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The Effect of Digitalization on Energy Trilemma in the MENA region

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Abstract

The Middle East and North Africa (MENA) region faces numerous challenges while ensuring energy security, affordability, and environmental sustainability. A wide range of studies suggest that digitalization, alongside efficient energy conversion technologies, can help address the three conflicting energy trilemma dimensions (i.e., energy security, affordability, and environmental sustainability) (Salah et al., 2022). The study will investigate the effect of digitalization on the energy trilemma dimensions individually and collectively by creating an energy trilemma index using the Principal component analysis (PCA). The study employed the generalized method of moment (GMM) for 11 MENA countries over the period 2000–2021 to investigate the effect of digitalization on the energy trilemma and its dimensions in the short run while employing the fully modified ordinary least squares (FMOLS) to investigate the same effect in the long run. The GMM results reveal that digitalization has an insignificant effect on the energy trilemma index and its three dimensions in the short run. The FMOLS results reveal a positive effect of digitalization on the energy trilemma index and its energy security and affordability dimensions while a negative effect on the environmental sustainability dimension in the long run. These findings emphasize the paramount importance of digitalization in improving energy trilemma dimensions.

Keywords: *Digitalization - Energy trilemma- GMM- FMOLS.*

Introduction

The international community has become increasingly concerned with sustainable development, particularly with solving the problems of energy security, energy inequality, and environmental sustainability. These three problems constitute the global energy trilemma (GET) (Grigoryev and Medzhidova, 2020). In this context, a wide range of studies demonstrate the importance of digitalization in improving energy security, energy equity, and environmental sustainability. It is often envisioned as a possible enabler for a world with secured energy use and low carbon through utilizing the existing technological potentials in the sectors that have the highest potential for smart solutions (i.e., transportation, building, and energy sectors) (Coroamă and Mattern, 2019).

The study will focus on the MENA region due to its great suitability for studying the effect of digitalization on the energy dilemma, as the MENA region is characterized by an unsustainable increase in energy consumption, heavy reliance on hydrocarbons, and growing carbon emissions (see Figures 1 and 2), driven by economic development, industrialization, population growth, and increasing needs for water desalination and air conditioning (Hafner, 2023). The previously mentioned challenges will in turn affect its ability to achieve a balance between the three conflicting issues.

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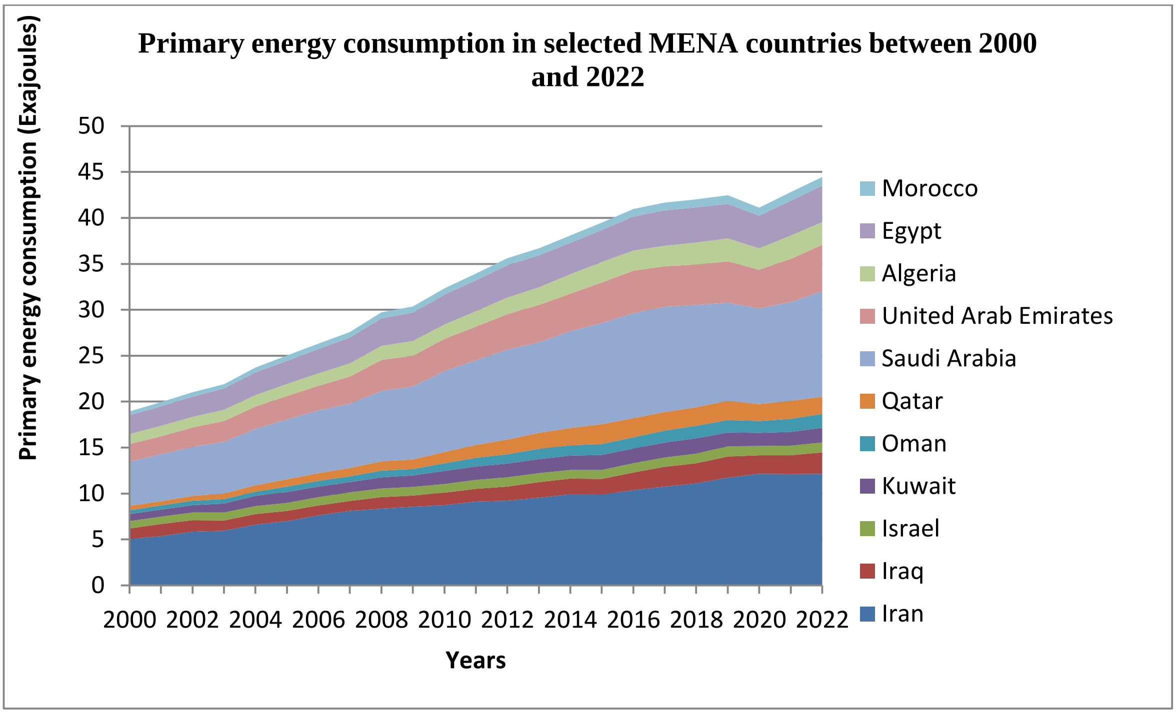
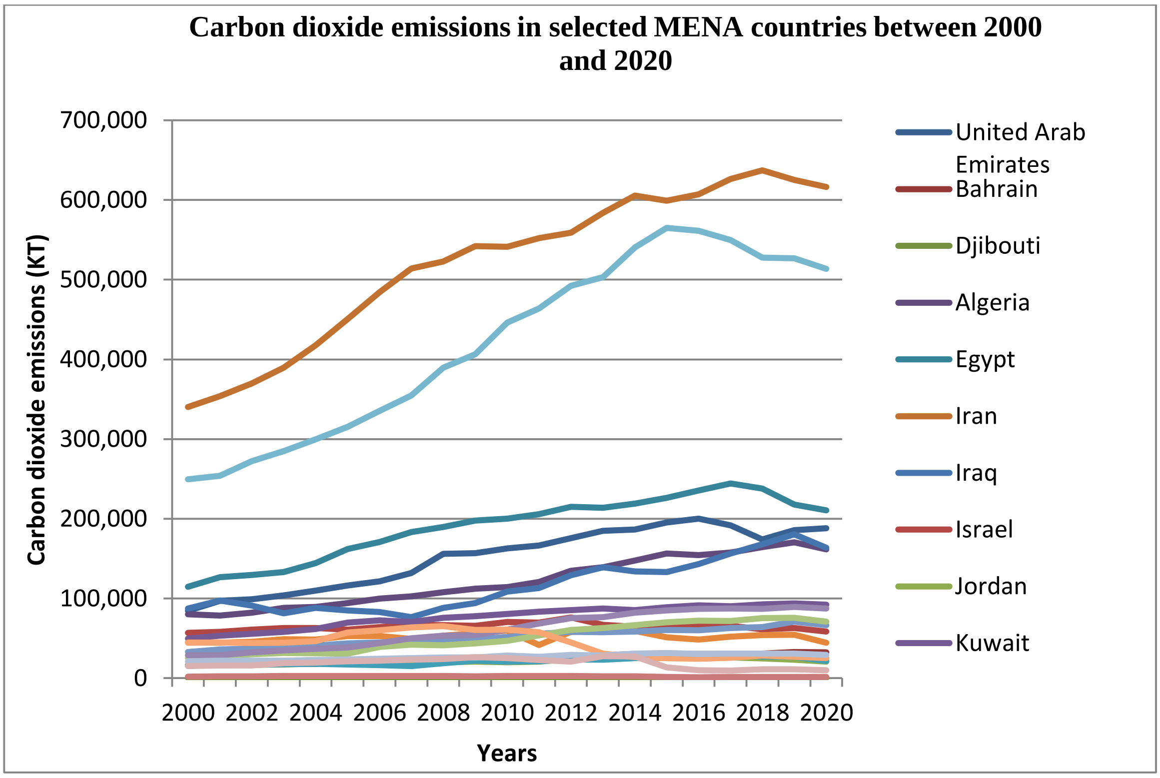
Figure 1. Primary Energy Consumption in Selected MENA Countries Between 2000 And 2021



Source: author's elaboration based on BP statistical review of world energy.

Figure 2. Carbon Dioxide Emissions in Selected MENA Countries Between 2000 and 2020



Source: author's elaboration based on World Bank.

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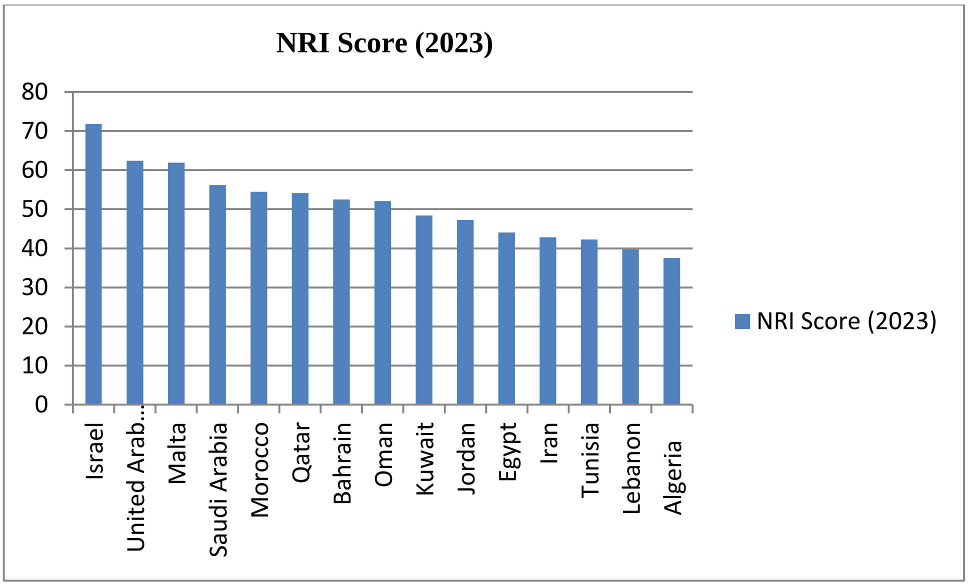
At the same time, most countries in the MENA region are on their way to becoming global leaders of digital transformation according to the networked readiness index[4], as shown in Figure 3. They are pursuing policies that support digitalization to ensure energy security, affordability, and environmental sustainability. However, these countries are not well equipped to utilize new technologies for further development and their governance for innovation and ICT is severely inadequate.

