may influence CG across the region (i.e. at the aggregate level).

First, renewable energy can reduce dependence on polluting energies. Indeed, the adoption of low-carbon energy resources limits environmental degradation (Ulucak, 2020; Raihan and Tuspekova, 2022). As mentioned by Kahia et al. (2017), MENA

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economies are still heavily dependent on fossil energy sources. Using clean energy could reduce the budget deficit for net oil-importing countries and preserve natural resources for net oil-exporting countries. However, other work has not found a link between sustainable growth and green energy (Murshed, 2024). In this context, developing countries lack the technologies, infrastructure and human and physical capital essential for the installation of renewable energies. The current investment rate in renewable energy in the MENA region remains relatively low (Bellakhal et al., 2019). However, over the past decade, solar and wind energy have expanded in middle-income countries in the MENA region (e.g., Egypt, Morocco, Tunisia) and in high-income countries (e.g., United Arab Emirates).

Second, natural resource rents can be used to support decarbonization policy (Zafar et al., 2019; Dada et al., 2022). However, the exploitation of fossil fuels can promote environmental degradation (Bekun et al., 2019, Ahmad et al., 2020). For oil-exporting countries in the region, oil and gas exports represent a significant share of income. For example, in 2017, fossil fuel rents contributed 38% of Iraq's GDP, 37% of Kuwait's GDP, 23% of Saudi Arabia's GDP, and 23% of Oman's GDP (Tagliapietra, 2019). Therefore, the impact of resource abundance on green growth in MENA countries will depend on ecological policies implemented by governments.

Third, good governance could improve the quality of institutions and reduce risks and therefore promote GG. In this context, Song et al. (2023) demonstrated that well-functioning economic and political institutions boost green growth in the long run. Similarly, Qiu et al. (2022) found that decreasing political and economic risks will promote environmental protection. For their part, Rong et al. (2024) demonstrated that economic risk improves environmental quality, while financial risk reduces ecological quality in China. For the MENA region, economic and financial instability and geopolitical risks may hamper sustainable growth, through declining domestic and foreign investments in clean energy.

Fourth, research and development (R&D) expenditures are essential for sustainable developments. Technological progress helps reduce waste and energy intensity in production (Lee and Min, 2015). The public sector remains the main contributor to innovation in the MENA region. Governments in these countries are called upon to attract entrepreneurs and the private sector to invest in innovation, especially in eco-friendly projects.

Very little work has focused on the determinants of green growth in the MENA region. Thus, our article has the advantage of studying the impact of R&D, natural resource rents, clean energy and aggregate risk on environmentally adjusted multifactor productivity growth. Furthermore, our article contributes to the sustainable development literature through the construction of a composite risk index that integrates political, financial and economic risk.

The rest of the study is organized as follows. Section 2 provides a brief literature review. Section 3 discusses the methodology and data used. Section 4 analyzes the results. Finally, Section 5 concludes and makes policy recommendations.

2. LITERATURE REVIEW

2.1. R&D and Green Growth

The transition to a green economy requires good technical competence, with an emphasis on research and experimental development (R&D) of countries (Ndlovu and Inglesi-Lotz, 2020). The pioneering studies of Romer (1986; 1990) highlighted the importance of technological progress as a generator of growth. R&D spending is also considered a catalyst for innovation. The dissemination and acquisition of new knowledge will enable both energy savings (Wang and Zhang, 2020) and productivity gains (Acheampong and Opoku, 2023). In other words, R&D plays a determining role in sustainable development and the reduction of fossil fuel prices. Using the Cross-Sectional Autoregressive Distributed Lags (CS-ARDL) for a sample of 21 high-income OECD countries between 1990 and 2021, Eid et al. (2024) show that renewable energy R&D significantly reduces CO_2 emissions in the long run. Innovation can affect the economy through multiple channels: improving the competitiveness of businesses both nationally and internationally, development of the financial sector, modernization of infrastructure, etc. (Thompson, 2018; Pradhan et al., 2020). The phenomenon of technological catch-up vis-à-vis the most advanced economies has been driven by foreign direct investment and international trade. Furthermore, technological innovation is not always synonymous with environmental protection; it can also generate CO_2 emissions (Zhang et al., 2018). Thus, technological progress may raise concerns about its impact on income and pollution. Most studies carried out on the issue very often highlight the role of innovation in economic development (Fan et al., 2017; Xiong et al., 2020; Jian et al., 2021; Li and Wei, 2021). But in recent years, considerable interest is increasingly being given to examining the link between R&D and sustainable development (Ahmad et al., 2023). As a result, this paper will examine the impact of innovation on green growth, which will make it possible to identify recommendations for establishing appropriate economic and environmental policies.

