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RESEARCH PAPER

Investigating the Effectiveness of E-government in Improving Environmental Quality: Evidence from MENA Countries

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Abstract

In recent decades, the destruction of the environment and the emission of greenhouse gases such as CO_2 has become a national and transnational crisis for many governments worldwide. In this respect, information and communication technology (ICT) and its increasing growth in these years have given governments an appropriate opportunity to implement and expand e-government and to create a chain of changes in governance and macro-management. Also, by providing efficient electronic services, they can better deal with the existing challenges and play a more effective role in improving society's environmental quality and welfare. The present research investigates the relationship between the development of e-government and CO_2 emissions in the Middle East and North African countries (MENA) between 2007 and 2022, using the GMM approach. The obtained results show that the development of e-government has had a negative and significant impact on CO_2 emissions in the mentioned countries. Moreover, the results affirmed the EKC hypothesis in the MENA countries since economic growth is positively linked to CO_2 emissions. In contrast, the economic growth square is linked negatively to the environmental degradation indicator. Furthermore, per capita energy consumption, industry development, and urbanization positively affect CO_2 emissions, and trade openness has statistically insignificant effects on CO_2 emissions. Thus, the authorities in this group of countries must take necessary measures to reduce carbon dioxide emissions and help improve environmental quality by implementing and improving electronic government as much as possible.

Keywords: CO_2 Emissions, Economics, EGDI, Middle East and North African Countries (MENA), Panel Data.
JEL Classification: C33, H11, N70, O1, Q53.

1. Introduction

In the last two decades, environmental standards and environmental considerations have been the subject of intense research. With the growth and

development of societies, the quality of the environment has become more important. Despite the fundamental differences in nature and nature of the environmental problems, the whole issue is visible in all countries. In this regard, the environment is one of the main pillars of sustainable development (Arbab and Shabani, 2017). In recent years, the concentration of greenhouse gases has been increasing significantly. This factor is the main cause of global warming and a serious threat to environmental sustainability (Pachauri et al., 2014). Since greenhouse gas emissions, the ground temperature has risen about 0.6℃ and reached the highest level in the past millennium. Meanwhile, carbon dioxide is a more durable gas in the atmosphere than other greenhouse gases. This gas is continuously distributed worldwide and leads to severe global warming (Ahmet et al., 2021). Global warming reports warn that if carbon dioxide emissions continue at the current rate, the average global temperature will increase by 4℃ (5.4 and 7.2°F) until 2100. Such a temperature rise will lead to plant and animal species extinction, changes in agricultural patterns, and rising sea levels (Xiaoyan et al., 2021). However, natural factors such as topography and climate affect air quality. In this connection, the growing economic activities and population growth after the Industrial Revolution have been the main sources of carbon dioxide and air pollution. Factors such as population growth, the increased number of factories, the rapid expansion of transportation, the multitude of old and worn-out vehicles, and excessive fuel consumption are the basis for creating and expanding air pollution (Alliance Development Works and Unu-Ehs, 2013).

In recent years, e-Government has played an important role in the dimensions of human life as a product of the evolution of information and communication technology (ICT), and governments have been trying to establish an important step in its establishment. E-government has tried to tackle the move toward the information community by better offering services, promoting community welfare, and overcoming existing challenges, especially in environmental quality improvement.

In recent years, the electronic state's implementation and evolution have changed the way of governance and government management and entered a new era of urban management and industrial management, agriculture, and services (Ameli, 2017). In fact, e-government allows government, citizens, businesses, and customers to work more efficiently. It facilitates the relationship between a government with citizens (B2C), government relationship with the business (G2B), business relationship (B2B), and each other. Furthermore, it makes the

relationship of businesses (B2C) easier, less expensive, and more cost-effective**.** E-government can be defined in many dimensions, such as electronic society, electronic management**,** and electronic citizens. Successful e-government implementation can improve government services, reduce costs and energy, enhance participation through government and citizens' knowledge, empower citizens, improve business and industry interaction, increase effectiveness and efficiency in stakeholder satisfaction**,** and improve services (Huo et al., 2021). In general, digitization of information, non-physical transfers, reducing the need for large space in offices and warehouses, shortening the supply chain, lowering energy consumption, and increasing the recycling possibility are among the important and positive results of the development of e-government on the environment.