Figure 3: NRI index for selected MENA countries.



Source: author's elaboration on NRI 2023[5].

Accordingly, it is crucial for policymakers in the region to give attention to the effect of ICT technologies on the energy trilemma and deal with the challenges that face digitalization in the region, such as the infrastructural conditions required for them, security and privacy risks, a lack of digital literacy, a lack of awareness of the relevance of digital government in the public sector and society, and a lack of political will to reap the benefits of digitalization in the region's energy sector (Göll and Zwiers, 2018).

The rest of the study is structured as follows: Section 2 gives an overview of energy trilemma and digitalization concepts, accompanied by a review of the literature on the impact of digitalization on energy trilemma, especially in the MENA region. Section 3 presents the methodology used in our study. Section 4 discusses the empirical results of our study. Section 5 concludes the study and discusses policy implications.

Literature Review

The concept of a trilemma or quandary is used in different contexts and by different fields of study. In this study, the 'trilemma' term is used to describe a situation where it is hard to decide which of the three courses of action to take. The study will tackle the concept of the energy trilemma, and the World Energy Council defines clearly the energy trilemma as a set of objectives that governments must balance in order to ensure

[4] The Network Readiness Index 2020 measures how well an economy is using information and communications technologies to boost competitiveness and well-being. It ranks a total of 134 economies that collectively account for almost 98 percent of global gross domestic product (GDP). The NRI covers issues ranging from future technologies such as artificial intelligence (AI) and the Internet of Things (IoT) to the role of the digital economy in reaching the Sustainable Development Goals (SDGs).

[5] https://networkreadinessindex.org/countries/

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energy security, achieve energy equity, and mitigate climate change (Šprajc et al., 2019). ' The weaker version of the energy trilemma reveals that progress towards achieving all three objectives can be made exceptionally, while the stronger version reveals the possibility of a choice between the three policy objectives by policymakers, as only two of them can be achieved simultaneously (the stronger version). On the first view, the trilemma cannot be solved but only managed. However, from the second perspective, the trilemma can never be fully resolved. Despite the fact that it has been rare in the literature to contemplate the tensions between even two of these trilemma components, it is of particular importance to study them collectively (Gunningham, 2013). The study will focus on the energy trilemma index, its three pillars, and their connections with digitalization.

The first pillar of the energy trilemma, i.e., energy security, is commonly defined as having a dependable and sufficient supply of energy at an affordable price, which by definition also includes addressing short-term and long-term energy insecurity (Gunningham, 2013). It is worth mentioning that the 1997 economic crisis (and the more frequent and pervasive power outages that followed), the fuel shortages that have occurred since 2000, the increasing net oil import dependency coupled with the high oil dependency, and the serious shortcomings in fuel supply management, distribution, and infrastructure have all served to highlight the importance of energy security (Hafner, 2023).

Our review confirms that energy security refers to a concept that is highly context-dependent. Apart from the previously mentioned concept that is used in our study, there is currently no common definition (Ang et al., 2015). From these definitions, it is shown that energy security can be defined considering seven main themes, i.e., energy availability, infrastructure, energy prices, socioeconomic impacts, environment, governance, and energy efficiency. In other words, energy security is governed by two distinct groups of activities, as indicated in the literature. The first group of activities includes energy generation and distribution processes that guarantee adequate and timely energy supply for equipment, including the physical availability of energy(availability feature), the ability to pay for energy purchases and imports(affordability) and access to energy based on transportation systems and political connections (accessibility) (Thanh,2022), while the second group focuses on activities that contribute to the sustainability of energy consumption, including economic benefits, energy efficiency and societal and environmental impacts (receivability), and the relationship between energy system and carbon emissions from primary energy use (developmental capacity) as well as the long term development of the energy system using non-fossil fuels considering that governance has a crucial role in that by improving the country's economic performance through increasing electricity supply based renewable energy sources (sustainability)(Fang et al.,2018).

Although MENA countries have the resources to meet their rapidly growing domestic demand, there are significant disparities in energy supply per capita among them, as shown in Figure 4. The figure depicts countries like Qatar, Kuwait, and the UAE that exhibit extremely high energy supplies per capita due to their significant oil and gas reserves, while others such as Yemen, Tunisia, and Egypt, have much lower figures. In addition, certain countries, like Iraq and Libya, show fluctuations in energy supply per capita, likely influenced by political instability and economic factors such as sanctions or conflicts (Hafner, 2023).

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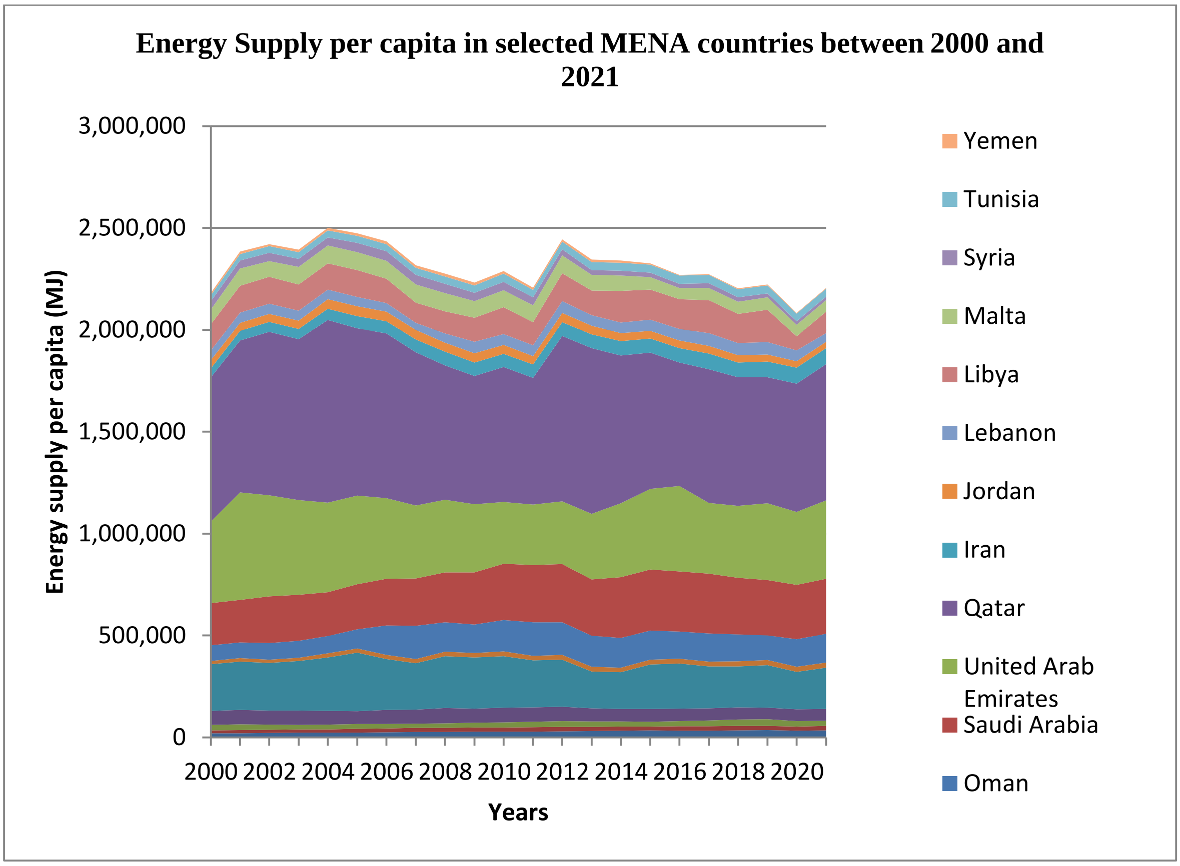
Figure 4. Energy Supply Per Capita in Selected MENA Countries Between 2000 And 2021



Source: author's elaboration based on International Energy Agency.

In addition, their primary energy mix is largely dependent on hydrocarbons, as figure 5 reveals, and their needs will erode their export base under the existing trends and policies.