2.2. Environmental Quality and Green Growth

Ahmad et al. (2023) point out that the increase in fossil energy consumption reduces sustainable development in China. Indeed, a 1% increase in dirty energy consumption reduces sustainable development by 5.329 and 3.186% in the short and long term, respectively. Using a sample of 40 developed and 73 developing countries, Güney (2019) finds that renewable energy stimulates green growth. The beneficial effects of using renewable energies are greater than those provided by employing fossil sources. In another research, Güney (2021) uses the panel cointegration technique for 20 high-income countries from 1990 to 2015. In the long run, renewable (non-renewable) energy consumption has a positive (negative) impact on sustainable development. These same findings are supported by the previous work of Güney and Kantar (2020). The latter show that biomass energy consumption promotes green growth in OECD countries. More recent, Wei and Huang (2022) use a sample of 10 Asian economies from 1990 to 2020. The results revealed that renewable energy positively impacts adjusted net savings (ANS). Likewise, reducing the consumption of polluting energies is essential to achieve sustainable development goals. Using the Method of

Moment Quantiles (MMQR) to study the green growth of BRICS economies from 1990 to 2019, Wang et al. (2023) find that clean energy use boosts green growth from the 25th (lower) to the 95th (higher) quantiles. Furthermore, environmental depletion measured by natural resource rent as a percentage of GDP can harm green growth. In this context, Koirala and Pradhan (2020) demonstrate that rent has a negative impact on ANS for 12 Asian countries. This implies that when a country exhausts its natural resources, it may embark on a poorly sustainable path.

As previously demonstrated, fossil fuel consumption and natural resource rent are used as proxies for environmental degradation while renewable energy is used as a proxy for a healthy environment. Thus, our work contributes to the existing literature by studying the impact of renewable energies on adjusted net savings.

2.3. Institutional Quality and Green Growth

A lot of work has studied the link between institutional development and economic growth (Acemoglu et al., 2005). In this framework, political institutions stimulate economic activity through the establishment of a climate of trust between the various stakeholders. To begin with, democracy provides political checks and balances, responsiveness to citizens' needs, and independence from legal power, thus enabling economic development (Hasan et al., 2009). Furthermore, the protection of property rights stimulates private investment and financial market development (Claessens and Laeven, 2003). Finally, the fight against corruption contributes to lowering substantial economic costs (Mauro, 1995). In addition, a better quality of political institutions will make it possible to achieve a dual objective of growth and environmental preservation (Rizk and Slimane, 2018; Danish and Ulucak, 2020; Ahmad et al., 2021). Financial institutions, another component of the institutional framework, play a crucial role in economic development, through the creation of a climate of attraction for foreign direct investments. However, the impact of financial stability on environmental quality and green growth remains unclear. Indeed, efficient financial institutions can encourage investment in green technology (Kirikkaleli and Sofuoğlu, 2023; Wang et al., 2023). Conversely, a stable financial environment can encourage the granting of credit and therefore increase the consumption of energy-intensive products (Oyebanji et al., 2023). It is therefore essential to integrate financial stability as a component of institutional quality. In addition, economic institutions can foster entrepreneurship and private investment and therefore growth (Djankov et al., 2006). Indeed, entrepreneurs consider that inflation and public and trade deficits present a threat to economic development. Alternatively, Lei and Yang (2022) highlight the presence of a link between economic risk and natural resource volatility, which could reduce income. Along the same lines, Zheng et al. (2023) find that economic stability is essential to Chinese economic performance. Indeed, the fall in economic risk could promote technological progress and the reduction in the consumption of non-renewable energies, which contributes to the fight against pollution (Wang and Razzaq, 2022; Razzaq et al., 2023). However, economic stability could encourage more investment and production, which will accentuate environmental degradation. Indeed, periods of recession can lead to a slowdown in economic activity and a drop in fossil fuel consumption (Chiu and Lee, 2019; Rong et al., 2024). Despite their importance, financial and economic risks have been neglected in the existing literature. Thus, our paper has the advantage of building a composite risk index including political risk, financial risk, and economic risk.

3. DATA AND METHODOLOGY FRAMEWORK

3.1. Methodology Framework

Keeping into consideration the objective of revealing the long-run green growth determinants in the context of the MENA countries, this current study explains green growth (GG) as a linear function of aggregate risk (RISK), renewable energy (REN), natural resource abundance (TNR), and Research and Development Expenditure (R&D) as follows:

$$GG_t = \alpha_0 + \alpha_1\, RISK_t + \alpha_2\, REN_t + \alpha_3\, TNR_t + \alpha_4\, R\&D_t + \varepsilon_t \tag{1}$$

The existence of the long-run (equilibrium) relationship needs to test the presence of the cointegration connection between the green growth and the explaining variables. Hence, the most used cointegration analysis are the two-step equations procedure elaborated by Engle and Granger (1987), and developed by Johansen (1988) and Johansen and Juseluis (1990). However, these techniques require the use of integrated variables at the same order. To overcome these limitations, Pesaran and Shin (1998) developed the autoregressive distributed lag model (ARDL). Comparing to the Johansen method, this single-equation approach can be more efficient and it admits a mixture of stationary and nonstationary variables without the need for pretesting the order of integration. To test the cointegration relationship between the different series of the model, Pesaran et al. (2001) proposed the procedure and the critical values of "bounds test." Further, Narayan (2005) introduced an additional critical values bounds which are more suitable in the case of small sample size.