Recent research has emphasized the impact of economic and communication technology factors on the quality of the situation. However, the present study employs a political and functional framework to investigate the relationship between the e-government development index on environmental quality performance (carbon dioxide emission), which has been less considered in previous studies. This study reviews and analyzes the impact of the e-government development index (EGDI) on carbon dioxide dissemination in 17 countries in the Middle East and North Africa (MENA), including Iran, during the 2007 to 2022 period. It is worth noting that these countries were selected based on the statistics available for the required variables. Also, GDP variables, per capita energy consumption, industry development index, urbanization rate, and trade intensity index are introduced as control variables.

The remainder of this article is organized as follows: Sections 2, 3, and 4 are devoted to theoretical foundations, the background of the study, the method, and materials and materials of the study, respectively. Also, Sections 5 and 6 offer the research findings and conclusion & policy implications, respectively.

2. Theoretical Literature

2.1 An Overview of the E-Government

The term "e-government" is applied to describe a variety of interactions between public authorities on one side, vidual citizens and other residents, or businesses and other non-governmental entities on the other side, using information and communications technology (Reitz, 2006). One of the popular definitions provided by the World Bank for e-government is: "the use by government agencies of information technologies (such as Wide Area

Networks, the Internet, and mobile computing) that can transform relations with citizens, businesses, and other arms of government" (The World Bank, 2015). "e-government" generally refers to local or national government information and services being made available. through the internet via web browsers or mobile apps. Examples of information provided may include new business regulations, announcements of public events, and general updates on current affairs. Examples of services provided may include the renewal of driver's licenses, payment of taxes, and applications for business permits. E-government encompasses various sub-concepts describing specific types of interactions, such as "e-filing," "e-publication," "e-procurement," and "e-payment" (Reitz, 2006). It is commonly recognized that one of the most important factors in public acceptance of e-government, i.e., the willingness of public constituents to partake in e-government services, is confidence in government (Bélanger and Carter, 2008). The main objective of e-government is to improve efficiency, reduce government cost and time (i.e., tangible outcomes), and achieve citizens' satisfaction and trust in government (i.e., intangible results) (Malodia et al., 2021). The E-Government Digital Index (EGDI) is the concept to increase the development of Southeast Asia. EGDI can be defined as the use of information and communication technology (ICT) in communicating with governments and conducting business through electronic media (Turmanidze et al., 2020). The development of e-Government can be traced by analyzing the United Nations e-Government survey reports around the world. Since 2001, every two years, the United Nations Department of Economic and Social Policy has reviewed the level of development of e-government services in all 193 member countries. However, it is only since 2003 that the United Nations has presented the collected information in the form of a report. Eleven editions of the survey were published until June 2023: 2003, 2004, 2005, 2008, 2010, 2012, 2014, 2016, 2018, 2020, and 2022. The reports show the level of e-government development in each country. They also identify countries and regions where the potential of information and communication technology (ICT) and e-government is exploited and which countries should be supported in their development. The e-government development is measured according to the UN-developed EGDI (E-Government Development Index). This index is designed to assess the e-government development at the national level. It is a composite index based on a weighted average of three standardized indicators. Each of the three indicators, also composite measures, can be extracted and analyzed independently.

One-third of the EGDI relies on the Telecommunications Infrastructure Index (TII) calculated from data provided by the International Telecommunication Union (ITU). Another one-third of the EGDI depends on the Human Capital Index (HCI), which is calculated from data provided by the United Nations Educational, Scientific and Cultural Organization (United Nations Department of Economic and Social Affairs, 2022), which assesses the national online presence of all 193 UN member states. The above index also includes the E-Participation Index (EPI), an index complementary to the UN E-government survey that focuses on governments' use of online services in order to share electronic information, run e-consultation and make e-decisions. The methodological basis for calculating the EGDI remained consistent across all survey periods, while its components (the three index-building indicators) were updated to reflect current trends in e-government, telecommunications, and human capital. It is worth noting that until 2008 the EGDI was treated as a measurement of e-government readiness (E-Government Readiness Index, EGRI). Only since 2010 has the name of the index been changed to the E-Government Development Index (EGDI) (with minor changes to the methodology). The composite value of each component indicator discussed here is then normalized to fall between 0 and 1, and the overall EGDI value is obtained by taking the arithmetic mean of the three components (Ziolo et al., 2022).