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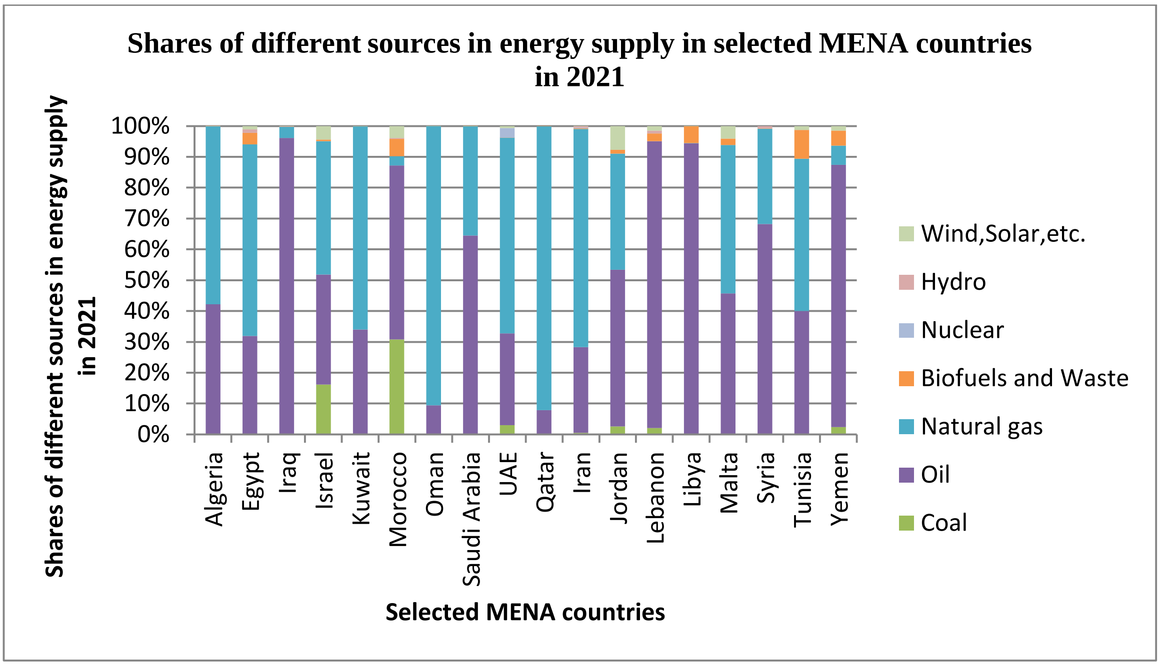
Figure 5. Shares Of Different Sources in Energy Supply in Selected MENA Countries In 2021



Source: author's elaboration based on BP statistical review of world energy.

The second pillar of the energy trilemma relates to energy poverty, energy equity, or energy affordability, as different studies use different expressions with approximately the same meaning. Energy equity is defined as a country's ability to provide reliable, affordable, and ample energy for domestic and commercial use and can be represented by access to electricity, heat, and clean cooking facilities (Khan et al., 2021). The MENA region is home to some of the world's highest exporters of oil and natural gas. However, despite its vast oil and gas reserves, it is also home to a significant portion of the world's energy-poor people, with about 13 million of the 486.1 million people living in the region having no access to electricity. Moreover, 24 million people suffered from a lack of clean fuels and technologies for cooking in 2021 (World Bank, 2024).

In this regard, Figure 6 illustrates the percentage of the population with access to electricity in MENA countries between 2000 and 2021. The figure shows that some countries have consistently maintained high levels of electricity access, like Israel, the United Arab Emirates, Kuwait, and Bahrain, which maintained percentages of 100. Moreover, some countries have shown improvements in their access rates, such as Tunisia, Djibouti, and Yemen, while Syria and Libya have shown declines in their access rates due to political instability and economic factors such as sanctions or conflicts.

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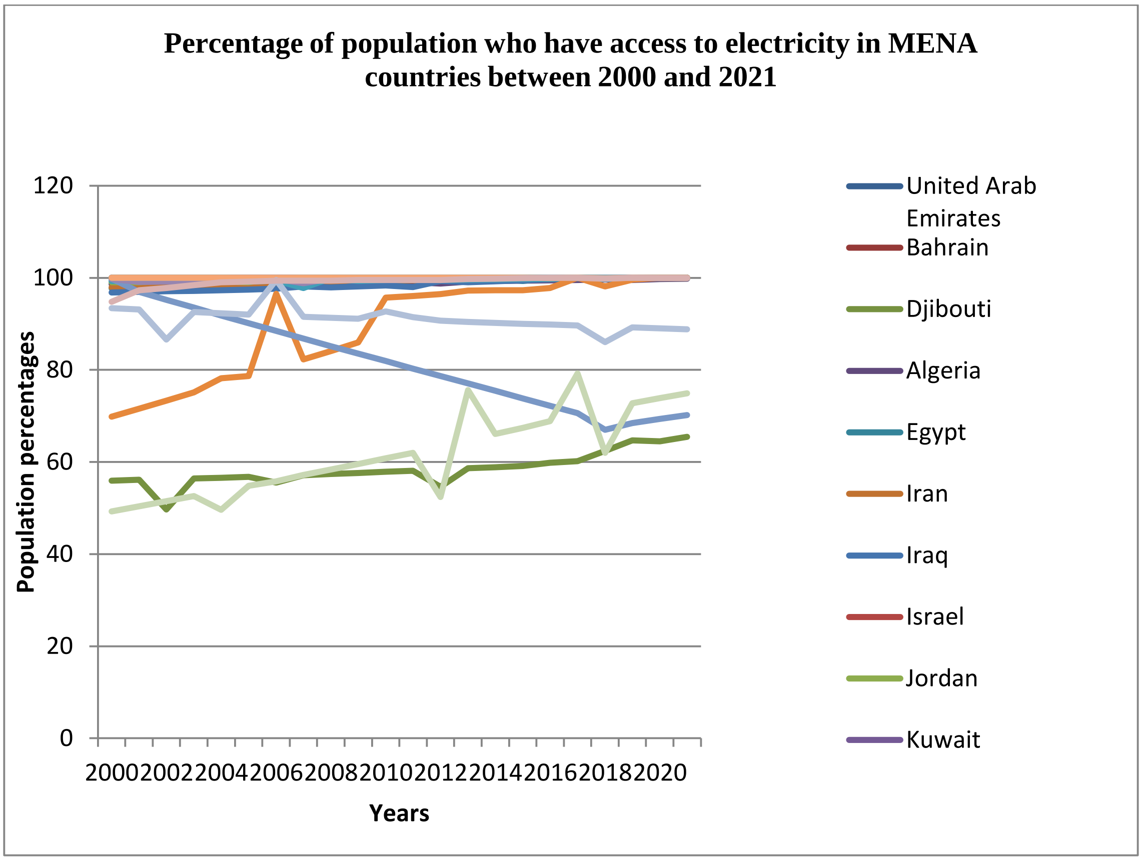
Figure 6: the percentage of population with access to electricity in MENA countries between 2000 and 2021.



Source: author's elaboration based on World Bank.

In addition, it was found that most MENA countries have access to clean fuels and technologies for cooking, with a percentage above 80%, except Djibouti, Iraq, and Yemen, as Figure 7 indicates. This reveals the great efforts of MENA countries in dealing with energy poverty.

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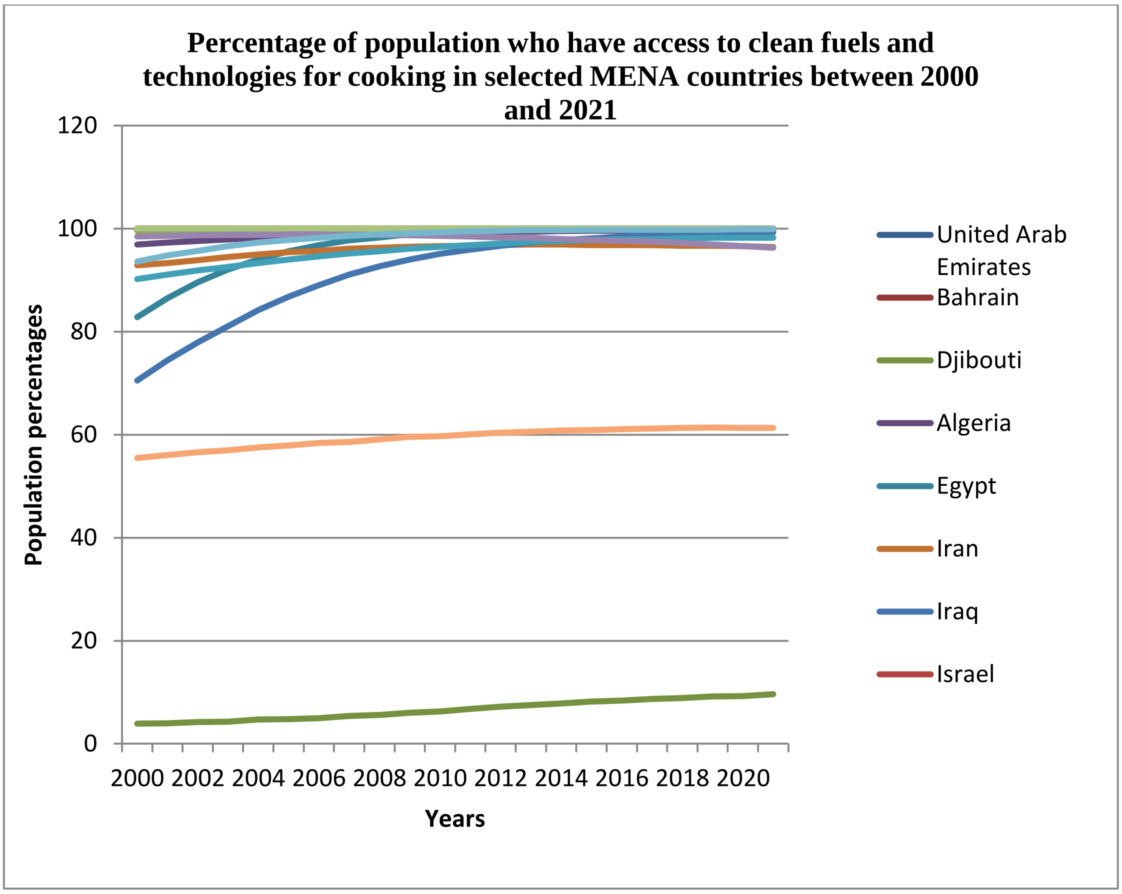
Figure 7. The Percentage of Population With Access to Clean Fuels and Technologies for Cooking In Selected MENA Countries Between 2000 And 2021.