It is in this context that Eq. (2) will be expressed as follows:

$$\begin{aligned}\Delta GG_t = {} & \beta_0 + \sum_{i=1}^{p-1} \beta_{1i}\Delta GG_{t-i} + \sum_{i=0}^{q-1} \beta_{2i}\Delta RISK_{t-i} \\ & + \sum_{i=0}^{q-1} \beta_{3i}\ \Delta REN_{t-i} + \sum_{i=0}^{q-1} \beta_{4i}\ \Delta TNR\ _{t-i} \\ & + \sum_{i=0}^{q-1} \beta_{5i}\ \Delta \mathrm{R\,\&\,D}_{t-i} + \ \theta_1\ GG_{t-1}\ + \theta_2\ RISK_{t-1} \\ & + \ \theta_3\ REN_{t-1} + \ \theta_4\ TNR_{t-1} + \theta_5\ \mathrm{R\,\&\,D}_{t-1} + \varepsilon_t \end{aligned} \tag{2}$$

Where Δ denotes the first difference operator; β_{1i}–β_{5i} represent the coefficients of error correction model (ECM); θ_1–θ_5 are the coefficients of the long-term relationship; p is lag length of the dependent variable; q is lag length of the independent variables; and ϵ_t is an error term $\mathrm{ii}d\left(0,\sigma_\mu^2\right)$.

The first step of this work is to test the order of integration of time series. Indeed, we must ensure that none of them is integrated at order I(2).

The second step is to verify the existence of a long-term relationship. As in the symmetric case, two tests can be proposed. On the one hand, the F-statistics introduced by Pesaran et al. (2001), denoted F_{PSS}, allows to test the following hypotheses: The null hypothesis is the absence of a long-term equilibrium relationship:
H_0: $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$. Against the alternative hypothesis
H_0: $\theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 = 0$

Two critical values are provided by Pesaran et al. (2001). The critical values of the lower bound critical value correspond to the case where all variables are integrated in order (0), i.e. there is no cointegration relationship, while the critical values of the upper bound critical value correspond to the case of a cointegration relationship. If the F statistic is greater than the upper bound, H_0 is rejected and if the value of F is less than the lower bound, H_0 is not rejected. When the F is between the two bounds, we can't conclude.

On the other hand, the t-statistics proposed by Banerjee et al. (1998), denoted t_{BDM}, examines the null hypothesis of the absence of a cointegration relation, with H_0: $\theta_1 = 0$ against H_0: $\theta_1 < 0$.

The third step consists of checking the robustness of the long-term ARDL estimates. To do this, we employ the cointegration regression models, namely FMOLS (Phillips and Hansen, 1990), DOLS (Stock and Watson, 1993) and Canonical Cointegrating Regression (CCR) (Park, 1992). These techniques allow to eliminate nuisances linked to endogeneity and serial correlation.

3.2. Data Sources and Descriptions

In our research, we use annual data for MENA countries over the period from 1996 to 2020, considering data availability. The dependent variable: green growth (GG) is measured as adjusted net savings, while the independent variables are renewable energy consumption (REN) as a share of total energy consumption, and natural resource abundance (TNR) as the total natural resources' rents (% of GDP). In addition, the research and development expenditures (R&D) as a percentage share of GDP is used as a proxy for technological advancements. These four variables are extracted from the world bank (World Development Indicators WDI)[1].

The "adjusted net savings" are calculated by taking net national savings plus education expenditures and subtracting net forest, mineral, and carbon dioxide depletion (Hunjra et al., 2023).

$$ANS = \frac{GNS - Dh + CSE - \sum R_{n,i} - CD}{GNI} \quad (3)$$

where, gross national saving is represented by GNS, produced capital depreciation is indicated by Dh, CSE shows current expenditure on education (non-fixed capital), $R_{n,i}$ indicates natural capital rent depletion, damages from CO_2 emissions are represented by CD and gross national income is shown by GNI (Wei and Huang, 2022).

