



Article Energy–Growth Nexus in the MENA Region: A Dynamic Panel Threshold Estimation

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Abstract: This study provides new evidence regarding the nonlinear relationship between energy consumption and economic growth in the Middle East and North Africa (MENA) region for the 1990–2014 period. The empirical estimation is conducted using a dynamic panel threshold model. We found one threshold in the relationship between energy consumption and economic growth and one threshold in the relationship between carbon dioxide (CO_2) emissions and economic growth. The results indicate that energy consumption positively and significantly affects economic growth in the low energy consumption regime. In contrast, it has a negative and significant impact on economic growth in the high energy consumption regime. Moreover, CO₂ emissions are positively and significantly related to economic growth in the low regime of CO₂ emissions. Nevertheless, the relationship between CO_2 emissions and economic growth in the high CO_2 emissions regime is negative and significant. Therefore, policymakers should implement other effective energy policies, such as stricter regulations on CO₂ emissions, increase energy efficiency, and replace fossil fuels with cleaner energy sources to avoid unnecessary CO₂ emissions and combat global warming. Future studies should identify the root causes of failures and issues in real time for inflation and link the energy-growth nexus to achieving the 2030 Sustainable Development Goals (SDGs) Agenda, Goal 7: Affordable and Clean Energy.

Keywords: MENA region; energy consumption; economic growth; threshold regression analysis

JEL Classification: Q43; O11; C24

1. Introduction

The relationship between energy usage and economic growth has been widely debated by many researchers and decisionmakers for several years, given the importance of energy factors in the production process since the oil crisis in 1970. Authors of [1] conducted the first study demonstrating the importance of the relationship between energy usage and economic growth. They found a one-way causal relation between energy usage and economic growth in the USA. Studying this relationship may help governments design their energy policies to boost economic growth, as numerous studies have found that energy consumption causes economic growth [2–5]. According to [6], energy plays a significant role in both the economy's supply and demand side. On the demand side, consumers use energy in their everyday lives. The source of energy production is the main concern, as many countries use fossil fuels such as coal and natural gas as energy sources. Energy is also used in the production process as an intermediate good; therefore, energy plays a central role in countries' social and economic development.

Energy is the main source of economic growth because it is involved in many consumption and production activities; energy is considered one of the primary inputs. The use of energy increases economic productivity and industrial growth and is important



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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). for any modern economy [7]. Energy consumption is associated with national output. Therefore, the amount of energy consumed per person is a key indicator of economic progress. In general, countries with high energy consumption per capita are often more developed than countries with low energy consumption per capita [8]. Moreover, energy is necessary for social development and economic growth. The major challenge facing future generations is how to conserve the environment in the face of expanded carbon dioxide (CO_2) resulting from an increase in energy consumption while achieving the requisite pace of economic growth [9]. In this regard, many empirical papers have confirmed a nonlinear link between energy use and economic growth [10–13]. Based on the level of energy use, they have discovered asymmetric effects of energy consumption on economic growth.

According to [14], fossil fuels represent approximately 81 percent of global energy sources, with coal accounting for 28.9 percent, natural gas accounting for 21.4 percent, and oil accounting for 31.1 percent. Moreover, the estimated energy consumption will increase by 53 percent; 70 percent of this consumption will come from developing countries. Energy demand increases daily; however, due to the global abundance of energy resources, some places have more energy resource reserves than others. In addition, imbalances in energy consumption also exist between regions and countries [15]. Therefore, since fossil fuels are the main energy source, researchers should consider the negative externalities of energy usage because fossil fuels damage the environment due to rising air pollution and global warming. In other words, increased energy use may result in reduced benefits of economic growth [16]. Hence, environmental considerations should not be overlooked when researching the relationship between energy use and economic growth.

The Middle East and North Africa (MENA) are two regions that are often grouped because they have many common sets of challenges, mainly geographical and heritage features. Moreover, the MENA region is economically different in terms of economic development and various endowments of natural resources. Thus, with differences and common features, it is attractive to analyze this region. According to [17], the MENA region has experienced more conflicts than any region in the world. Thus, with a different endowment of natural resources and economic growth in each area, policymakers need to plan the economic growth of this MENA region more systematically in the future. Over the course of the last five decades, the MENA region's economic growth performance has been insufficient, despite the region's rich natural resources. It does not align with other developing regions and countries. When comparing the MENA region's growth rates with those of other areas worldwide, the former fluctuate and are lower than comparable underperforming regions such as Sub-Saharan Africa (SSA). These fluctuations in development rates derived from social and political instability, and the fluctuations in oil prices reflected these countries' energy consumption [18]. Therefore, the MENA region is characterized by a high level of fluctuation for many reasons, such as oil price volatility, remittances and capital flows, climatic conditions, regional conflicts, and political instability [19].

As shown in Figure 1, the MENA region includes 20 countries distributed across two continents with around 381 million populations, equal to 6 percent of the world population. The economic performance of this region has faced shocks in the last decade, such as the global financial crisis and the political transitions in some countries. Today, conflicts in some countries affect the MENA region's development. Moreover, low oil prices in the last few years have weakened the economies of Arab countries, especially those which depend on oil export to sustain their fiscal balances, particularly the GCC countries [20]. In addition, the MENA region has the highest unemployment rates in the world, according to the data presented by the International Labor Organization. The MENA region with 22%. The inflation rate of 12.3% in 1990, ranked second after the Americas region with 22%. The inflation rate in the MENA region was at the highest level of 6.5% in 2017 compared to other regions, according to the World Bank data.