Source: author's elaboration based on World Bank.

The third and final pillar of the trilemma is environmental sustainability, which signifies the transition of an energy system to a low- or zero-carbon one in order to combat climate change (Khan et al., 2021). In this regard, rapid development and population growth in MENA countries have led to increased consumption of fossil fuels, water, and other non-renewable natural resources, which burden the environment and contribute significantly to carbon dioxide emissions, as revealed by Figure 2. Despite that, MENA countries have taken positive steps in the last decade to solve the main environmental problems and improve sustainability in their countries[6].

In this theme, there are numerous alternatives that could help tackle the conflicting aforementioned issues. These alternatives encompass creating strategic oil reserves, broadening their sources of energy supply, switching to sustainable energy by partaking in technological advancements, and proceeding with the implementation of more efficient conversion technologies, such as fuel cells for diverse applications (Salah et al., 2022). Hence, digitalization is one of the most important solutions that could help in tackling the conflicting aforementioned issues.

Digitalization involves the integration of digital technologies into various aspects of our lives, including business, education, healthcare, and more. Digitalization affects the energy sector heavily and creates huge economic benefits. With the increasing use of new digital devices at all power system levels, new digital technologies will establish an Energy 4.0 era in the energy sector (Singh et al., 2022). Moreover, intelligent

[6] https://www.ecomena.org/sustainability-middle-east/

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and efficient energy management at all stages of the power system, from infrastructure and production to end-user devices, can enhance decarbonization and sustainable energy sources (Cronin et al., 2018).

Most MENA countries are on their way to becoming global leaders of digital transformation according to the networked readiness index, as Figure 3 indicates, but they are very diverse due to different levels of development both between and within countries. Several reports and studies have shown that most countries in the Middle East and North Africa region are not well equipped to utilize new technologies, and their governance for innovation and ICT is severely inadequate. Nevertheless, nearly all countries in the region are pursuing policies supporting digitalization to ensure energy security, equity, and sustainability, allowing external actors to induce technological trends indirectly via competition and other similar structural mechanisms or directly by multinational corporations (such as Google and Facebook) or supranational institutions (for instance, the World Bank, United Nations, Food and Agriculture Organization, and European Union) (Göll and Zwiers, 2018).

Despite the fact that the implications of digitalization on any one of the three dimensions of the energy trilemma were not analyzed until the early 1990s, ICT development is believed to have a positive effect on energy security, affordability, and environmental sustainability. Since then, a number of studies have used a macro framework to investigate the effect of ICT on energy security, affordability, and environmental sustainability, yielding mixed results that can be summarized in three divergent views (Zhang and Liu, 2015). The first viewpoint considers that the ICT sector has caused an increase in CO2 emissions, reduced energy security, or one of its dimensions, and energy affordability due to rebound effects, dependence on non-renewables and the difficulties of the construction and maintenance of complex digital infrastructures (International Energy Agency, 2017, Nizam et al., 2020, Han, 2022, and Thanh et al., 2022).

The second viewpoint is more optimistic. It believes that digitalization affects energy security and energy affordability positively and reduces carbon emissions (Zhang and Liu, 2015; Lu, 2018; Miskiewicz, 2022; Ha, 2022; and Thanh et al., 2022). Proponents of this view believe that the potential emission reduction of ICT is much larger than the direct footprint of the ICT sector and justify their opinion on the ground that energy sector digitalization enables more efficient energy production and identifies opportunities for energy efficiency improvements and renewable energy integration (Saeed, 2021), enhancing the reliability and resilience of energy systems (Avancini et al., 2019). In addition, it allows for remote monitoring and control, reducing the cost of generation and maintenance, increasing the affordability of energy, and optimizing energy storage systems such as batteries and pumped hydroelectric storage. (Zhang et al., 2023).

The third viewpoint suggests that the relation of ICT to any of the three dimensions of the energy trilemma seems uncertain. Plepys (2002), Pamlin and Pahlman (2008) concluded that the relation of ICT to the environment is uncertain in the presence of rebound effects in the analysis or when direct and indirect effects are considered in the analysis.

Based on the previous literature, it is obvious that digitalization may have a profound effect on the energy trilemma, whether positive or negative. This effect deserves investigation, especially in the MENA region, due to their future perspectives regarding energy sector transformation, energy sustainability, and carbon emissions mitigation, as mentioned previously.

Methodology

This section starts with a sample description and model specification. Then, data descriptions are presented, and finally, the estimation method is discussed.

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Sample Description and Model Specification

The empirical analysis includes panel data for 11[7] MENA countries over the period 2000–2021, based on the availability of data.

To investigate the effect of digitalization on energy trilemma and its three dimensions, Real gross domestic product (Al-Mulali et al., 2015; Zhang and Liu, 2015; Lu, 2018; Nizam et al., 2020; and Thanh et al., 2022), financial development (Lu, 2018) and the share of natural resource rents in GDP (Göll and Zwiers, 2018) may be considered the main contributors to the energy trilemma and digitalization models, as concluded by several researchers in the literature. An econometric model of the following specification was estimated, considering the previously mentioned variables as control variables:

$$ETI_{it} = \alpha0 + \alpha1\ ICT_{it} + \alpha2\ GDP_{it} + \alpha3\ FD_{it} + \alpha4\ RGDP_{it} + \xi t \quad (1)$$

where i = 1, 2,..., N and t = 1, 2,..., T denote the country and time period, ETI stands for energy trilemma index. ICT stands for information and communication technology and it is a proxy for digitalization. GDP_{it} represents the real gross domestic product; FD_{it} stands for financial development; $RGDP_{it}$ stands for the share of total natural resources rents to GDP and ξt denotes the estimated residuals.

It should be noted that the model will be estimated using each dimension of the energy trilemma index as a dependent variable in three separate equations by using a representative proxy for each dimension of the three dimensions of the trilemma index to get useful implications on each one. Hence, the following three equations will also be estimated separately:

$$ES_{it} = \alpha0 + \alpha1\ ICT_{it} + \alpha2\ GDP_{it} + \alpha3\ FD_{it} + \alpha4\ RGDP_{it} + \xi t \quad (2)$$

$$EA_{it} = \alpha0 + \alpha1\ ICT_{it} + \alpha2\ GDP_{it} + \alpha3\ FD_{it} + \alpha4\ RGDP_{it} + \xi t \quad (3)$$

$$EES_{it} = \alpha0 + \alpha1\ ICT_{it} + \alpha2\ GDP_{it} + \alpha3\ FD_{it} + \alpha4\ RGDP_{it} + \xi t \quad (4)$$

where ES_{it} stands for energy security. EA_{it} stands for energy affordability, and EES_{it} stands for environmental sustainability.

It should be noted also that the unit-expressed variables[8] were transformed into a natural logarithm since this makes the interpretation of the model easy and straightforward, representing percentage change (elasticity) (Ng and Cribbie, 2019).

Variables and Data

The main variables that contribute to the study are the energy trilemma index with its dimensions and ICT, while other variables work as control variables. Energy trilemma index is measured by using three dimensions; energy security (measured by using the per capita total energy supply (MJ) and the ratio of energy supply to energy consumption (Khan et al.,2021and Ha, 2022) ,energy affordability (measured by using the percentage of the population with electricity access and the percentage of the population with clean fuels technologies for cooking (Al-Mulali et al., 2015 and Miskiewicz ,2022) and environmental sustainability(measured using carbon dioxide emissions in kilo tones and the share of renewables in total final energy consumption (Al-Mulali et al., 2015, Zhang and Liu , 2015, Lu ,2018, Nizam et al. , 2020, Thanh et al., 2022 and Miskiewicz , 2022) . The energy trilemma index will be created by merging energy affordability, energy security, and energy sustainability using principal component analysis (PCA) to capture

[7] Algeria, Egypt, Iran, Iraq, Israel, Kuwait, Morocco, Oman, Qatar, Saudi Arabia and United Arab Emirates.

[8] The logarithmic transformation was not applied to the percentage variables and also to the index variable due to its zero or negative values.

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the impact of digitalization on the energy trilemma in the MENA region (Khan et al., 2021; Ha, 2022). The higher the value of the index, the better the country is at balancing between the energy trilemma dimensions.

In the individual indicator models, energy security is measured by using the per capita total energy supply (MJ), energy affordability is measured by the average of the percentage of the population with electricity access and the percentage of the population with clean fuel technologies for cooking, and environmental sustainability is measured using carbon dioxide emissions in kilotones.

ICT measurement is based on the basic three-stage model: the first stage: ICT readiness, which reflects the level of ICT infrastructure and access; the second stage: ICT use and intensity, which reflects the level of use of ICT and the capacity to use ICT effectively; and the third stage: ICT impact, which reflects the result of efficient and effective use of ICT in society. In this study, ICT development includes the first two stages due to data availability. The indicators measuring ICT readiness include fixed telephone lines per 100 people and mobile cellular telephone subscriptions per 100 people while the indicators measuring ICT use and intensity include Internet users per 100 people. Therefore, the study establishes a digitalization proxy that combines stages 1 and 2 with three indicators by taking the average score of fixed telephone lines per 100 people, mobile cellular telephone subscriptions per 100 people, and Internet users per 100 people as a proxy for ICT development (Lu, 2018; Nizam et al., 2020).