1 The World Bank provides statistics for each region, including the MENA region.

To have a precise idea of the risks incurred by the MENA countries, we built a composite risk index. The Composite Political, Financial, and Economic Risk (CPFER)[2] Index is taken from the International Country Risk Guide (ICRG) database. The ICRG is relatively better than other databases in estimating risk, thanks to, on the one hand, the availability of data for a sufficiently long period of time and, on the other hand, the frequent use of this source in research work (Chen et al., 2016). For the proportion, political risk contributes 50% of the CPFER, while financial risk and economic risk each contribute 25%. The highest overall score (100) indicates the lowest risk, and the lowest score (zero) denotes the highest risk.

$$RISK = \sum_{j=1}^{3} (100 - CPFER_{ij}) \quad (4)$$

Where, $CPFER_{ij}$ represents each type of risk j related to country i, and 100 is the maximum value of the composite risk[3]. We transformed the original risk index value to (100–$CPFER_{ij}$), so that a higher value of the risk index implies greater risk.

Table 1 provides acronyms, measurements, sources, and descriptions of all variables. We also transformed all the series to natural logarithmic to provide empirically consistent and reliable results, and to avoid problems of heteroscedasticity. Table 2 presents the descriptive statistics of the data. The maximum deviation was recorded by the natural resource rents. This can be explained by the variation in energy production and by price fluctuations on international markets. Regarding linearity, the null hypothesis of a normal distribution is accepted for all series. The correlation study shows that oil consumption is positively related to oil price, income, and financial development, while it is negatively related to industrial development. The time trends of the variables are presented in Figure 1.

4. EMPIRICAL FINDINGS AND DISCUSSION

4.1. Unit Root Tests

To examine the stationarity of the series, several economists have used the Dickey and Fuller augmented ADF test (Dickey and Fuller, 1979), the PP test (Phillips and Perron, 1988) and the KPSS test (Kwiatkowski et al., 1992). The results of the various unit root tests without structural breaks reported in Table 3 demonstrate that all the series are stationary in first difference I(1).

However, these tests (i.e., ADF, PP and KPSS) can provide biased results due to the presence of structural breaks in the dynamics of macroeconomic series. Likewise, Nusair (2016) points out that these traditional tests may fail to reject the null hypothesis of a unit root when structural breaks are present. Thus, we will also carry out unit root tests with break. The first one is the Zivot and

2 Political risk corresponds to all events and decisions of a legal, political, and administrative nature, whether national or international. Financial risk measures a country's ability to honor its commitments, by paying its official and commercial debts. Economic risk assesses the pace of growth based on GDP, inflation, fiscal balance, and trade balance. For more details on the ICRG methodology to calculate these three risks, see https://www.prsgroup.com/.

3 We used the average risk of MENA countries.

Figure 1: Green Growth, Renewable Energy, Natural Resource Abundance, Research and Development, and Aggregate risk, trends in MENA region