2.2 The Relationship between EGDI and Environment

The natural environment has been unprecedentedly challenged because of the exponential growth of the human population, greater interest in economic development and industrialization, and increasing anthropogenic activities (Arora, 2018; Chakravarty and Mandal, 2020). To achieve environmental sustainability, many governments have allocated substantial investments to e-government initiatives, e.g., the development and use of information and digital technologies for improving government services and administrations (Medaglia et al., 2021) Providing a digital platform for citizens to participate, engage, and be empowered in environmental decision-making and other activities is critical for achieving sustainability goals (Koontz, 2006). Citizens are much more enthusiastic and eager than ever to use ICT technologies and engage (i.e., perform e-collaboration) in environmental preservation (He et al., 2017).

Since central and local governments are the main stakeholders that influence environmental sustainability (Zampo and Pramatari, 2011), many authors are

interested in better understanding the impact of the digital revolution on the environment and identifying the relationship between e-government and sustainable development. e-government affords citizens an opportunity to inform and participate in environmental issues (Hay and Griffiths, 2008) the importance of strategic alignment in e-government transformation layers is essential for environmental sustainability (Haigh and Griffiths, 2008). Some researchers believe that the safest way to improve the environment is for countries to move towards a service economy, the main driver of which is the development of ICT infrastructure and the evolution of e-government (Panayotou et al., 2000). Environmental sustainability is the result of e-government initiatives, and the development of e-government has a positive effect on environmental sustainability through saving fossil fuel consumption and reducing paper consumption and carbon footprint (Al-Khouri., 2013; Krishnan et al., 2013). Additionally, remote work options and teleconferencing facilities can decrease the travel-related carbon footprints of government employees. Digitization of affairs through the evolution of e-government can reduce energy demand or harmful emissions (GeSI, 2015). In addition, the development of e-government can greatly help governments in the successful management of natural resources (NICA, 2015). The development of e-government not only directly affects the sustainability of the environment, but it can also have indirect effects by increasing the effectiveness of the government on the environment, the implementation of e-government reduces urban transportation, traffic, and air pollution (Young Bum, 2017; Jouzbarkand et al., 2011; Ernst and Young, 2003). E-government can facilitate the collection, analysis, and dissemination of environmental data. Through online platforms and databases, governments can monitor various environmental indicators such as air quality, water pollution levels, waste management, and deforestation rates. Timely and accurate information enables better decision-making and targeted interventions to improve environmental quality. E-government platforms can promote citizen engagement in environmental issues. Online portals, forums, and social media channels provide opportunities for individuals to voice their concerns, provide feedback, and participate in environmental decision-making processes. This increased transparency and inclusivity can lead to greater public awareness, accountability, and collective action toward environmental conservation. E-government can also streamline administrative processes and improve coordination among different government agencies involved in environmental management. Electronic systems for permitting, licensing, and compliance monitoring can enhance efficiency, reduce bureaucratic delays, and ensure better

enforcement of environmental regulations. This can contribute to more effective policy formulation and implementation.

At a more general glance, Jafari Parviz et al. (2021) states that by developing ICT, previous production processes are corrected, and environmental quality is improved by reducing the consumption of raw materials and physical resources. In such a way, manufacturing mechanisms that require high energy consumption are replaced by more optimal methods that require low energy consumption and higher productivity. Replacing physical books with electronic books, electronic systems, virtual summits, smart transportation systems, geographic location determination systems (GPS), and smart traffic control systems can increase energy consumption and decrease the emissions of the environment.