In addition, real gross domestic product, monetary sector credit to the private sector as a percentage of GDP, i.e., a proxy for financial development (Lu, 2018), and the share of total natural resources rents to GDP are the independent variables used in our analysis, as mentioned previously.

It is also worth mentioning that if the ETI variable takes negative values, then the logarithmic transformation cannot be applied to the index due to zero or negative values, and the arbitrary choice of an arbitrary positive to replace or transform zero or negative values will change the structure of the original data, affecting the empirical results. Then the inverse hyperbolic sine (IHS) transformation is used in econometric analysis to transform right-skewed variables when the logarithmic transformation cannot be applied. While the unit of measurement of IHS-transformed variables can substantially affect the regression results, the study applied it for the index variable since it does not have a unit of measurement (Pence, 2006).

Estimation Method

Generalized method of moments and fully modified ordinary least squares are utilized to investigate the effect of digitalization on the energy trilemma index and its three dimensions in 11 MENA region countries over the period 2000–2021. First, for short-run estimation, the study uses the GMM technique developed by Arellano and Bond (1991). The GMM is a consistent estimator that uses a variety of instruments and lag-dependent and pre-specified variables for each period, overcoming the endogenity problem that is common in panel data models (Esily et al., 2023).

Second, for the long-run estimation, unit root tests (i.e., Im, Peseran, and Shin (IPs), Pesaran CADF) are used to determine the order of integration of each variable (Yahyaoui and Bouchoucha, 2021). If the variables are stationary, pooled, fixed effects, and random effects models will be employed.

If the variables are not stationary, cointegration tests (i.e., the Kao test and the Pedroni tests proposed in Kao (1999) and Pedroni (1999, 2004), respectively), will be employed to identify the presence of a long-run relationship among the concerned variables. If the variables are cointegrated, the fully modified ordinary least squares method (FMOLS) is used to quantify the long-run relationship between the concerned variables. FMOLS tackles the issues of serial correlation and endogeneity that commonly arise in traditional ordinary least squares (OLS) estimation and mitigates the bias seen in small samples (Yahyaoui and Bouchoucha, 2021).

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Empirical Results

In this section, the results of the pre-elementary procedures for panel data estimation are presented followed by the panel cointegration test, then the GMM and FMOLS estimation results are discussed.

Pre-elementary procedures of panel data estimation

In this section, the results of the pre-elementary procedures for panel data estimation are presented, followed by the panel cointegration test, and then the GMM and FMOLS estimation results are discussed.

Prior to panel estimation, Breusch-Pagan LM, Pesaran scaled LM, Bias-corrected scaled LM, and Pesaran CD tests are employed to examine the cross-section dependence in the data (Esily et al., 2023). Table 1 reports the results of CD tests, which indicate the rejection of the null hypothesis of no cross-section dependence at a 1% significance level[9]. This outcome implies that the panel data suffer from CD problem across cross-sections and the chosen parameters during the period of study.

Table 1. Panel Cross-Section Dependence Estimations

Variable	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
A.ETI	393.1153*** (0.0000)	32.23803*** (0.0000)	31.96303*** (0.0000)	14.26399*** (0.0000)
LnES	467.8307*** (0.0000)	39.36186*** (0.0000)	39.09996*** (0.0000)	1.236643*** (0.2162)
LnESS	884.8085*** (0.0000)	79.11913*** (0.0000)	78.84413*** (0.0000)	28.82693*** (0.0000)
ICT	1093.318*** (0.0000)	98.99977*** (0.0000)	98.73787*** (0.0000)	33.04505*** (0.0000)
LnGDP	1068.378*** (0.0000)	96.62184*** (0.0000)	96.35993*** (0.0000)	32.62952*** (0.0000)
FD	575.7478*** (0.0000)	49.65136*** (0.0000)	49.38945*** (0.0000)	7.559613*** (0.0000)
RGDP	522.6374*** (0.0000)	44.58748*** (0.0000)	44.32557*** (0.0000)	17.97351*** (0.0000)

Note: The test statistic for the test cannot be calculated for energy affordability variable (undefined test statistic).

Source: Calculated by the author.

Standard errors are in parentheses

*** P<0.01, ** P<0.05,*P<0.1.

The Hsiao test is also employed to examine the homogeneity of coefficients, and tables 2, 3, 4,and 5 represent the results of the test for models (1), (2), (3), and (4) respectively (Esily et al., 2023). The null hypothesis (the slope coefficients are homogenous) was rejected in all models since the probability values of the test findings were less than 1% and 5%, and the heterogeneity of the cointegration coefficients was established.

[9] The test statistic for the cross section dependence tests can not be calculated for the energy affordability variable.

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Table 2. Homogeneity Test When A.ETI is the Dependent Variable

Hypotheses	F-Stat	P-Value
H1	178.7635	5.8E-121***
H2	28.55574	1.00E-55***
H3	122.2561	1.11E-80***

Table 3. Homogeneity Test When Lnes is the Dependent Variable

Hypotheses	F-Stat	P-Value
H1	809.8731	8.4E-182***
H2	21.87741	2.91E-49***
H3	805.1504	3.3E-163***

Table 4. Homogeneity Test When EA is the Dependent Variable

Hypotheses	F-Stat	P-Value
H1	62.04835	1.09E-87***
H2	45.25101	1.72E-72***
H3	13.88153	9.31E-19***

Table 5. Homogeneity Test When Lness is the Dependent Variable

Hypotheses	F-Stat	P-Value
H1	482.4330	5.3E-156***
H2	12.28118	2.73E-32***
H3	738.1720	8.1E-155***

Source: Calculated by the author.

*** P<0.01, ** P<0.05,*P<0.1.

Therefore, to establish an unbiased and consistent estimation, we should first apply the Pesaran CADF second-generation panel unit root test to assess the order of integration for the concerned variables (Choi, 2006). Table 6 reports the results of the Pesaran CADF panel unit root tests with and without a trend term. The panel unit root test indicates that all the variables are non-stationary at level 1, except the energy affordability variable, since the Pesaran CADF test indicates that it is integrated of order 2. However, if the cross-section dependence for the energy affordability variable cannot be detected as mentioned before, then it is better to depend on the comparable modified Fisher unit root test in assessing its order of integration, and then it is considered to be a stationary variable as indicated by the modified Fisher test in table 6.

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Table 6. Panel Unit Root Tests Results

Pesaran CADF test :

Variable	Level		Difference			Decision
	Deterministic term	p-value	Deterministic term	p-value	Difference	
A.ETI	Trend and intercept	0.465 (0.679)	Trend and intercept	-8.379 (0.000)	1	I(1)***
LnES	Trend and intercept	-0.663 (0.254)	Trend and intercept	-6.748 (0.000)	1	I(1)***
EA	Trend and intercept	5.711 (1.000)	Trend and intercept	-2.945 (0.002)	2	I(2)***
LnESS	Trend and intercept	-5.613 (0.000)	Trend and intercept	-0.287 (0.387)	1	I(1)***
ICT	Trend and intercept	0.417 (0.662)	Trend and intercept	-4.676 (0.000)	1	I(1)***
LnGDP	Trend and intercept	1.088 (0.862)	Trend and intercept	-6.125 (0.000)	1	I(1)***
FD	Trend and intercept	1.762 (0.961)	Trend and intercept	-7.328 (0.000)	1	I(1)***
RGDP	Trend and intercept	2.534 (0.994)	Trend and intercept	-4.942 (0.000)	1	I(1)***
Modified Fisher test for the energy affordability variable.						
EA	Trend and intercept	39.0899 (0.0004)	------	------		I(0)***

Source: Calculated by the author.

Standard errors are in parentheses

*** P<0.01, ** P<0.05,*P<0.1

Panel Cointegration Tests

To investigate the existence of a long-term relationship between information and communication technologies and the energy trilemma, or one of its three dimensions. The heterogeneous panel cointegration test advanced by Pedroni (1999, 2004), which allows for cross-section interdependence with different individual effects and heterogeneity under the alternative hypothesis (Joëts, 2011), is employed as follows:

$$Y_{it} = \gamma_{it} + S_i t + \gamma_{1i} ICT_{it} + \gamma_{2i} GDP_{it} + \gamma_{3i} FD_{it} + \gamma_{4i} RGDP_{it} + \xi_{it} \quad (5)$$

where i = 1,...,N for each country in the panel and t = 1,...,T refers to the time period. Y_{it} represents the dependent variable, whether it is ETIit, ESit, EAit, or EES_{it}. The parameters allow for the possibility of country-specific fixed effects and deterministic trends, respectively. ξit denotes the estimated residuals, which represent deviations from the long-run relationship.

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Tables 7,8,9and 10 report both the within and between dimension panel cointegration test statistics, where ETI_{it}, ES_{it}, EAit, and EES_{it} are the dependent variables, respectively. When ETI_{it} and EES_{it} are the dependent variables, panel ADF-statistic, group PP-statistic, and group ADF-statistic reject the null hypothesis of no cointegration at the 1% significance level[10]. When ES_{it} and EA_{it} are the dependent variables, panel PP-statistics, panel ADF-statistic, group PP-statistic, and group ADF-statistic reject the null hypothesis of no cointegration at the 1% significance level.