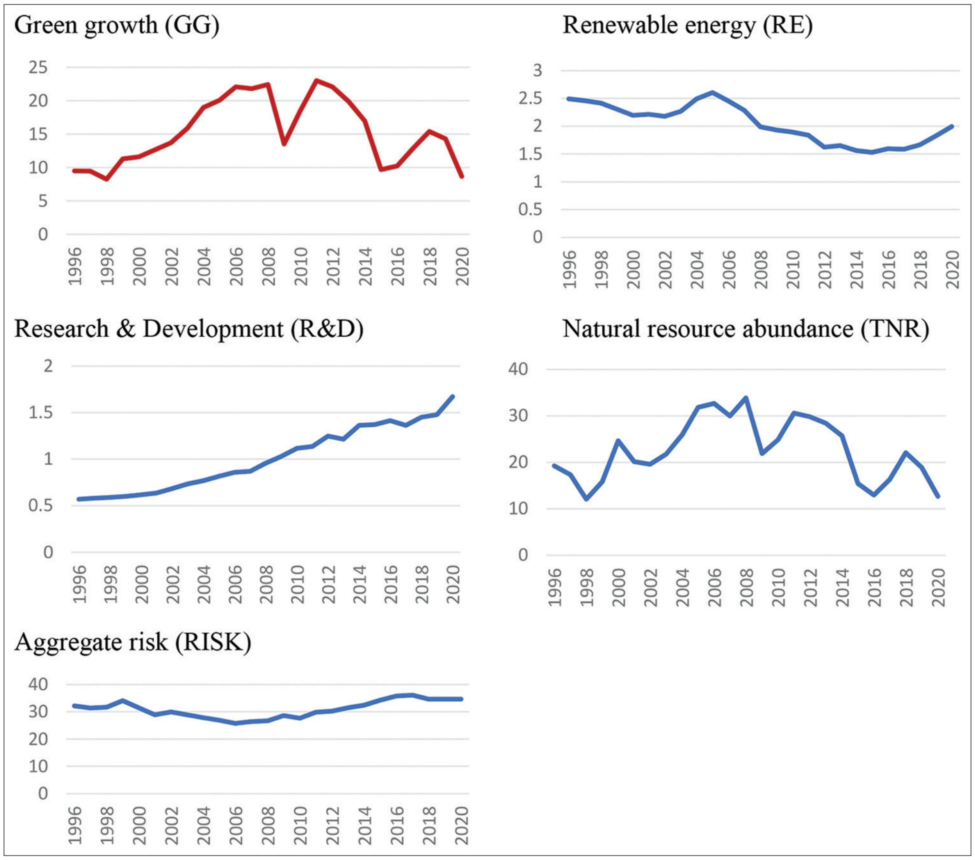

Table 1: Variable definitions and data sources

Variable	Description	Symbol	References	Data source
Green Growth	Adjusted net savings, excluding particular emission damage (percentage GNI)	GG	Ahmed et al. (2022) Kamoun et al. (2019) Lee et al. (2023)	World development indicators
Renewable Energy	Renewable Energy Consumption % of Total Energy Consumption	REN	Güney (2019) Murshed (2024) Raihan and Tuspekova, (2022)	World development indicators
Natural Resource Abundance	Total natural resources rents (% of GDP)	TNR	Dada and Al-Faryan, (2024) Hunjra et al. (2023) Shuayb et al (2024)	World development indicators
Research and Development	R&D Expenditure (% of GDP)	R&D	Fang et al (2022) Song et al. (2019) Wang et al. (2023)	World development indicators
Aggregate risk	Political, Financial, and Economic Risk	RISK	Rong et al. (2024) Wang et al. (2023) Zhao et al. (2021)	https://www.prsgroup.com/

Table 2: Descriptive statistic of variables

Variable	LGG	LRISK	LREN	LTNR	LR&D
Mean	2.654	3.434	3.067	−0.025	0.699
Maximum	3.134	3.663	3.521	0.680	0.957
Minimum	2.108	3.246	2.492	−0.562	0.423
Standard deviation	0.345	0.110	0.304	0.374	0.172
Jarque-Bera	1.975	0.840	1.247	1.696	2.060
Probability	0.372	0.656	0.536	0.428	0.356

Andrews (1992) unit root test (ZA test). It allows to consider a structural rupture introduced endogenously. The null hypothesis assumes that the series has a single root without any break. The alternative hypothesis assumes that the series is stationary with only one break at an unknown date.

The results of the ZA test presented in Table 4 confirm the conclusions provided by the unit root tests without breaks, except for the R&D which is stationary at level I(0) for the model with a break in intercept. The presence of several breaks also may have consequences for the conclusions derived from this test[4].

4 The ZA test maintains the linearity assumption under the unit root null hypothesis, which can lead to incorrectly estimate the break point (Boutabba, 2014).

Therefore, a second step considers the presence of these breaks, using the Lee and Strazicich (2003) Lagrange multiplier (LM) test that assumes two endogenous breaks under both the null and alternative hypotheses.

Two versions of this test are employed, namely the "A" model or the "crash" model, which captures a sudden one-off change in the level of the series, and the "C" model or "Break" model, which captures a change in the slope of the trend. As shown in Table 5, the null hypothesis is accepted for all variables, except for the REN series (model A). None of the variables is integrated of order I(2), which justifies the application of the ARDL model.

The LM unit root test statistic is generated from the following regression:

$$\Delta R_t = \delta^{'}.\Delta Z_t + \varphi.\tilde{S}_{t-1} + u_t \quad (5)$$

Where Z is a vector of exogenous variables, i.e. $Z_t = \left[1, t, D_{1t}, D_{2t}\right]'$ with D_{1t} and D_{2t} the shift dummies ("crash" model). $\tilde{S}$ denotes the detrended series: $\tilde{S}_t = R_t - \tilde{\psi}_x - Z_t.\tilde{\delta}$; $\tilde{\delta}$ are coefficients in the regression of ΔR_t on ΔZ_t and $\tilde{\psi}_x$ is given by $R_1 - Z_1.\tilde{\delta}$ [5]. The LM test statistics is the t-ratio testing the null hypothesis: $\phi = 0$.

4.2. ARDL Results

The number of lags is determined from the Schwarz information criterion (SIC). Although the Akaike Information Criterion (AIC) makes it possible to determine, in a relevant manner, the optimal number of lag length, the SIC always selects a parsimonious model and avoids a large prediction error (Kassim, 2016). In addition, the optimal lag length selected is the one which respects the criteria of absence of serial correlation. The maximum number of lags selected in ARDL model is 1. The results presented in Table 6 confirm the existence of a long-term relation between the study variables. Indeed, the calculated F-statistic of Bounds test is greater than the upper critical bound, even at the 1% significance level. Likewise, the t-statistic of the BDM test are above the upper critical bounds. Therefore, the null hypothesis of no symmetric cointegration is rejected. Furthermore, the diagnostic tests highlight an absence of serial correlation in the residuals (X^2 Serial), an absence of conditional heteroskedasticity (X^2 ARCH) and heteroskedasticity (X^2 BPGH), a normal distribution of the errors (J-B), and a correct specification of the models (X^2 RESET). Alternatively, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUM), shown in Figure 2, prove that the coefficients are stable.