Figure 1. Map of the MENA region.

The historic unemployment and inflation rates in the MENA countries are reported in [21]. The MENA countries are divided into two subgroups: nonoil-exporting countries and oil-exporting countries. The average unemployment rate in nonoil-exporting countries averages 11.75 percent, reaching an ultimate height of 13.25 percent in 2002 and record a low rate of 10.55 percent in 1999. On the other hand, the average unemployment rate in oil-exporting countries is 9.12 percent, reaching an all-time high rate of 10.39 percent in 2000 and a record low rate of 7.96 percent in 2013. The average inflation rate in nonoil-exporting countries is 6.85 percent, reaching an ultimate height of 17.28 percent in 1992 and a record low rate of 1.14 percent in 2016. The average inflation rate in oil-exporting countries is 5.93 percent, reaching an all-time high rate of 12.25 percent in 2008 and a record low rate of 1.31 percent in 2001. This shows that unemployment and inflation rates in nonoil-exporting countries are higher than the oil-exporting countries. It reveals the differences in economic level in the MENA countries. Therefore, the MENA region is characterized by a high level of fluctuation for many reasons, such as oil price volatility, remittances and capital flows, climatic conditions, regional conflicts, political instability, and economic performances (unemployment and inflation rates) [19].

Relative to global energy growth, the MENA region doubled its share of world energy demand from 4% in 1990 to 8% in 2015. The majority of energy demand growth in the MENA region comes from Gulf Cooperation Council (GCC) countries and Iran. Qatar and Oman exhibited the fastest growth in energy demand between 1990 and 2014, with annual averages of 8.1% and 7.4%, respectively, while 42% of the total energy demand came from Saudi Arabia and Iran. These countries had increased energy demand, and many development initiatives, particularly in GCC countries, drove high economic growth rates, while these countries also benefited from their reserves of crude oil and gas resources. On the other hand, for nonoil-exporting countries, economic activities can be boosted due to low oil prices, where low oil prices raise households' and firms' real income [22].

The question is how energy use in the MENA region relates to economic growth, because energy is such an important part of the production process in any economy, although the energy usage projection is hard to predict due to various uncertainty of the external factors such as the COVID-19 pandemic and other crisis episodes [23]. As a result, many empirical studies in the MENA region have examined the link and causal relationship between energy use and economic growth [19,24–30]. The outcomes of empirical studies provide evidence of a link between energy usage and economic development, which helps policymakers, economists, and international organizations in this field.

As a result, there are three objectives of the current study. The first objective is to determine whether there is a nonlinear link between energy consumption and economic growth in the MENA region between 1990 and 2014. The second objective is to determine the optimal energy consumption level that stimulates economic growth, since consuming more energy will affect economic growth due to CO_2 emissions, as noted by [31]. The third objective is to answer a central question of how much energy the economy needs to function smoothly to enhance social development and achieve sustainable development goals. The

current study supports policymakers in the MENA region and the existing literature in the following respects. First, this study provides information to help policymakers design effective energy policies to boost economic growth. Second, this study extends the previous literature by considering all countries in the MENA region. Third, previous studies on the MENA region address the impact of and the linear link between energy usage and economic growth under the assumption that these factors have a direct link. In contrast, the current study improves on past research by assuming that the effects of energy consumption on economic development will be asymmetric depending on energy usage. A dynamic panel threshold model is used in this investigation as developed by [32]. This research is divided into five components. Section 2 presents an overview of the theoretical background and empirical analyses on the relationship between energy use and economic growth. In Section 3, the methodology and data used in this study are explained, and in Section 4, the empirical results are presented. Conclusions are provided in Section 5.

2. Review of the Literature

2.1. Theoretical Background

Capital and labor are considered key factors of the production process in the early neoclassical growth model developed by [33], also known as the exogenous growth model, and technology is considered an exogenous factor in determining growth. This model does not regard energy as affecting economic growth. Energy was considered to be an intermediate factor in production. In 1970, the oil crisis negatively influenced economic development; the significance of energy in economic growth is defined by output and investment. Energy is a vital input that cannot be replaced with any other inputs [19].

We must develop the endogenous growth model to address the limitations of the neoclassical (exogenous) growth model. It takes knowledge into account as an element in the production process. The endogenous growth model is designed to explain long-term growth by endogenizing productivity growth or technological progress [34]. Technology is the ultimate predictor of long-term growth in this paradigm, and it is determined by investment in technological research. Therefore, technology is considered an endogenous input in the aggregate production function [35]. According to [35], technology is tied to energy because most technology depends on energy sources' availability to function. Without a reliable energy source such as electricity or petroleum, technologies such as machinery and plants are practically useless. There is no way to run a manufacturing process without using energy. Energy is an important factor to ensure technology utilization. Labor and capital and energy consumption will be used to specify the endogenous growth model. The nature of the link between economic growth and energy use led to four key hypotheses in the literature. First, the growth hypothesis considers energy to be the most important factor in economic growth. Economic growth is determined by energy consumption; reducing energy consumption may slow economic growth, and vice versa. Second, the conservative hypothesis assumes a one-way causal relationship between economic growth and energy consumption; this means that energy consumption is not caused by higher economic growth but rather by it. Third, the neutrality hypothesis holds that there is no causal relationship between these variables, implying that neither economic growth nor energy use affects the other. Fourth, the feedback hypothesis asserts that economic growth and energy use are linked in a two-way causal manner and asserts the importance of this link [36].