Table 7. Pedroni Cointegration Test Result When A.ETI is the Dependent Variable

Within dimension		Between dimension	
Test statistics		Test statistics	
Panel v-statistic	-2.343175 (0.9904)	Group ϱ-statistic	3.273888 (0.9995)
Panel ϱ-statistic	2.265537 (0.9883)	Group PP-statistic	-6.013414 (0.0000)***
Panel PP-statistic	-0.769901 (0.2207)	Group ADF-statistic	-4.798984 (0.0000)***
Panel ADF-statistic	-1.637314 (0.0508)*		

Table 8. Pedroni Cointegration Test Result When Lnes is the Dependent Variable

Within dimension		Between dimension	
Test statistics		Test statistics	
Panel v-statistic	-2.089935 (0.9817)	Group ϱ-statistic	3.011092 (0.9987)
Panel ϱ-statistic	2.029004 (0.9788)	Group PP-statistic	-6.723932 (0.0000)***
Panel PP-statistic	-2.637088 (0.0042)***	Group ADF-statistic	-6.885241 (0.0000)***
Panel ADF-statistic	-6.018978 (0.0000)***		

Table 9. Pedroni Cointegration Test Result When EA is the Dependent Variable

Within dimension		Between dimension	
Test statistics		Test statistics	
Panel v-statistic	-7.493692 (1.0000)	Group ϱ-statistic	1.744647 (0.9595)
Panel ϱ-statistic	1.293158 (0.9020)	Group PP-statistic	-10.93869 (0.0000)***
Panel PP-statistic	-6.418145 (0.0000)***	Group ADF-statistic	-7.501104 (0.0000)***
Panel ADF-statistic	-3.395053 (0.0003)***		

Table 10. Pedroni Cointegration Test Result When Lness is the Dependent Variable

Within dimension		Between dimension	
Test statistics		Test statistics	
Panel v-statistic	-0.299914 (0.6179)	Group ϱ-statistic	3.859511 (0.9999)
Panel ϱ-statistic	2.732788 (0.9969)	Group PP-statistic	-3.980320 (0.0000)***
Panel PP-statistic	0.081838 (0.5326)	Group ADF-statistic	-4.209579 (0.0000)***
Panel ADF-statistic	-3.174481 (0.0008)***		

Source: Calculated by the author.

Standard errors are in parentheses

*** P<0.01, ** P<0.05,*P<0.1

[10] Except the Panel ADF-Statistic that reveals rejection of the null hypothesis at the 10% significance level when ETI_{it} is the dependent variable.

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Empirical Results and Discussion

Short Run Estimation Results

After finishing the pre-elementary procedures of panel data estimations, we can present the short run relationships by estimating the models using the system generalized method of moments (GMM). Table 11 shows the estimation results of the GMM. Moreover, by looking to the results of the estimation tests in table 11, it was found that the null hypothesis of no serial correlation is not rejected in first and second t-order auto regression (AR1 and AR2). Also, in terms of the over-identification test and validity of instruments, Sargan is not rejecting the null hypothesis indicating that the GMM estimation didn't suffer from serial autocorrelation and over-identification problems.

Table 11. GMM Estimation for the Four Models

Dependent Variable	A.ETI	LnES	EA	LnESS
Constant	63.63727* (0.099)	-3.937407 (0.572)	16.48388*** (0.000)	0.3336255* (0.057)
ICT	0.0922 (0.102)	-0.0007021 (0.562)	0.0050371 (0.131)	-0.000067 (0.755)
LnGDP	-2.255328* (0.099)	0.5285733* (0.066)	0.0229516 (0.603)	-0.0019699 (0.717)
FD	0.001855 (0.777)	-0.000252 (0.979)	0.0019468 (0.718)	-0.0004962* (0.067)
RGDP	0.0034873** (.048)	0.0004356 (0.708)	0.0141228** (0.025)	0.0016049*** (0.000)
AR(1)	-0.67794 (0.4978)	0.35108 (0.7255)	----------	----------
AR(2)	1.5234 (0.1277)	-0.49964 (0.6175)	----------	----------
Sagran	4.96377 (1.0000)	3.192808 (1.0000)	209.8938 (0.4308)	193.0273 (0.0602)

Note : GMM two-step estimator is used to be able to apply the autocorrelation test except where EA and LnESS are the dependent variable, The one-step GMM estimator is used as the the variance- covariance matrix in the GMM two-step estimator is not full rank.

Also, the lagged difference of the dependent variable is used as the instrument in all models except the model where energy affordability is the dependent one[11]*.*

Source: Calculated by the author.

Standard errors are in parentheses

*** P<0.01, ** P<0.05,*P<0.1.

The GMM results reveal that information and communication technology has no significant effect on the energy trilemma index and its three dimensions in the short run. This can be justified on the ground that some MENA countries try to find a way to secure and decarbonize their energy sector by exploiting their existing capacities, technologies, and competitive advantages in traditional energy forms, but they cannot achieve their targets in the short run (Hafner et al., 2023). In addition, the MENA region's energy

[11] lagged difference of the dependent variable, ICT and LnGDP are used to make the instruments valid.

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transformation towards clean and low-carbon energy technologies cannot have a considerable effect on the region's energy security, affordability, and environmental sustainability due to their weak applicability in the short run.

The GMM estimation results also reveal that economic activity has a significant impact on the energy trilemma index and energy security while having no significant effect on energy affordability and environmental sustainability in the short run. This means that a 1 percent increase in gross domestic product causes a decrease in energy trilemma of 2.25 percent and an increase in energy security of 0.528 percent. The positive effect of economic activity on energy security can be justified on the ground that the increase in GDP causes an increase in energy consumption, and hence energy supply in a trial to maintain energy security in the region (Manchanda, 2023). While the insignificant effect of economic activity on energy affordability and environmental sustainability can be justified on the ground that while countries with high economic activity try to maintain energy security, they need to focus on devising policy strategies to improve energy affordability with technological sophistication and digital amalgamation, and this cannot be achieved completely in the short term (Wang et al., 2022). In addition, these countries try to depend on fossil fuels and renewables, exploiting their a little bit advanced technologies to maintain energy security, which might preserve environmental sustainability without having a considerable effect on carbon emissions (Chi et al., 2023). In light of the previous explanation, countries with higher economic activity cannot achieve the balance between the energy trilemma dimensions due to their concentration on the energy security dimension, neglecting the other two dimensions in the short run, and this justifies the little significant negative effect of higher economic activity on the energy trilemma index.

The results of the model also show that financial development has no significant effect on the energy trilemma index and its dimensions, except the environmental sustainability dimension, since a 1 percent increase in financial development mitigates carbon emissions by 0.0004 percent in the short run. This result can be attributed to the claim that financial development can improve energy security and affordability by providing citizens funds for electricity and renewable energy technologies access and providing cheap credit facilities for electricity production companies (Khan and Majeed, 2023). However, most MENA countries cannot attain these achievements completely in the short run due to their inadequate infrastructure and the high digital illiteracy rate caused by COVID-19 and conflicts in Syria, Iraq, and Yemen (Hafner et al., 2023). While financial development contributes to a slight reduction in carbon emissions by encouraging technological advances in the energy sector and hence more energy production in the short run (Charfeddine and Kahia, 2019), Hence, MENA countries that witness financial development may not achieve the balance between energy trilemma dimensions in the short run.

Finally, the model reveals that countries with higher resources (oil exporter countries) such as Saudi Arabia can improve the energy trilemma index, energy affordability, while increasing carbon dioxide emissions in the short run. This means that a 1 percent increase in natural resource rent increases the energy trilemma index, energy affordability, and carbon dioxide emissions by 0.003 percent, 0.014 percent, and 0.0016 percent, respectively, in the short run. These results can be attributed to the region's abundance of oil and gas and its heavy reliance on oil and gas energy resources instead of renewables in the short run, easing energy affordability, increasing carbon dioxide emissions, and causing a little improvement in the energy trilemma index in the short run **(**Hafner et al., 2023)**.**

Long Run Estimation Results

The long-run dynamic relationships are estimated by the fully modified ordinary least squares (FMOLS) technique and the results are shown in Table 12.

Table 12. FMOLS Estimation for the Four Models

Dependent Variable	A.ETI	LnES	EA	LnESS	Model (1) where A.ETI is the dependent variable and

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					ICT*RGDP is the interaction term
ICT	0.004217** (0.0105)	0.005735*** (0.001113)	0.035397** (0.017307)	0.006118*** (0.000742)	0.009507*** (0.002877)
LnGDP	0.452690** (0.0105)	-0.241620* (0.093042)	1.965959 (1.447135)	0.341125* (0.062117)	0.377250 (0.171527)
FD	-0.007120*** (0.0006)	-0.003781** (0.001039)	-0.018857** (0.016155)	0.000890*** (0.000723)	-0.007319*** (0.001976)
RGDP	-0.002498 (0.5434)	-0.004763*** (0.002202)	0.049485** (0.034250)	-0.004878*** (0.001455)	0.003984*** (0.005036)
ICT*RGDP					-0.000169*** (6.51E-05)

Source: Calculated by the author.