Table 3: Results of unit root tests without structural breaks

Variable	ADF		PP		KPSS
	Level	First difference	Level	First difference	Level
LGG	−1.707	−3.830***	−1.793	−3.764***	0.203***
LRISK	−0.791	−2.811**	−0.870	−4.289***	0.276***
LREN	−1.655	−2.558**	−1.423	−2.529**	0.087***
LTNR	−1.694	−4.939***	−1.604	−3.800***	0.202***
LR&D	0.033	−6.193***	0.322	−6.076***	0.725*

ADF, PP and KPSS denote the statistics of Augmented Dickey and Fuller (1979), Phillips and Perron (1988) and Kwiatkowski et al. (1992) unit root test, respectively. The optimal lag length of ADF test is chosen based on Schwarz information criterion (SIC) (Schwarz, 1978) and the optimal bandwidths of PP unit root test and KPSS stationarity test are determined based on Newey-West criterion (Newey and West, 1994). The null hypothesis of ADF and PP tests is a unit root and that of KPSS test is stationarity. *, ** and *** denote rejection of the null hypothesis at 10%, 5% and 1% significance levels, respectively

5 see Lee and Strazicich, 2003 p. 1083 for more details.

Table 4: Results of unit root test (ZA test)

Variable	Break in intercept		Break in trend		Break in both intercept and trend	
	Level	First difference	Level	First difference	Level	First difference
LGG	−2.687	−6.022***	−3.422	−6.122***	−3.245	−6.542***
LRISK	−3.497	−5.653***	−3.501	−4.934***	−3.143	−5.672***
LREN	−2.322	−5.338**	−1.915	−4.124*	−2.095	−5.277**
LTNR	−3.473	−5.094**	−3.734	−4.524**	−3.569	−5.156**
LR&D	−5.658***	−5.154**	−3.884	−4.725**	−4.174	−5.288**

ZA denotes the statistics of Zivot and Andrews's (1992) unit root test. Critical values for the model with a break in intercept are: −5.34 (1%), −4.93 (5%) and−4.58 (10%). Critical values for the model with a break in trend are: −4.80 (1%), −4.42 (5%) and−4.11 (10%). Critical values for the model with a break in both intercept and trend are: −5.57 (1%), −5.08 (5%) and−4.82 (10%). *, ** and *** denote rejection of the null hypothesis at 10%, 5% and 1% significance levels, respectively

Table 5: Results of unit root test (LM test)

Variable	LGG	LRISK	LREN	LTNR	LR&D
Model A					
Level	−6.398***	−6.548***	−3.041	−8.468***	−4.727***
(TB1-TB2)	(2006-2008)	(2008-2014)	(2011-2015)	(2010-2015)	(2006-2014)
First difference	−12.14***	−9.786***	−23.586***	−6.764***	−4.249***
(TB1-TB2)	(2008-2012)	(2011-2014)	(2008-2013)	(2011-2016)	(2006-2015)
Model C					
Level	−8.412***	−13.40***	−44.206***	−18.318***	−8.737***
(TB1-TB2)	(2006-2010)	(2008-2018)	(2006-2016)	(2008-2018)	(2008-2016)
First difference	−14.841**	−48.02***	−10.478***	−131.193***	−56.690***
(TB1-TB2)	(2008-2012)	(2007-2010)	(2009-2013)	(2008-2011)	(2010-2013)

LM: Lagrange multiplier. Denotes the statistics of Lee and Strazicich (2013). These authors use the 10% asymptotic normal value of 1.645 on the t-statistic of the last lagged term. TB1 and TB2 are the break dates. *, ** and *** denote rejection of the null hypothesis at 10%, 5% and 1% significance levels, respectively