On the other hand, few studies focus on the negative relationship between e-government and environmental sustainability. Haigh (2004) explained the contradictory effects of e-government on environmental sustainability in literature. this author notes plenty of research gaps in e-government literature. He argues that an accurate explanation of the relationship between e-government and environmental sustainability requires and focuses on potential factors that exceed the quality of e-government by living quality. He also recognizes the need to evaluate ICT infrastructure that may lead to inefficient energy consumption and to acknowledge the problem of electronic waste or high energy infrastructure and applications, e.g., cloud computing centers, data centers, ultra-fast servers, and cooling equipment. Al-Khouri (2013) argues that although the world has grown significantly with the help of ICT, it has increased social costs. Therefore, it can potentially and indirectly have negative effects on the environment. This author also argues that environmental stability must be a key principle in electronic state initiatives. carbon dioxide emissions significantly increase during the production and distribution process of IT and communication technology equipment. ICT equipment waste electronic waste (e.g., electronic devices consumed and their components such as phones, computers, and compact tablets) have harmful effects on the environment (Park et al., 2018).

3. Literature Review

The research related to the impact of electronic government on environmental quality has been conducted qualitatively and most of the studies have focused on the impact of information technology on the environment. Since e-government means the use of information technology in all fields, so this section refers to studies that are closely related to the subject of the present research.

Falahi et al. (2012) have shown that ICT directly impacts environmental quality in Iran.

Moradhasssel and Mozayeni (2013) showed that ICT in developed countries moderates the increasing trend of environmental pollution accumulation. In contrast, in developed countries, the impact of ICT on environmental pollution has not been noticeable. The results also showed that the increase in the number of Internet users had lowered environmental quality in Iran.

Zhang and Liu (2015) examined the impact of the ICT industry on CO_2 emissions at the national and regional China levels using the STIRPAT model and provincial panel data between 2000 and 2010. This study showed the significant effect of ICT development on carbon dioxide emissions.

In a study, Salahuddin et al. (2016) investigated the short- and long-run effects of Internet usage and economic growth on carbon dioxide (CO_2) emissions using OECD panel data from 1991 to 2012. They found that information technology in OECD has directlyaffected carbon dioxide emissions in the long run.

Arbab and Shabani (2017) examined the relationship between ICT and environmental pollution in D_8 member states during the 1994-2004 period. The results revealed a significant relationship between ICT and the reduction of air pollution, suggesting the improving quality of the environment in parallel with ICT development.

Aragis and Ozjan (2017) analyzed the impact of information and communication technology (ICT) on CO2 emissions using a panel of 20 emerging economies from 1990 to 2015. The findings showed that increasing access to the Internet has led to a decrease in air pollution. In addition, the results of the panel causality test show unidirectional causality from Internet use to CO2 emissions.

In another study, Añón Higón et al. (2017) studied the relationship between ICT and carbon dioxide emissions in 142 economies, (116 developing and 26 developed countries), over the period 1995 to 2010 using a panel data approach. The results confirmed that the relationship between ICT and CO2 emissions is an inverted U-shaped relationship. Moreover, while for the sample of developing countries, the ICT turning point is well above the mean value, the opposite is true for the sample of developed countries. This implies that many developed countries have already attained the level of ICT development, at which CO_2 emissions decrease as the level of ICT development improves further.

Krishnan and Teo (2017) examined the relationship between e-government development and e-commerce development (e-business) with environmental

stability. For this purpose, they used statistical data from 122 countries from 2004 to 2008. The results showed that both e-government development and e-business development have a positive direct impact on environmental sustainability.

In another study, Asongu et al. (2017) examined the effect of information and communication technology (ICT) on carbon dioxide (CO_2) emissions in forty-four Sub-Saharan African countries for the period 2000–2012 using the GMM approach. The findings broadly show that ICT can be employed to dampen the potentially negative effect of environmental pollution on human development.

Park et al. (2018) investigated the impact of using the Internet on carbon dioxide emissions in EU-selected countries based on the group average method from 2001 to 2014. The experimental findings revealed that using the Internet has a long-term direct relationship with the release of carbon dioxide and reduced environmental quality in EU member states. In other words, their innovative findings show that using the Internet threatens sustainable development.