Standard errors are in parentheses

*** P<0.01, ** P<0.05,*P<0.1.

The long-run panel projections in this analysis reveal that information and communication technology is positively associated with the energy trilemma index, energy security and energy affordability dimensions while negativity associated with the environmental sustainability dimension. This means that a 1 percent increase in information and communication technology enhances the energy trilemma index, energy security, and energy affordability by 0.004 percent, 0.0057 percent, and 0.035 percent, respectively. While a 1 percent increase in information and communication technology causes an increase in carbon emissions by 0.0061 percent in the long run, These results can be justified on the ground that information and communication technology augments scale economics and diversification and facilitates energy efficiency, demand-side management, and policy formulation in the long run to promote energy security and affordability in the region, while causing a slight increase in carbon emissions due to high population growth, economic growth, and industry localization in the region (Wang et al., 2022; Hafner et al., 2023).

FMOLS estimation results also reveal that a 1 percent increase in economic activity increases the energy trilemma index and carbon dioxide emissions by 0.45 percent and 0.34 percent, respectively, while decreasing energy security by 0.24 percent and having no significant effect on energy affordability in the long run. The negative effect of economic activity on energy security can be justified on the ground that the huge increase in population in the region in the long run[12] exceeds the increase in energy supply as a result of the increase in GDP, causing a decrease in per capita energy supply (Manchanda, 2023). In addition, the significant increase in carbon dioxide emissions is caused by increasing population and increasing energy consumption, despite the exploitation of advanced technologies to transform toward renewables (Chi et al., 2023). While the insignificant effect of economic activity on energy affordability can be justified on the ground that the heavy increase in energy demand in the region caused by population growth, economic growth, industry localization, and dependence on energy-intensive water desalination due to water scarcity in the region prevents the efficient exploitation of digital amalgamation and devising policies developed by these countries to improve energy affordability (Wang et al., 2022). Countries with higher economic activity can achieve the balance between energy trilemma dimensions due to their concentration on achieving energy security and energy affordability, relying mostly on fossil fuels and renewables in a trial to mitigate carbon emissions, as mentioned above. However, this can not happen in the region due to the previously mentioned long run factors.

[12] https://www.imf.org/external/pubs/ft/mena/04econ.htm

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The results of the model also show that financial development has a significant negative effect on the energy trilemma index, energy security, and energy affordability while having a significant positive effect on carbon dioxide emissions. This means that a 1 percent increase in financial development increases carbon dioxide emissions by 0.00089 percent while decreasing the energy trilemma index, energy security, and energy affordability by 0.0071 percent, 0.0037 percent, and 0.0188 percent, respectively, in the long run. These results can be attributed to the heavy increase in energy demand in the region as a result of population growth and the high digital illiteracy rate in the region that outpaced the achievements caused by financial development in providing citizens funds for electricity and renewable energy technologies access and providing cheap credit facilities for electricity production (Hafner et al., 2023; Khan and Majeed, 2023).However, financial development contributes to a slight carbon emission increase due to the heavy increase in energy demand in the region as a result of population growth and financial development. Hence, countries that witness financial development cannot achieve the balance between energy trilemma dimensions in the long run due to the previously mentioned factors.

Finally, the model reveals that countries with higher resources (oil exporting countries) can reduce energy trilemma index, energy security, and carbon dioxide emissions while improving energy affordability in the long run. This means that a 1 percent increase in natural resources reduces the energy trilemma index, energy security, and carbon dioxide emissions by 0.002 percent, 0.004 percent, and 0.0048 percent, respectively, while improving energy affordability by 0.049 percent in the long run. Energy affordability could be improved in oil exporting countries as a result of extensive energy production due to the financial development and credit facility easing exist in these countries (Khan and Majeed, 2023). While the decrease in energy trilemma index, energy security, and carbon dioxide emissions can be attributed to the adoption of conservation policies[13] in these countries due to their heavy oil and gas exports and also due to the environmental considerations they adopted (Hafner et al., 2023).

The interaction term between information and communication technologies and natural resource rents is added to investigate whether a country is an oil importing or an oil exporting one affect the digitalization – energy trilemma relationship or not. Table 12 also reports the results of model (1) with the concerned interaction term. The interaction coefficient between information and communication technologies and natural resource rents is found to be statistically negative, indicating that the positive effect of information and communication technology on the energy trilemma index decreases in oil-exporting countries due to their concentration on exploiting information and communication technology to enhance oil and gas production and exports with an ignorance of ensuring energy security. In addition, population growth may cause high energy consumption and then carbon dioxide emissions in the long run. Then the insufficient efforts of oil exporting countries to ensure energy security and environmental sustainability may create a deficiency in achieving the balance between the three dimensions of the trilemma (Hafner et al., 2023).

Conclusion and Policy Implications

This study is regarded as a first attempt to investigate the effect of digitalization on the energy trilemma in the MENA region over the period from 2000 to 2021. The study also aims at providing recommendations for policymakers concerning digital transformation that are compatible with securing energy supply and mitigating carbon emissions in the region.

To reach the previous objectives of the thesis, a preparatory literature accompanied by a brief overview of digitalization and the energy sector in the MENA region was needed to understand how digitalization affects the energy trilemma in the region. It was found that digitalization and information and communications technologies (ICT) in the MENA region are very diverse due to different levels of development both between and within countries. Nevertheless, nearly all countries in the region are pursuing policies supporting digitalization.

[13] https://www.undp.org/saudi-arabia/stories/saudi-arabia-government-join-forces-implement-energy-efficiency-labels

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Concerning energy trilemma dimensions in the MENA region, it was found that the MENA region relies heavily on hydrocarbons for its energy mix, leading to concerns about eroding export base due to growing domestic demand. Despite vast oil and gas reserves, millions in the region lack access to electricity and clean cooking fuels. However, MENA countries have made progress in addressing environmental issues and improving sustainability. In this regard, digitalizing the energy sector has allowed for greater integration of renewable energy sources, improved energy efficiency, and better demand-side management to address the energy trilemma's sustainability dimension.

Finally, it was found that three distinct perspectives on the impact of digitalization on the energy trilemma have been identified: the optimistic view sees technological advancements as solutions to securing energy supply and reducing environmental harm; the pessimistic view reflects doubts about the effectiveness of technology in addressing these issues; and the third view regards the connection between ICT and the energy trilemma as uncertain.

In addition, a panel data model will be applied to study the effect of digitalization on the energy trilemma in the region. The generalized method of moment (GMM) and the fully modified ordinary least squares (FMOLS) are employed to examine this effect in the short and long run, respectively.

The GMM results reveal that information and communication technology has an insignificant effect on the energy trilemma index and its three dimensions in the short run. This is can be justified on the ground that some MENA countries try to find a way to decarbonize their energy sector by exploiting their existing capacities, technologies and competitive advantages in traditional energy forms but they can not achieve their targets in the short run (Hafner et al., 2023).

FMOLS results reveal that information and communication technology is positively associated with the energy trilemma index and its energy security and affordability dimensions while negatively associated with the environmental sustainability dimension in the long run. This may be grounded in ICT's synergistic effects in the region since ICT facilitates energy efficiency, renewable energy integration, demand-side management, and policy formulation, all of which contribute to improving the energy trilemma index.

Policy Recommendations

Based on the previous information concerning the role of digitalization in tackling the energy trilemma and its three dimensions, policymakers can enhance energy security, affordability, and environmental sustainability by involving digitalization in the energy sector through:

- Promoting digital infrastructure such as broadband connectivity and data networks and establishing data sharing mechanisms between energy stakeholders, including energy producers, distributors, consumers, and technology providers, to facilitate the integration of digital technologies in the energy sector and enable efficient data collection, analysis, and monitoring of energy systems (Zhang et al., 2023).
- Investing in research and development initiatives that focus on digital solutions for the energy sector and support innovation hubs, start-ups, and academic institutions to develop and deploy technologies such as smart grids, energy management systems, and Internet of Things (IoT) devices for efficient energy use (Nizam et al., 2020).
- Investing in training programs and educational initiatives that enhance digital literacy and technical skills for professionals in the energy sector will ensure a competent workforce capable of effectively utilizing digital tools and technologies for energy management and decision-making (Oyelaran et al., 2007).
- Fostering international collaboration and knowledge-sharing platforms such as partnerships, conferences, and forums dedicated to energy and digitalization to exchange best practices, lessons

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learned, and success stories in utilizing digitalization to address the energy trilemma (Zhang et al., 2023).

References

Hafner, M., Raimondi, P. P., & Bonometti, B. (2023), The MENA region: an economic, energy, and historical context. In The Energy Sector and Energy Geopolitics in the MENA Region at a Crossroad: Towards a Great Transformation?, Springer International Publishing, pp. 3-25.

Oyelaran-Oyeyinka, B., Lal, K., & Adeya, C. N. (2007). Institutional support for collective ICT learning: Cluster development in Kenya and Ghana. In B. Oyelaran-Oyeyinka & D. McCormick (Eds.), Industrial clusters and innovation systems in Africa: Institutions, markets, and policy (pp. 269–293). United Nations University Press. http://collections.unu.edu/view/UNU:2478

Reference to a Journal publication

Al-Mulali, U., Sheau-Ting, L., & Ozturk, I. (2015), "The global move toward Internet shopping and its influence on pollution: an empirical analysis", Environmental Science and Pollution Research, Vol. 22 No.13,pp. 9717-9727.

Ang, B. W., Choong, W. L., & Ng, T. S. (2015), "Energy security: Definitions, dimensions and indexes", Renewable and sustainable energy reviews, Vol .42, pp.1077-1093.

Avancini, D. B., Rodrigues, J. J., Martins, S. G., Rabêlo, R. A., Al-Muhtadi, J., & Solic, P. (2019), "Energy meters evolution in smart grids: A review", Journal of cleaner production, Vol. 217, pp.702-715.