Figure 2: CUSUM and CUSUMQ from autoregressive distributed lag model

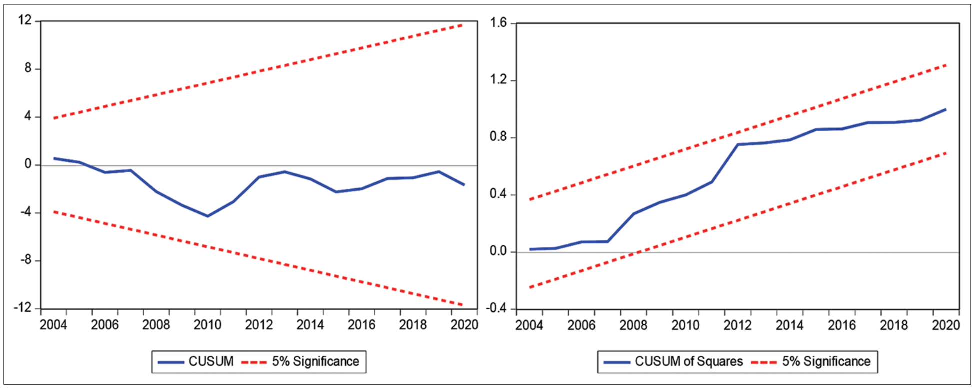

Table 6: Results of the ARDL cointegration test

F-Bounds test			T-Bounds test		
Significance level (%)	I (0)	I (1)	Significance level (%)	I (0)	I (1)
10	2.45	3.52	10	−2.57	−3.66
5	2.86	4.01	5	−2.86	−3.99
2.5	3.25	4.49	2.5	−3.13	−4.26
1	3.74	5.06	1	−3.43	−4.6
F-statistic=22.044***			T_{BDM} = −9.035***		

I (0) and I (1) denote lower and upper bounds, respectively. The critical values of F-Bounds test are given by Pesaran et al. (2001). Critical values of T-Bounds test are from Banerjee et al. (1998). *, ** and *** denote rejection of the null hypothesis at 10%, 5% and 1% significance levels, respectively

As shown in Table 7, R&D contributes to sustainable development and green productivity in the MENA region. A 1% rise in Research and Development expenditures increases green growth by 0.3% in the long term. This result is consistent with the work of Gazdar (2024), who found a positive relationship between R&D and green growth in 10 MENA countries. This finding also confirms the "technology push" hypothesis, which suggests that R&D investments can stimulate the development of green technologies and therefore sustainable development (Shen and Lin, 2020). Indeed, research and development spending to fight global warming and pollution promotes green growth, by reducing existing technological inefficiencies and optimizing the use of rare resources (Sohag et al., 2019). Achieving United Nations SDG 9 requires the development of an R&D-based action plan (Ahmad et al., 2023). Through investment in research and development (R&D), companies can increase their sustainable patents, while considering environmental concerns.

Furthermore, the results show that aggregate risk is inversely linked to sustainable development. A 1% increase in RISK leads to a 0.68% decrease in green growth. This outcome is consistent with those of Rong et al. (2024) who find that financial risk attenuates environmental quality in China. Similarly, our results support those of Degbedji et al. (2024), who find a positive relationship between good institutional quality and green growth in West African economic and monetary union. Political, financial and economic stability is essential for sustainable development, especially when implementing green projects. Consequently, an increase in risks reduces investor confidence, knowledge exchange, technology transfer, and the realization of sustainable development projects (Qamruzzaman and Karim, 2024).

Table 7: ARDL long-run coefficient estimates

Dependent variable: LGG ARDL (1, 1, 0, 0,0)			
Variable	Coefficient	Standard errors	Prob.
LRISK	−0.682*	0.327	0.0522
LREN	0.091	0.186	0.6282
LTNR	0.785***	0.092	0.0000
LR&D	0.297***	0.078	0.0015
Constant	2.557*	1.441	0.0939
R^2	0.936		
Adj-R^2	0.914		
Cointeq=LGG - (−0.6829*LRISK+0.0919*LREN+0.7855*LTNR+0 .2975*LR&D+2.5578)			
Diagnostic tests			
X^2 Serial	0.972 [0.401]		
X^2 ARCH	0.505 [0.484]		
X^2 BPGH	1.861[0.146]		
X^2 RESET	0.102 [0.902]		
J-B	0.908 [0.634]		
CUSUM	Stable		
CUSUMQ	Stable		

X^2 Serial, X^2 ARCH, X^2 BPGH, X^2 REST, and Normality denote the Breusch-Godfrey LM test for serial autocorrelation, the autoregressive conditional heteroscedasticity test for conditional heteroscedasticity, the Breusch-Pagan-Godfrey heteroscedasticity test for conditional heteroscedasticity, the Ramsey Regression Equation Specification Error Test for functional form, and the Jarque-Bera statistic for error normality (J-B). The associated probability values for diagnostic tests are in square brackets []. ***, **, and * represent 1%, 5% and 1% level of significance, respectively

Regarding the relationship between natural resource abundance and green growth, a 1% increase in TNR leads to a 0.78% rise in GG. This result is consistent with those of Hunjra et al. (2023) for 42 developing countries, and Dada and Al-Faryan (2024) for Saudi Arabia. However, this outcome does not support the works of Koirala and Pradhan (2020) for 12 Asian countries. This finding suggests that natural resource rents reduce pollution and stimulate sustainable growth. First, rents from non-renewable resources can be used to finance environmentally friendly projects. For example, under the Middle East Green Initiative, Saudi Arabia is leading efforts to combat deforestation. Second, natural resources (i.e., biomass and gas) can be used to produce renewable energy, thereby reducing dependence on fossil fuels (Wang et al., 2020). Third, oil-exporting countries in the MENA region, particularly the Gulf Cooperation Council, obtain significant revenues from the sale of fossil fuels. In 2017, the region provided 37% of global oil production and 22% of global gas production (Tagliapietra, 2019). These riches increase gross national savings.