Haseeb et al. (2019) investigated the impact of Internet use and mobile subscriptions (ICTS) on carbon dioxide release in the Brix Group (Brazil, Russia, India, China, and South Africa) in 2014-1994 based on dynamic regression (DSU). The results showed that using the Internet and mobile subscriptions (ICTS) significantly negatively impacted carbon dioxide emissions. In other words, ICT positively contributes to environmental quality.

Avom et al. (2020) examined the impact of ICT on carbon dioxide emissions in the Persian Gulf countries through the method of panel data over the period 2000 to 2015. The results indicated that ICT directly affects carbon dioxide emissions, suggesting a U-shaped relationship between ICT and Carbon dioxide emissions.

Jafari Parviz Khanlou et al. (2021) concluded that ICT directly and significantly impacted carbon dioxide emissions in the Persian Gulf countries. As can be seen, earlier research has rarely examined the impact of e-government on environmental quality. Meanwhile, most of the research has examined the impact of ICT on environmental quality, indicating the importance and development of the present study.

Xiaoyan et al. (2021) investigated the impact of the digital economy on carbon dioxide emissions in 190 countries from 2005 to 2016 with the approach of the Data Panel with constant impacts with the regression method. The results indicated a U-shaped and non-linear relationship between carbon dioxide emissions and digital economics.

Dhaoui (2021) examined the role of e-government in various aspects of economic and social development and environmental development in 15 countries

in the Middle East and North Africa between 2003 and 2018 through the data panel. This author employed the environmental management index to measure environmental sustainability. The results showed that e-government development has no positive or significant impact on the various dimensions of development, especially the environment.

Ziolo et al. (2022) examined the relationship between the Electronic Government Development Index (EGDI) and ESG factors (environmental, social, and economic factors) in 26 European countries (in the period 2003-2020). For the study, the TOPSIS (order priority technique with similarity to the ideal solution) linear ordering method was used, followed by the Percal index and the method of selecting optimal predictors - Hellwig's method. The main findings show statistically significant relationships between EGDI and total variables representing environmental, social, and economic domains.

Dutta and Hazarika (2023) conducted research on the effect of urbanization along with the gross domestic product (GDP) per capita, foreign direct investment (FDI) inflow, trade openness, and mobile phone penetration on carbon dioxide emissions in 68 low-income and lower-middle-income countries across Asia, Africa, Middle East, and South America using the fully modified ordinary least squares method between 2000 and 2019. Results showed that urbanization followed by GDP per capita are the key promoters of CO2 emissions across all countries, whereas the direction and significance of inward FDI and trade openness varied across regions. Furthermore, it was observed that mobile phone penetration (as an indicator of information and communication technology (ICT)) has a significant and negative relationship with CO_2 emissions.

4. Data and Methodology

4.1 Method

In this study, a dynamic panel model is required regarding the dynamic nature of the data included in the study and the dependence of their current behavior on their past behavior. Thus, the dynamic nature of the model prevents using standard Ordinary Least Squares (OLS) estimators, which might be biased and inconsistent due to the correlation between the unobserved panel-level effects and the lagged dependent variable (Hasanovic and Latic, 2017). Therefore, the fixed/random effect models used for panel data do not solve the econometric problems inherent in dynamic models. In this respect, Arellano and Bond (1991) introduced a new generalized method of moments (GMM) estimator for the dynamic panel model to address the endogeneity problem. This model generates biased findings and