Charfeddine, L., & Kahia, M. (2019),Impact of renewable energy consumption and financial development on CO2 emissions and economic growth in the MENA region: a panel vector autoregressive (PVAR) analysis, Renewable energy, Vol. 139, pp.198-213.

Chi, Y., Esily, R. R., Ibrahiem, D. M., Houssam, N., Chen, Y., Jia, X., & Zhang, X. (2023), Is North Africa region on track to energy trilemma for enhancing economic progress? The role of population growth and energy usage, Energy Strategy Reviews, Vol.50, p.101245.

Choi, I. (2006), Nonstationary panels, Econometric theory, Vol. 1, pp.511-539.

Coroamă, V. C., & Mattern, F. (2019). "Digital Rebound–Why Digitalization Will Not Redeem Us Our Environmental Sins", In 6th International Conference on ICT for Sustainability, Lappeenranta, Finland 2019.

Cronin, J., Anandarajah, G., & Dessens, O. (2018), "Climate change impacts on the energy system: a review of trends and gaps", Climatic change, Vol. 151, pp.79-93.

Esily, R. R., Yuanying, C., Ibrahiem, D. M., Houssam, N., Makled, R. A., & Chen, Y. (2023), Environmental benefits of energy poverty alleviation, renewable resources, and urbanization in North Africa, Utilities Policy,Vol. 82, p.101561.

Fang, D., Shi, S., & Yu, Q. (2018), "Evaluation of sustainable energy security and an empirical analysis of China". Sustainability, Vol. 10 No.5, p. 1685.

Göll, E., & Zwiers, J. (2018)," Technological trends in the MENA region: the cases of digitalization and information and communications technology (ICT) ".

Grigoryev, L. M., & Medzhidova, D. D. (2020)," Global energy trilemma" Russian Journal of Economics, Vol 6, p. 437.

Gunningham, N. (2013), "Managing the energy trilemma: The case of Indonesia" , Energy Policy,VOL 54, pp.184-193.

Ha, L. T. (2022), Are digital business and digital public services a driver for better energy security? Evidence from a European sample, Environmental Science and Pollution Research,Vol. 29 No.18, pp.27232-27256.

Han, X., Chen, Y., Feng, Q., & Luo, H. (2022), "Augmented reality in professional training: A review of the literature from 2001 to 2020", Applied Sciences,Vol. 12 No.3, p.1024.

Joëts 2, M. (2011), On the relationship between forward prices of crude oil and domestic fuel: A panel data cointegration approach 1, Économie internationale, No. 2,pp. 39-49.

Khan, I., Hou, F., Irfan, M., Zakari, A., & Le, H. P. (2021), "Does energy trilemma a driver of economic growth? The roles of energy use, population growth, and financial development", Renewable and Sustainable Energy Reviews, Vol. 146, p. 111157.

Khan, M., & Majeed, M. T. (2023), Financial sector development and energy poverty: empirical evidence from developing countries, Environmental Science and Pollution Research,Vol. 30 No.16,pp. 46107-46119.

Lu, W. C. (2018), "The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries", Mitigation and Adaptation Strategies for Global Change, Vol. 23 No.8, pp.1351-1365.

Manchanda, H. (2023), The relationship between economic growth, energy consumption, and CO2 emissions: A comprehensive analysis. ET Energy World.

Miskiewicz, R. (2022), "Clean and Affordable Energy within Sustainable Development Goals: The Role of Governance Digitalization", Energies,Vol. 15 No.24, 9571.

Network readiness index (2024), " Network readiness index", available at: https://networkreadinessindex.org/countries/

Ng, V. K., & Cribbie, R. A. (2019), The gamma generalized linear model, log transformation, and the robust Yuen-Welch test for analyzing group means with skewed and heteroscedastic data, Communications in Statistics-Simulation and Computation, Vol. 48 No.8,pp. 2269-2286.

Nizam, H. A., Zaman, K., Khan, K. B., Batool, R., Khurshid, M. A., Shoukry, A. M.,& Gani, S. (2020), "Achieving environmental sustainability through information technology:"Digital Pakistan" initiative for green development", Environmental Science and Pollution Research, pp.1-16.

Pamlin, D., & Pahlman, S. (2008), "Outline for the first global IT strategy for CO2 reductions", A billion tonnes of CO2 reductions and beyond through transformative change. WWF Sweden.

Volume: 3, No: 8, pp. 11837 – 11859
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5785
Pence, K. M. (2006), The role of wealth transformations: An application to estimating the effect of tax incentives on saving, Contributions in Economic Analysis & Policy,Vol. 5 No.1.
Plepys, A. (2002), "The grey side of ICT. Environmental Impact Assessment Review", Vol. 22 No.5, pp. 509–523.
Saeed, F. (2021), "Environmental sustainability and digitization"., International Journal of Modern Agriculture and Environment, Vol. 1 No.2, pp.83-98.
Salah,S.,Eltaweel,M., Abeykoon,C.(2022), " Towards a sustainable energy future for Egypt: A systematic review of renewable energy sources, technologies, challenges, and recommendations",Cleaner Engineering and Technology,Vol. 8, p.100497.

Singh, R., Akram, S. V., Gehlot, A., Buddhi, D., Priyadarshi, N., & Twala, B. (2022), "Energy System 4.0: Digitalization of the energy sector with inclination towards sustainability", Sensors, Vol. 22 No.17, p.6619.
Šprajc, P., Bjegović, M., & Vasić, B. (2019)," Energy security in decision making and governance-Methodological analysis of energy trilemma index", Renewable and Sustainable Energy Reviews,Vol 114, p.109341.
Thanh, T. T., Ha, L. T., Dung, H. P., & Huong, T. T. L. (2022), Impacts of digitalization on energy security: evidence from European countries. Environment, Development and Sustainability, p.1-46.
The international encyclopedia of communication theory and philosophy) 2016)," Digitalization", The international encyclopedia of communication theory, pp.1-11.
Wang, J., Ghosh, S., Olayinka, O. A., Doğan, B., Shah, M. I., & Zhong, K. (2022), Achieving energy security amidst the world uncertainty in newly industrialized economies: The role of technological advancement, Energy,Vol. 261, p.125265.
Yahyaoui, I., & Bouchoucha, N. (2021), The long-run relationship between ODA, growth and governance: An application of FMOLS and DOLS approaches, African Development Review,Vol. 33 No.1,pp. 38-54.
Zhang, C., & Liu, C. (2015), "The impact of ICT industry on CO2 emissions: a regional analysis in China", Renewable and Sustainable Energy Reviews, Vol. 44, pp.12-19.
Zhang, S. H., Yang, J., & Feng, C. (2023), "Can internet development alleviate energy poverty? Evidence from China", Energy Policy,Vol. 173, p.113407.
Reference to a website
British Petroleum (BP) Statistical Review of World Energy, (2024),Primary energy consumption. available at: https://www.bp.com/en/global/corporate/energy-economics.html
United Nations Development Program (2021), " Saudi Arabia: government join forces to implement Energy Efficiency Labels ", available at: https://www.undp.org/saudi-arabia/stories/saudi-arabia-government-join-forces-implement-energy-efficiency-labels
International Energy Agency (2017), " Digitalization and Energy", available at : https://www.iea.org/reports/digitalisation-and-energy

EcoMENA (2023), " Sustainability in the Middle East: Complications and Opportunities", available at: https://www.ecomena.org/sustainability-middle-east/
Reference to a database
International Energy Agency (IEA),(2024),Total energy supply by source . available at: https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=ALGERIA&fuel=Energy%20supply&indicator=TESbySource
International Energy Agency (IEA),(2024),Total energy supply by source . available at: https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=ALGERIA&fuel=Energy%20supply&indicator=TESbySource
International Energy Agency (IEA),(2024),Total energy supply per capita . available at: https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=ALGERIA&fuel=Energy%20supply&indicator=TESbyPop
International Monetary Fund (2024), " Growth and Stability in the Middle East and North Africa", available at: https://www.imf.org/external/pubs/ft/mena/04econ.htm
WorldBank.(2024). Access to clean fuels and technologies for cooking (% of population) .available at: https://data.worldbank.org/indicator/EG.CFT.ACCS.ZS
WorldBank.(2024). Access to electricity (% of population).available at:https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
WorldBank.(2024). Carbon dioxide emissions. available at: https://data.worldbank.org/indicator/EN.ATM.CO2E.KT
WorldBank.(2024). Fixed telephone supscreptions per 100 people .available at: https://data.worldbank.org/indicator/IT.MLT.MAIN
WorldBank.(2024). Gross Domestic Product .available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.KN
WorldBank.(2024). Individuals using the Internet (% of population) available at: https://data.worldbank.org/indicator/IT.NET.USER.ZS
WorldBank.(2024). Mobile cellular telephone subscriptions per 100 people. available at: https://data.worldbank.org/indicator/IT.CEL.SETS.P2
WorldBank.(2024). Monetary sector credit to private sector (% GDP).available at: https://data.worldbank.org/indicator/FM.AST.PRVT.GD.ZS
WorldBank.(2024). Total natural resources rents (% of GDP).available at: https://data.worldbank.org/indicator/NY.GDP.TOTL.RT.ZS
WorldBank.(2024).Population.available at: https://data.worldbank.org/indicator/SP.POP.TOTL
WorldBank.(2024).The share of renewables in total final energy consumption. available at: https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS

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