Fossil fuels are the main energy source for many activities, such as residential consumption, industrial processes, and transportation, since fossil fuels are readily available and relatively cheap. Therefore, increasing energy consumption leads to more CO_2 emissions from using fossil fuels. Carbon emissions from burning fossil fuels have significantly contributed to climate change, leading to global warming and environmental pollution. This phenomenon has severe consequences for the global ecosystem [11]. Several scholars and economists have attempted to study the relationship between environmental degradation, energy use, and economic growth using the environmental Kuznets curve (EKC). The EKC contends that income growth and environmental harm have an inverted U-shaped relationship, whereby environmental damage increases until a certain critical point while income increases. After this turning point, environmental damage begins to decline with an increase in income [16,37–39].

From the theoretical review, it is clear how energy use, CO_2 emissions, and economic growth are linked. Therefore, when studying the link between energy usage and economic development, environmental damage should not be ignored, as fossil fuels are the primary energy source, which may have a negative externality due to air pollution and global warming. Hence, the current study investigates the relationship between energy consumption and economic growth using two energy-related threshold variables. These two variables are energy usage and CO_2 emissions. This study differs from the previous studies where the main focuses were, among others, on wealth inclusivity [40], environment [41], income inequality [42], green technology [43], sustainable development agenda [44], institutional quality [45], and labor market perspective [20], although all the areas can be linked with the energy–growth nexus through various channels.

2.2. Empirical Review

Several empirical studies have been undertaken in various nations throughout various periods, with the majority of these studies focusing on the relationship between these two variables and their direction. The causal relationship between energy consumption and economic growth has been presented in the literature using four perspectives: the growth hypothesis, conservation hypothesis, neutrality hypothesis, and feedback hypothesis.

Authors of [1] were the first to present groundbreaking research on this subject; they demonstrate a one-way relationship in the United States, extending from economic growth to energy use (1947–1974). The study's findings corroborate the conservation hypothesis, implying that energy use has little impact on economic growth; additionally, other empirical research supports this perspective [46–54]. These studies suggest that governments could follow energy conservation policies.

On the other hand, many studies confirm the growth hypothesis in several countries and regions, implying that energy is considered the main engine for economic growth. Several studies have revealed that energy consumption has a beneficial impact on economic growth [5,55–67]. In contrast, many studies have found that economic policies intended to decrease energy consumption have no effects on economic growth [68–75]. Their findings corroborate the neutrality hypothesis, which states that energy consumption and economic growth have no impact on one another.

Furthermore, many empirical studies show that energy use and economic growth are interdependent. In other words, there is a link between energy consumption and economic growth, which supports the feedback hypothesis. Such findings have been obtained by many empirical studies [76–85]. Furthermore, numerous empirical investigations on the trivariate link among energy consumption, CO_2 emissions, and economic growth have been conducted. For instance, several studies have applied various estimation techniques on data from multiple countries [16,86–89]. These empirical works have obtained mixed results, mainly for different policy purposes.

According to [90], most early research focused on the relationship between energy consumption and economic growth, assuming a linear relationship between the two variables. However, the relationship between energy use and economic growth may be nonlinear. In other words, the asymmetric effect of energy consumption on economic growth is determined by the degree of energy use. Few empirical studies have examined whether energy consumption has a nonlinear effect on economic growth, that is, whether there is a threshold effect. Furthermore, [10] used one- and two-sector models of Taiwan's growth to determine whether energy consumption has linear or nonlinear effects on economic growth (1955–2003). A nonlinear association (U-shaped relationship) between energy use and economic growth was observed in this study. The authors of [10] performed another analysis using data from 82 nations over five years (1971–2002). The findings

revealed that energy consumption and economic growth had a nonlinear relationship. In [91], the authors examined whether the level of energy intensity affects economic growth in Turkey during the period 1975–2013. The outcomes of this study confirmed that there was a nonlinear relationship in Turkey between these two factors.

Moreover, Taiwanese researchers [12] examined the link between energy usage and economic growth (1982–2014). The results of their threshold model demonstrated that there was a regime-dependent relationship between energy consumption and economic development and that the relationship between these two variables was nonlinear, meaning that the outcomes varied depending on the amount of energy consumed. Authors of [13], on the other hand, focused on the asymmetric influence of energy use on economic growth in five Turkish provinces (1991–2012). The results of their dynamic panel threshold study indicated that energy consumption and economic growth had a nonlinear relationship. They discovered that, if energy intensity exceeds a threshold, energy consumption has a negative impact on economic growth, but it can have a positive impact if the energy intensity is below the threshold. As a result, this research advises against neglecting energy threshold levels when developing energy strategies.

Regarding the nonlinear link between CO_2 emissions and economic development, ref. [92] found one transition function in the relationship between CO_2 emissions and economic growth in China using a panel smooth transition regression model. Furthermore, ref. [93] used a dynamic threshold model to investigate the relationship between CO_2 and economic growths. In a group of 31 developing nations, they identified evidence of a threshold effect between these two factors. Authors of [94] investigated the link between CO_2 emissions and economic growth for a group of 36 countries. A panel smooth transition regression model shows that there is a nonlinear relationship between these two variables. Recent evidence [37,38] shows that the informal economy has an asymmetric positive impact on energy consumption.

In line with Environmental, Social, and Corporate Governance (ESG) initiatives worldwide, the COVID-19 pandemic has reinforced the importance of ESG issues and accelerated the transition to a more inclusive energy–growth nexus. As highlighted by [43–45], countries that perform well on the energy–growth nexus with good ESG scores are less risky, better positioned for the long term, and better prepared for uncertainty. The findings were supported by [40,95,96].