Table 8: DOLS, FMOLS and CCR results

Dependent variable: LGG			
Variable	**DOLS**	**FMOLS**	**CCR**
LRISK	−1.486*** (0.477)	−0.488* (0.257)	−0.626** (0.293)
LREN	−0.232 (0.261)	−0.064 (0.165)	−0.131 (0.160)
LTNR	0.604*** (0.142)	0.884*** (0.077)	0.864*** (0.091)
LR&D	0.233* (0.117)	0.1926** (0.069)	0.192** (0.072)
Constant	6.115** (2.123)	1.689 (1.252)	2.265* (1.318)
R^2	0.944	0.905	0.902
Adj-R^2	0.914	0.885	0.882

Standard errors in parentheses (). ***, **, and * represent 1%, 5% and 1% level of significance, respectively

Moreover, the results show that the demand for renewable energies is positively linked to green growth. However, this sign is not significant. This result is consistent with the work of Murshed (2024) who found a positive but non-significant relationship between REN and sustainable growth for 11 developing countries, including Egypt and Iran. Therefore, the important question here is why renewable energy consumption is unable to drive green growth in the MENA region? Two answers can be presented. The first is that the consumption of renewable energies only represents on average 2% of total energy demand between 1996 and 2020. This observation is justified because this region depends mainly on fossil fuel sources. As a result, a modest share of non-polluting energy cannot effectively stimulate green growth. A second explanation is that the region is composed mostly of middle-income countries that cannot afford the costs of renewable energy (Bellakhal et al., 2019).

4.3. Robustness Check

As mentioned in Table 8, the FMOLS, DOLS and CCR methods confirm the conclusions of the ARDL approach. All three models highlight an inverse relationship between aggregate risk and green growth, while resource abundance and research spending boost sustainable growth. The sign of renewable energy consumption changes from positive to negative but remains statistically insignificant.

5. CONCLUSION AND POLICY IMPLICATIONS

The present research examines the impact of aggregate risk, renewable energy, natural resource abundance, and research and development expenditure on green growth in the MENA region. The study uses annual frequency data for the period 1980-2020. For empirical purposes, we apply unit root tests both without breaks and with structural breaks to study the stationarity of time series. These tests demonstrate that time series are stationary either at level or in first difference. This supports the use of ARDL regression. The cointegration test reveals the existence of a long run relation between green growth and its determinants. In the long run, aggregate risk negatively impacts green output while R&D and natural resource rents promote sustainable development. The ARDL model estimates are robust to various specifications, namely FMOLS, DOLS and CCR. Based on these conclusions, some important implications can be provided to help guide policymakers and environmentalists.

The effects of R&D spending vary across world regions. In this context, governments of the least sustainable MENA countries should invest in scientific research and technology to preserve the environment. Firms can also play an important role. By integrating green R&D into their production processes, companies (especially those operating in the industrial sector) can reduce manufacturing costs and increase returns to scale. This makes them more competitive in national and international markets. In the MENA region, the average level of corporate environmental, social and governance responsibility is low. According to a joint report by the European Bank for Reconstruction and Development, the European Investment Bank and the World Bank (2022), Tunisian and Jordanian companies occupy the top steps of the podium in the region, but they remain far behind their counterparts in emerging economies. To minimize their environmental footprint, companies can invest in energy efficiency. Similarly, policymakers should support companies that want to improve their green practices, through increasing investments and removing bureaucratic obstacles.

Moreover, limiting economic, financial, and political risks promotes green growth. Thus, better institutional quality in the MENA region will translate into lower composite risk. Likewise, reducing these risks could encourage sustainable development. Therefore, policy makers should focus on improving the effectiveness of national institutions, through strengthening the legislative and regulatory framework. Internationally, MENA countries must prioritize negotiations to absorb geopolitical tensions.

To avoid the massive exploitation of natural resources and its negative externalities on the environment, policy makers must use the fossil resources rents to invest in replacement capital. Furthermore, the diversification of budget revenues and economic activity in these countries will help to limit dependence on non-renewable resources. Indeed, the decline in production and the repetitive shocks to international prices of polluting energy present a challenge and an opportunity for this region to change its economic policies.

To develop the role of renewable energies in economic and ecological development, MENA countries should take certain actions, namely: avoid waste through a circular approach thus allowing reuse and recycling; use environmentally friendly energy in different sectors such as transport and construction; and reduce polluting emissions from conventional materials that cannot be substituted. MENA countries can move towards a sustained growth model by reducing their CO_2 emissions. This could be done through the introduction of ecological taxes on polluting industries, the use of clean energy (i.e., geothermal, wind, solar, hydroelectric, biomass, and biofuels) and the granting of subsidies to eco-friendly firms.

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