handles unobserved heterogeneity between banks, which cannot be correctly measured. They proposed to incorporate additional instruments in the dynamic panel model and to use different transformations. Later, Arellano and Bover (1995) and Blundell and Bond (1998) proposed an improvement of the Arellano & Bond estimator by imposing additional restrictions on the initial conditions. These efforts allow for the introduction of more instruments to improve efficiency. Accordingly, the model combines the first difference in equations with equations at the level where the variables' first differences are instrumented. Besides, it generates a system of two equations (System GMM), one original and one transformed. GMM controls for endogeneity, unobserved panel, heterogeneity, autocorrelation, omitted variable bias, and measurement errors. Bond (2002) claims that the unit root property biases the difference GMM estimator, whereas System GMM produces more exact findings. The differenced GMM method corrects endogeneity by first differencing all regressors and removing fixed effects. However, the first difference transformation is flawed because it subtracts the prior observation from the current one, amplifying data loss gaps (Ullah et al., 2018). As a result, it affects the projected result to some extent. To correct endogeneity, the System GMM technique introduces more instruments for the lagged dependent variable and any other endogenous variable to drastically enhance efficiency. Besides, it transforms the instruments to make them uncorrelated (exogenous) with fixed effects. Finally, instead of removing the prior observation from the current one as Differenced GMM does, System GMM subtracts the average of all future available variable observations (Roodman, 2009). Generally, this method is used when the number of cross-cutting variables (N) is greater than the number of times and years (T) (Baltagi, 2008). In the present study, this condition is affected such that the number of countries (N = 17) exceeds the time period (T = 16). As a result, System GMM was used in this study to investigate the relationship between the explanatory and dependent variables under study.

4.2 Data

In the present study, the impact of e-government development on carbon dioxide dissemination is examined in 17 countries in the Middle East and North Africa (i.e., Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Lebanon, Libya, Morocco, Malta, Oman, Saudi Arabia, Syria, Tunisia, United Arab Emirates, and Yemen) from 2003 to 2018. To this end, the Generalized Method of Moment (GMM) approach in STATA14 software is applied. It is of note that the countries were chosen based on the statistics available for the required variables. The variables'

statistical data are compiled from the World Bank World Development Indicators (WDI), CO_2 Emissions of all world countries Report (2022), and the UN Department of Economic and Social Affairs. All variables have also been used as logarithmic to explain the elasticity. The model is inspired by Dhaoui (2021) and Liu and Bae (2018) as Equation (1):

$$LCO_{2_{it}} = f(LEGDI_{it}, LGDP_{it}, LGDP^2{}_{it}, LEN_{it}, LIND_{it}, LUR_{it}, LTR_{it}) \quad (1)$$

$LCO_{2_{it}}$: The dependent variable in this study is the logarithm of the per capita emission of carbon dioxide (Tons Per Capita).

$LEGDI_{it}$: It is the logarithm of e-government development. EGDI is the criterion for measuring and ranking countries for e-government development. Given the importance of this variable in the present study, inspired by the study of Dhaoui (2021), the data existing by the linearization method (assuming that the variables follow the linear process) were calculated and used. Electronic government development will reduce air pollution (carbon dioxide emissions) and environmental stability by improving government activities, saving energy, reducing urban trips, and reducing paper consumption.

$LGDP_{it}$: It is the logarithm of Per Capita Gross Domestic Product (constant 2015 US$). In scientific literature, there are three major views on the effect of GDP on carbon dioxide. The first view is raised by many social scientists and natural sciences who believe that higher levels of economic activity (production or consumption) require more energy and raw materials, resulting in greater amounts of sub-materials. Extraction of the future of natural resources results in increased environmental degradation (Panayotou, 1993). The second view is raised by those who believe that the fastest way to improve the quality of the environment (reduced pollution) depends on the path of economic growth. The reason is that higher income levels increase demand for commodities that use fewer raw materials. The third view, raised in the early 1990s, became known as the Kuznets curve. This view considers the reversal relationship between economic growth and environmental quality criteria. According to this hypothesis, the relationship between economic growth and environmental quality, whether positive or negative, is not constant while a country develops (Pajouyan and Moradhassles, 2007).

$LGDP^2{}_{it}$: It is the square of the Logarithm of GDP (constant 2015 US$). This index has been used to investigate the existence of the Kuznets relationship in the countries under study. Awan and Azam (2022) examined the validity of the EKC hypothesis for the five most influenced economies of the G-20 and findings

confirm that veto-power economies have an N-shaped relationship between CO2 emissions and GDP per capita. Allard et al. (2018) evaluate the N-shaped environmental Kuznets curve (EKC) and realized there is a relationship between CO2 emissions and GDP per capita for 74 countries. Shehzad et al. (2022) scrutinized the N-shaped environmental Kuznets curve (EKC) theory. The verdicts confirmed the subsistence of an N-shaped relationship amid economic growth and ecological footprints in Algeria.