Although many empirical studies have been conducted on the relationship between energy use and economic growth, economists and policymakers continue to debate this topic, particularly from energy usage and conservation policy angles, as highlighted by [39,41,42,97,98]. As a result, various empirical studies in the MENA region have examined the relationship between energy use and economic growth and obtained varying results [19,25-30,99]. The linear association and causal relation between these two variables have been the focus of these studies. Given this context, the current work contributes to the body of knowledge in the following ways. First, using two energy-related threshold variables (energy consumption and CO_2 emissions), the present study explores the nonlinear relationship between energy use and economic growth. Second, in comparison to prior research, this study includes more MENA countries. Third, the current study investigates the nonlinear relationship between these variables using different econometric methods, including the dynamic panel threshold model.

3. Data and Methodology

3.1. Dataset

The dataset consists of a panel with observations on 20 countries in the MENA region (see Table A1 in Appendix A), with annual data for the 1990–2014 period, for a total observation window of 25 years. Our observation of data is up to 2014 to take advantage of balanced panel data, since the unbalanced panel data would lead to a loss of too many observations, which could affect the variables' coefficient estimates, as stated by [100,101]. The dependent variable is the real gross domestic product (RGDP) in U.S. dollars. The

collection of variables consists of seven variables, with the real gross domestic product (RGDP) in U.S. dollars as the dependent variable. The independent variables are gross fixed capital formation in U.S. dollars, total labor force, total government expenditure, inflation rate, CO₂ emissions (metric tonnage per capita), and energy usage (kilogram equivalent of oil per capita). The data for all the above variables are obtained from the World Development Indicators and the Energy Information Agency. The definitions of variables and the data sources are reported in Table A2 (see Appendix A). Table 1 shows the descriptive statistics for the study variables. The major measurements of our variables in the MENA region include the number of observations, mean, standard deviation, minimum value, and maximum value.

Table 1. Descriptive statistics.

Variable	Obs.	Mean	Std. Dev.	Min	Max
RGDP	480	24.221	1.577	19.950	27.580
CAP	480	22.690	1.764	17.220	26.326
LAB	480	14.935	1.444	12.261	17.628
GEXP	480	21.906	2.562	12.969	26.007
INF	480	8.313	14.156	-9.798	105.215
ENPC	480	7.349	1.295	5.116	10.004
CO ₂	480	9.699	13.428	0.041	70.042

3.2. Model Specification and Estimation Method

Equation (1) is developed based on the indication of endogenous growth theory [34,35], where the investment in the technology determines the economic growth or production function as an input factor. According to [35], technology is tied to energy because most technology depends on energy sources' availability to function. Therefore, this study will examine the effects of energy consumption on economic growth using two energy-related threshold variables (energy consumption and CO_2 emissions); we follow the study of [11]. The model is set as follows:

$$GDP_{i,t} = \beta_0 + \beta_1 CAP_{i,t} + \beta_2 LAB_{i,t} + \beta_3 GEXP_{i,t} + \beta_4 INF_{i,t} + \beta_5 ERV_{i,t} + \varepsilon_{it}$$
(1)

GDP is the dependent variable and refers to the pace of real GDP growth, and CAP denotes capital represented as a percentage of GDP (gross fixed capital formation). LAB is the labor force development, GEXP is total government expenditure as a percentage of GDP, INF is the inflation rate, and ERV represents the energy-related variables. ERV consists of the log of the energy consumption per capita (ENPC) and metric tons of CO₂ emissions per person (CO₂). These two energy-related variables are the threshold variables and are tested separately in the baseline model. ε_{it} is the error term; I = 1, 2, ..., 20 indicates countries; and t = 1, 2, ..., 25 represents time.

The econometric arguments on dynamic models have emphasized the effects of nonlinear asymmetric dynamics. In [102], the author created a model with a static panel threshold where the coefficients take various values to estimate a stationary exogenous variable. Authors of [103] developed a panel smooth transition regression methodology, which allows the coefficients to change gradually from one regime to the next, popularizing this method. These techniques are static and have not been established in dynamic panel models; however, the growing availability of massive panel datasets has driven complicated analyses of dynamic heterogeneous panels. The assumption of exogeneity of the regressors and/or the threshold variable is also a constraint. The standard least-squares method, as applied by [104,105], requires exogenous covariates. In [106], the authors lessened this restriction by allowing endogenous regressors, although they still assumed that the threshold variable was exogenous [107].

Remarkably, a difficult study has explored the nonlinear asymmetric issue in dynamic panels; specifically, when the period is short, there is considerable literature on the generalized method of moments (GMM) estimation of linear dynamic panels with heterogeneous individual effects [107]. Moreover, exogeneity may be restrictive in numerous real applications; hence, a dynamic panel model with a possible endogenous threshold variable was derived [107]. Compared with previous work, [32] improves the estimation by producing consistent and asymptotically normal estimates.

The following application will employ a dynamic panel threshold model, which expands the initial foundation from [108] by integrating endogenous regressors and dependent variable lags. In particular, the cross-sectional threshold model based on GMM from [106] allows for endogeneity, and a dynamic framework is used. The primary issue is transforming the panel threshold model to remove country-specific fixed impacts while maintaining the distributional assumptions within both models. Standard fixed effects elimination (e.g., first differencing) in dynamic panels is not possible because it induces serial links within the specified error conditions of the converted cross-section.

The authors of [109] developed forward orthogonal deviation transformation to remove fixed effects while avoiding serial correlation within converted errors to overcome this problem. The forward orthogonal deviation transformation ensures that the threshold model's initial distribution theory, as applied to static panels in [102], is applicable in a dynamic setting. Following [32,107,110], the dynamic panel threshold model is as follows:

$$GROWTH_{it} = (\emptyset_1 GROWTHLAG_{it} + \theta_{11} CAP_{it} + \theta_{21} LAB_{it} + \theta_{31} GEXP_{it} + \theta_{41} INF_{it})I(\beta_1 X_{it} \le \lambda)$$

$$(\emptyset_2 GROWTHLAG_{it} + \theta_{12} CAP_{it} + \theta_{22} LAB_{it} + \theta_{32} GEXP_{it} + \theta_{42} INF_{it})I(\beta_2 X_{it} > \lambda) + \mu_i + \varepsilon_{it}$$

$$(2)$$

where *GROWTHLAG*_{*it*} is *GROWTH*_{*t*-1}, μ_i is the country-specific effect, the error term is $\varepsilon_{it} \sim (0, \sigma^2)$, and the indicator function *I*(.) depicts the regime indicated by the threshold variable *X*_{*it*}. The marginal impact of *X* on *GROWTH* (economic growth) can be explained by β_1 (β_2), which represents the marginal influence of *X* on *GROWTH* in the low (high) *X* regime. In this case, the control variables (capital, labor, government expenditure, and inflation rate) are sets of exogenous variables, while *GROWTHLAG*_{*it*} is an endogenous variable.

A fixed effects transformation is used to remove individual effects as the first stage in the estimation procedure. However, in the dynamic model of Equation (2), the reason for these results is that the lagged dependent variable will remain permanently linked with the mean of the individual errors, and hence, the entirety of the transformed individual errors will be transformed [102]. Distribution theory will no longer be applicable to panel data because, first, differencing the dynamic Equation (2) will cause estimation problems, primarily negative serial correlation of the error terms. To remove the fixed effects, [109] introduced the forward orthogonal deviation transformation.

Forward orthogonal deviation transformation is unusual in that it avoids serial correlation of the transformed error terms. Rather than subtracting the previous observation from the current observation (first difference) or the mean from each observation (in transformation), it subtracts the average of all remaining observations of the variable in the future. As a result, the forward orthogonal deviation transformation is shown in Equation (3) as ε_{it}^* :

$$\varepsilon_{it}^* = \sqrt{\frac{T-t}{T-t+1}} \left[\varepsilon_{it} - \frac{1}{T-t} \left(\varepsilon_{i(t+1)} \right) \right] + \ldots + \varepsilon_{iT}$$
(3)

Thus, the forward orthogonal deviation transformation maintains the error terms as serially uncorrelated, i.e., Var (ε_i) = $\sigma^2 I_T \rightarrow Var(\varepsilon_i^*) = \sigma^2 I_{T-1}$.

In the first phase, the endogenous factors are evaluated using a reduced-form regression, Z_{2it} , as a function of the instruments X_{it} . Equation (2) is evaluated in step two using least squares for a fixed threshold where each Z_{2it} is replaced by its expected values from the first step. The threshold estimation in step three is selected such that it is associated with the lowest sum of squared residuals. Following [102,106], the confidence interval for the threshold evaluation is specified by { $\gamma : LR(\gamma) \leq C(\alpha)$ }, the 95th percentile of the asymptotic distribution of the likelihood ratio statistic L.R. (γ). When the threshold $\hat{\gamma}$ is specified, GMM will calculate the slope coefficients.

However, using GMM with a small cross-section sample may cause skewed standard errors and skewed estimated parameters [111], and the over-identification test is reduced [112]. The objective behind these concerns, according to [113], is instrument proliferation. The author proposed a new solution that reduces the instrumental matrix's dimensionality. To avoid an overfit of instrumented factors that could lead to biased coefficient evaluations, the instrument count will be lowered to one (p = 1).

4. Empirical Results

Table 2 shows the results of the dynamic panel threshold model that was used to investigate the asymmetric sensitivity of economic growth in the MENA area to energy-related variables (energy consumption and CO₂ emissions). In terms of the impact of energy use on economic growth at a certain point, the estimated energy consumption (ENPC) threshold level and the related 95 percent confidence interval are shown in the upper half of Table 2. The influence of energy consumption (ENPC) on economic growth (GROWTH) for both regime types is displayed in the middle of the table. The marginal impact of ENPC on GROWTH in the low energy consumption regime is represented by $\hat{\beta}_1$, whereas the marginal impact of ENPC on GROWTH in the high energy consumption regime is represented by $\hat{\beta}_2$. The low ENPC regime describes the situation in which energy consumption is less than the calculated threshold value. In the high ENPC regime, on the other hand, energy consumption surpasses the computed threshold value.