LEN_{it}: It is the logarithm of per capita energy consumption (kg of oil equivalent). In recent years, fossil fuel production, nuclear power plants, extensive use of water resources, irreparable damage such as air pollution, acid rains, nuclear waste, surface and groundwater pollution, forest damage, and soil erosion have exposed countries to many problems. Therefore, it is expected that the increase in per capita energy consumption will lead to increased carbon dioxide emissions. In a study, Acheampong (2018) realized that energy consumption stimulates CO2 emissions in the MENA region. The results of the study by Liu and Bae (2018) also show that an increase in energy consumption leads to an increase in carbon dioxide emissions in China. Massagony and Budiono (2023) found that fossil energy consumption has a positive effect on the rise of CO2 emissions in Indonesia.

$LIND_{it}$: It is the logarithm of the index of countries' industry development. In this study, the value-added ratio of the industry to domestic production was calculated .Clearly, the formation of huge polluting industries is wearing out the land and increasing carbon dioxide emissions by destroying the environment and the ecological system. The results of the Liu and Bae (2018) study show that industrialization in China leads to an increase in the increase of carbon dioxide emissions. The findings of Voumik and Ridwan (2023) indicate that industrialization harms the environment in Argentina in the long run. Hence, the increase in industries is expected to increase carbon dioxide emissions.

LUR_{it}: It is the logarithm of the urbanization rate. Studies on the impact of population growth and urban growth on environmental pollution indicate the relationship between these variables and the amount of air pollution emissions. Increasing urbanization due to the movement of humans from the village to the city has increased energy demand. Therefore, it has led to changes in lifestyle such as increased electric consumption, public transport system and hot water, and others. Previous research has investigated the impact of urban population growth rate on environmental pollution from two different points of view: Some researchers, such as Panayotou (1993), believe that increasing urban growth rate is

the most important factor in increasing environmental pollution. The results of the study by Liu & Bae (2018) also show that the increase in the rate of urbanization in China contributes to the increase in carbon dioxide emissions in China. Sofuoğlu et al. (2023) found that urbanization increases environmental pollution by increasing CO2 emissions in Turkey. Some other researchers, such as Tayibi (2015), show that an increase in urbanization through more efficient infrastructure, better use of the transportation system, and more powerful energy consumption led to improved environmental quality while declining the emission of destructive pollutants. Therefore, the impact of urban growth rate on environmental quality and air pollution can vary depending on the different conditions.

LTR_{it}: It is the logarithm of the trade openness. The openness of the trading index is the most common index for the degree of commercialization, which is calculated from a country's trade ratio (total exports and imports) to GDP. There are two contradictory views on the logic of communication and how the volume of trade affects environmental pollution. Bhagwati (1993) and Gallagher (2004), based on the trade hypothesis and pollution harbor, state that developed countries apply severe environmental policies to other countries. Therefore, during the trade, operations, and production process of pollutants in these countries, they are transferred to countries with mild environmental policies. As a result, developing countries become a shelter to attract pollutants. The results of the research of Khan et al. (2023) show that the openness of trade reduces the environmental quality in the long term as well as in the short term in Pakistan. The second view, presented by Grossman and Kruger (1991), refers to the positive impact of expanding trade volume on environmental quality. The researchers classified the effects of commercial liberalization on the environment into three classes: scales, composition, and technology. The effect of the scale indicates a change in the size of economic activities. The effect of the composition of change in the composition or basket of manufactured goods. Finally, the effect of technology also reflects the change in production technology, especially the change to clean and green technologies. With the realization of commercial liberalization, the effect of scale and the effect of technology leads to increased and decreased environmental degradation, respectively. The effect of the composition also varies depending on the relative advantage of manufactured goods in countries. Therefore, if a country has a relative advantage in producing clean goods, the composition of its manufactured goods will lead to more production of these commodities by commercial liberalization. It will be positive for the quality of the environment. Therefore, trade can reduce environmental pollution and spread carbon dioxide, on

the one hand, and increase carbon dioxide pollution and release, on the other hand. Accordingly, the effect of trade on the environment and the spread of carbon dioxide is vague.