ENPC CO_2 Threshold estimates $\hat{\lambda}$ 3.3529 7.4065 95% confidence interval [3.3079-3.3948] [6.6703-9.2427] Impact of ENPC/CO₂ 0.75 ** 0.845 *** $\hat{\boldsymbol{\beta}}_1$ -0.81 *** $\hat{\boldsymbol{\beta}}_2$ -0.822 **Impact of covariates (Lower regime) 0.875 ** **GROWTHLAG**_{it} 0.453 * 0.687 0.231 * CAP_{it} 0.523 ** 0.629 LAB_{it} 0.618 * 0.752 ** **GEXP**_{it} 0.205 * 0.254 * **INF**_{it} Impact of covariates (Upper regime) 0.298 ** 0.820 ** **GROWTHLAG**_{it} **CAP**_{it} 0.805 * 0.132 0.351 ** 0.791 *** LAB_{it} **GEXP**_{it} 0.783 ** 0.766 ** **INF**_{it} 0.397 * 0.262 Difference **GROWTHLAG**it -0.155-0.055CAP_{it} 0.118 -0.099LAB_{it} -0.1720.162 0.014 **GEXP**_{it} 0.165 **INF**_{it} 0.143 0.057 Linearity (p-value) 0.0013 0.0002 J-test (p-value) 0.152 0.129 Observations 480 480 20 20 N

Table 2. The dynamic panel threshold estimation results.

*** significance at the 1% level; ** significance at the 5% level; and * significance at the 10% level.

The determined optimal threshold level for energy consumption (ENPC) is 3.3529, with a 95 percent confidence interval of [3.3079–3.3948], as shown in Table 2. The regime-dependent coefficients are shown to be statistically significant, with values of $\hat{\beta}_1$ = 0.75 and $\hat{\beta}_2$ = -0.81. Therefore, 3.3529 is the log of threshold estimates for energy consumption. When energy consumption is lower than the threshold, it contributes positively to economic

growth. However, if energy consumption is higher than the threshold, then it contributes negatively to economic growth. Energy consumption in this study refers to nonrenewable energy, leading to environmental impacts in the medium and long term. By understanding this concept, policymakers could design a specific tax measure (energy tax) for those companies that are still heavily relying on nonrenewable energy while giving tax incentives for those companies switching to renewable energy. As a result, energy use has a greater impact on economic development above the calculated threshold value. These results are consistent with many empirical studies, such as [10–12,91,114].

Moreover, all the signs of the estimated coefficients of economic growth lag (GROWTH-LAG), capital (CAP), labor (LAB), government expenditure (GEXP), and inflation (INF) in the model align with economic theory. Depending on these results, energy consumption and economic growth have a nonlinear relationship. It has a single threshold value and operates in a two-regime-dependent way, with different effects on economic growth during high and low energy consumption phases. As a result, these findings support the existence of an inverted U-shaped link between energy consumption and economic growth in the MENA region. This shows when countries need to choose between growth and low energy consumption targets when setting their targets. The countries choosing growth and those choosing low energy consumption levels rely on various assumptions, while those interested in growth rely on the assumption that, while some countries say that energy consumption has a favorable impact on economic growth, others argue that energy consumption has a detrimental effect. This indicates that energy consumption contributes positively to economic growth to a certain point (threshold), but it contributes negatively when it exceeds that point.

To check the validity of the final specifications used above, the result of the null hypothesis of no threshold impact and the validity of over-identifying moment conditions are shown in Table 2. The bootstrap p-values of the test are all close to zero, which provides evidence favoring a threshold impact. Next, ENPC is utilized as the transition variable, and the J-test result indicates that the null hypothesis of valid instruments is not rejected.

In contrast, Table 2 shows the effects of CO₂ emissions on economic growth (GROWTH) at different levels. The computed CO₂ emissions threshold level and the associated 95 percent confidence interval are shown in the upper part of Table 2. The effects of CO₂ emissions on economic growth (GROWTH) for both regime types are represented in the middle of the table. $\hat{\beta}_1$ Refers to the marginal effect of CO₂ emissions on economic growth in the low CO₂ regime, and $\hat{\beta}_2$ refers to the marginal effect of CO₂ emissions on economic growth in the high CO₂ regime. The term "low CO₂ emissions regime" refers to a situation in which CO₂ levels are below the computed threshold value. On the other hand, in a high CO₂ emissions regime, CO₂ emissions have exceeded the computed threshold value.

The computed optimal CO₂ threshold value is 7.4065, with a 95 percent confidence interval of [6.6703–9.2427], as shown in Table 2. The coefficients that depend on the regime are determined to be statistically significant, with values of $\hat{\beta}_1 = 0.845$ and $\hat{\beta}_2 = -0.822$. CO₂ has a positive and major impact at low CO₂ levels but a negative and significant impact at high CO₂ levels. In other words, when CO₂ emissions are below a certain threshold, they boost economic growth. However, if CO₂ emissions are above the threshold level, they have a negative impact on economic growth. In particular, if the average country's CO₂ emissions are below the threshold, a 1% increase in CO₂ emissions will increase economic growth by 0.845 percent; however, when CO₂ emissions are above the threshold level, a 1% increase in CO₂ emissions results in a 0.822 percent reduction in economic growth. As a result, when CO₂ emissions are below the threshold level, their quantitative influence on economic growth is greater. These findings correspond with the studies of [11,92–94].

Moreover, all the signs of the estimated coefficients of economic growth lag (GROWTH-LAG), capital (CAP), labor (LAB), government expenditure (GEXP), and inflation (INF) in the model align with economic theory. Based on these results, CO_2 emissions and economic growth have a nonlinear relationship. It has a single threshold value and operates in two modes, with differing effects on economic growth in the high and low CO_2 emission

phases. Therefore, these results provide persuasive evidence for an inverted U-shaped relationship between CO_2 emissions and economic growth within the MENA region. This shows countries have to choose between growth and low CO_2 targets when setting their targets. The countries selecting growth and those selecting a low CO_2 level rely on various assumptions. While some interested in growth rely on the idea that CO_2 has a positive association with economic growth, other countries claim that CO_2 has a negative impact on economic growth. This means that CO_2 emissions contribute positively to economic growth up to a particular point (threshold), but they contribute negatively once that point is passed.

Moreover, Table 2 shows the test results for the null hypothesis of no threshold impact and the validity of over-identifying moment conditions, which may be used to verify the legitimacy of the ultimate specifications employed above. The test's bootstrap p-values are all near zero, indicating that threshold influence is likely. For the CO₂ emissions used as the transition variable, the J-test result indicates that the null hypothesis of valid instruments is not rejected.

However, the aforementioned empirical findings indicated that, because of CO_2 emissions from burning energy and its sources, the empirical findings of this study suggest that excessive energy use is not necessary for economic growth. As a result, economic growth will be aided by the effective use of energy and controlling CO_2 emissions to keep them below the threshold level. On the other hand, excessive energy use generates negative externalities such as air pollution, and global warming may exceed the benefits of economic expansion, in line with findings of [43–45,94].

According to [11], to address more specifically which policies are consistent with each country in obtaining the targeted effects of energy consumption, the present study provides a more in-depth analysis using the two threshold variables (energy consumption and CO_2 emissions) as the standards of demarcation. According to the current study's nonlinear empirical results, when these two variables exceed the threshold levels (i.e., the two threshold variables equal 1), energy use and economic growth have a negative relationship. A country in this position should adopt a more conservative energy policy to avoid harming the environment and wasting energy. Economic growth will be aided by energy efficiency and keeping CO_2 emissions below the threshold level. Otherwise, excessive energy use could result in negative externalities since environmental damage may outweigh the benefits of economic growth. When these two variables are below the threshold levels (i.e., when the two threshold variables equal 0), a country's energy strategy should be more active. As a result, this type of country can use energy more effectively to stimulate economic growth.

Furthermore, if a country's CO_2 emissions surpass the ideal level according to the threshold value, the country's CO_2 emissions exceed the optimum level. This suggests that energy use and economic growth have a negative relationship. The negative link is that, due to environmental changes, energy use cannot lead to economic growth. The negative impact of CO_2 emissions (-0.822) is, on the other hand, greater than the positive impact of energy consumption (0.75). As a result, such a country should cut its use of fossil fuels and replace them with cleaner energy sources and enact stricter CO_2 emission regulations.

As shown in Table 3, most countries have values of the two threshold variables (energy consumption and CO_2 emissions) lower than the turning point. This implies that those 12 countries (Jordan, Algeria, Tunisia, Syria, Palestine, Ethiopia, Djibouti, Turkey, Yemen, Egypt, Lebanon, and Morocco) have to use more energy to promote economic growth since they consume less than the optimal level. As a result, these countries will need to pursue a more aggressive energy policy. On the other hand, at least one threshold variable in the remaining eight countries is higher than the estimated turning point. Five of them (Saudi Arabia, United Arab Emirates, Kuwait, Qatar, and Bahrain) have values of both threshold variables (energy consumption and CO_2 emissions) over the turning point. To reduce excessive CO_2 emissions, these countries must improve their energy efficiency. As a result, these countries should pursue a more conservative energy policy. The last three countries

(Oman, Libya, and Iran) have one significant threshold variable, with CO_2 emissions being higher than the turning point in these countries. Therefore, they have to reduce the fossil fuel sources of energy since CO_2 emissions exceed the threshold level, impose effective rules to control CO_2 emissions, and adopt clean energy sources via renewable energy sources to increase the energy consumption needed to facilitate economic growth.

Country	ENPC	CO ₂	Above CO ₂ Threshold	Below CO ₂ Threshold
Jordan	0	0	No	No
Saudi Arabia	1	1	Yes	Yes
UAE	1	1	Yes	Yes
Kuwait	1	1	Yes	Yes
Algeria	0	0	No	No
Tunisia	0	0	No	No
Syria	0	0	No	No
Qatar	1	1	Yes	Yes
Palestine	0	0	No	No
Ethiopia	0	0	No	No
Djibouti	0	0	No	No
Bahrain	1	1	Yes	Yes
Oman	0	1	No	Yes
Libya	0	1	No	Yes
Turkey	0	0	No	No
Yemen	0	0	No	No
Egypt	0	0	No	No
Iran	0	1	No	Yes
Lebanon	0	0	No	No
Morocco	0	0	No	No

 Table 3. Significant threshold variables in each country.

Note: 1 refers to the case in which the variable's values are higher than the optimum value (turning point), while 0 indicates the variable's importance is less than the optimum value.

Moreover, [115] argued that endogeneity denotes circumstances in which an independent variable and the error term are correlated. The difference between exogenous and endogenous variables is generated in simultaneous equation models. Disregarding simultaneity in the estimation process contributes to biased estimations, as it violates the exogeneity assumption. In a regression model, the Hausman specification test detects endogenous regressors or predictor variables. The Durbin–Wu–Hausman (DWH) test is another name for the augmented regression test for endogeneity. The test includes two phases: (i) regress the endogenous variable on all supposed instruments and obtain the residuals and (ii) incorporate the residuals as additional regressors in the first ordinary least squares (OLS) approach. The null hypothesis of exogeneity can be rejected if the coefficients of the residuals are statistically significant. Both residual coefficients are not statistically significant, as seen in Table 4. As a result, the null hypothesis of exogeneity cannot be rejected.

Table 4. Durbin–Watson–Hausman endogeneity test results.

Variables	Coefficients	Variables	Coefficients
Intercept	0.5952 *	Intercept	0.5490 ***
ENPC	0.0478 **	CO ₂	0.0287 **
Residuals	0.1281	Residuals	0.5834
Prob. > F-value	0.2955	Prob. > F-value	0.2314

Note: ***, **, and * refer to significance levels of 1%, 5%, and 10%, respectively.

Moreover, as [116] suggested, robustness testing for threshold analysis using nonthreshold techniques provides a test for the existence of a U-shaped (or inverse U-shaped) relationship over an interval. The results shown in Table 5 support the statistical significance of a nonlinear relationship between energy consumption (Panel 1) and CO_2 emissions (panel 2) with economic growth at the 5% and 10% significance levels, respectively.

Table 5. Nonlinear relationship results.

	Lower Bound	Upper Bound
Panel 1 (ENPC)		
Interval	6.292799	10.00425
Slope	0.62328	-1.18722
Extreme point:	17.570496 **	
<i>p</i> -value	0.0137	
Panel 2 (CO ₂)		
Interval	1.352886	20.04223
Slope	0.0050499	-0.051233
Extreme point:	22.157968 *	
<i>p</i> -value	0.0925	

Note: ***, **, and * refer to significance levels of 1%, 5%, and 10%, respectively.

5. Discussion

The literature discusses the critical significance of energy in the production process and its subsequent growth. Economists have found that energy is a significant component of a country's production. However, the primary energy source is fossil fuels because they are readily available and relatively cheap compared with other sources. Therefore, increasing energy consumption may outweigh the advantages of economic growth because of environmental damage caused by CO_2 emissions in line with findings from [43–45,94].

Hence, those designing energy policies should pay attention to the negative externalities of overusing energy. In this regard, the present study provides new evidence by examining the effects of energy consumption on economic growth in the MENA region using two energy-related threshold variables (energy consumption and CO_2 emissions). The empirical results are based on the dynamic panel threshold model (threshold regression model) from [32] over the 1990–2014 period.

The new findings can be summarized as follows: First, the data reveal a nonlinear relationship between energy consumption and economic growth and between CO₂ emissions and economic growth. However, the findings on energy consumption and economic growth relationships are opposite to results found by [117]. Second, the findings of threshold estimations and associated confidence intervals suggest a single threshold for energy consumption and CO₂ emissions with values of 3.3529 and 7.4065, respectively. These results are consistent with many empirical studies, such as [10–12,91–94,114]. Third, the threshold effect results showed a significant and positive sign when both energy consumption and CO₂ emissions were below the threshold level but a significant and negative sign when both energy consumption and CO_2 emissions were above the threshold level. These findings are consistent with previous studies such as [10–12,91–94,114]. Moreover, except for inflation, all four control variables have a significant and predicted influence on economic growth. Fourth, the findings also revealed that 12 countries, out of a total of 20, have no thresholds greater than the turning point for both energy consumption and CO_2 emissions. In contrast, five countries have two threshold variables higher than the turning point; the remaining three countries have a single threshold (CO2 emissions) higher than the turning point.

6. Conclusions

The present study provides valuable information for policymakers to design energy policies. Based on our study, policymakers should pay attention to CO_2 emissions dynamism in creating their energy–growth policy since fossil fuels are still considered the main energy source, at least before the rapid commercialization of sustainable and affordable energy sources such as solar, hydrogen cell fuel, and biomass. Various mechanisms can be used as policy tools, mainly through targeted allocations and tax incentives to

support the ESG agenda. Therefore, increasing energy use causes an increase in CO_2 emissions, which has a detrimental impact on the environment. However, for countries without any threshold above the turning point, increasing energy consumption will boost economic growth while keeping CO_2 emissions below the threshold value by employing renewable energy sources. The five countries with two threshold variables higher than the turning point need to improve energy efficiency to reduce CO_2 emissions and employ a cleaner energy source. The remaining three countries have CO_2 emissions higher than the turning point. These countries should emphasize reducing fossil fuel sources of energy and replacing and applying more effective regulations to control high CO_2 emissions. All these energy policies will be welcomed to combat global warming.

Notwithstanding the importance of this research toward current literature and policy application, several limitations exist, including the lack of ESG mapping with the current energy policies within MENA countries; the assumptions of a causal relationship between the series to constant over time; and no interaction between the low-frequency macroeconomic variables with the volatility coming from the high-velocity energy-based commodity variables. Future research directions might leverage these limitations to contribute to the existing energy–growth literature.

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Appendix A

Table A1. List of 20 MENA countries.

MENA Countries			
Jordan	UAE	Syria	Palestine
Saudi Arabia	Kuwait	Iran	Morocco
Qatar	Oman	Egypt	Tunisia
Bahrain	Libya	Algeria	Djibouti
Lebanon	Turkey	Yemen	Ethiopia

Table A2. Definitions of variables and sources of data.

Variable	Label	Definition	Source
GDP	The growth rate of GDP	The growth rate of real gross domestic product	WDI
CAB	Capital	Total gross fixed capital formation as % of GDP	WDI
LAB	Labor	The growth rate of the total labor force	WDI
GEXP	Government expenditure	Total government spending on purchasing goods and services as % of GDP	WDI
INF	Inflation rate	Annual change in the consumer price index	WDI
ECPC	Energy consumption	Energy consumption (kg of oil equivalent per capita), which refers to the use of primary energy before transformation	IEA
CO ₂	Carbon dioxide emissions	Carbon dioxide emissions (metric tons per capita) as resulting from the burning of fossil fuels	IEA

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