4.3 The Panel Unit Root Tests

Using the panel unit root test, it is crucial to seek if the dependent and independent variables are stationary in a panel data analysis. In the current literature, we use the LLC test. The LLC test proposed by Levin, Lin, and Chu assumes the common unit root processcross sections. While H_0 is a non-stationary process with a unit root, H_1 is stationary with no unit root. Table (1) shows the results of the panel unit root tests for both dependent and independent variables at 95% significance levels. As can be seen from the results, all variables except $LGDP^2{}_{it}$ are stationary at the level. Therefore, it is necessary to perform the Cointegration test to investigate the long-term relationship between variables.

Table 1. Unit Root Test Results

Variables	Levin, Lin, & Chu Test	
	Statistic	**Probability**
$LCO_{2_{it}}$	-3.21	0.001
$LEGDI_{it}$	-2.21	0.013
$LGDP_{it}$	-1.55	0.062
$LGDP^2{}_{it}$	-1.58	0.047
LEN_{it}	-4.68	0.000
$LIND_{it}$	-2.50	0.006
LUR_{it}	-14.16	0.000
LTR_{it}	-3.42	0.003

Source: Research finding.

4.4 The Cointegration Test

The Cointegration test examines the existence of a long-term relationship between variables. If the variables are also stacked, they move together over time. As a result, short-term errors are corrected in the long run. In this regard, we focused on Pedroni Test (1999; 2004). The null hypothesis of Pedroni is the absence of cointegration, and its alternative is the existence of cointegration. The Cointegration test results (Table 2) indicate that the null hypothesis of no-cointegration is rejected at the 5% significance level for each panel data set. Therefore, our study's variables are cointegrated, and a long-run relationship exists between them.

Table 2. Pedroni Cointegration Test Results

Test	Statistic	Probability
Panel-PP-Statistic	-7.34	0.000
Panel-ADF-Statistic	-3.8	0.010
Group-PP-Statistic	-17.97	0.000
Group-ADF-Statistic	-1.59	0.045

Source: Research finding.

4.5 Diagnostic Test

To estimate the model with the GMM method, it is necessary to perform diagnostic tests. Sargan test assumes that the residuals or the error terms are not correlated with the instrument's variables. Test validity is established when the null hypothesis that the over-identifying instruments are valid is accepted (Roodman, 2009). Moreover, the autocorrelation/serial correlation test of the error term is displayed to test the null hypothesis of the differenced error term first and second-order serially correlated. This outcome means failure to reject the null hypothesis of no second-order serial correlation, suggesting that the original error term is serially uncorrelated and the moment conditions are correctly specified (i.e., AR(2) > 0.05). Table (3) presents the model results to identify the determinants of Environmental Quality (CO_2 emissions) in the Middle East & North African (MENA) countries. Based on the result reported in Table (3), the Wald-test statistics (Prob > F = 0.000) indicated the model's goodness of fit (GOF). As a result, the Sargan test (Prob > chi2 = 0.727) for the validity of the overidentifying restrictions in the GMM estimation is accepted for all specifications. Also, the second-order autocorrelation is rejected by the test for AR(2) (Prob> z= 0.293) as it indicates the absence of second-order autocorrelation.

Table 3. Diagnostic Test Results

Information & Tests		Amounts
Groups		17
Instruments		23
Observations		133
AR (1)	Statistic	-2.21
	Probability	0.027
AR (2)	Statistic	1.05
	Probability	0.293
Sargan-Test	Statistic	11.34
	Probability	0.727
Wald-Test	Probability	0.000

Source: Research finding.

4.6 Results

The variables' coefficients are interpreted and analyzed after ensuring the validity of the diagnostic test. Table (4) shows the results of the GMM estimate.

Table 4. Model Estimation Results with the GMM Method

Variables	Coefficient	Z-Statistic	St. Error	Probability
$L.LCO_{2_{it}}$	0.15	2.22	0.067	0.026
$LEGDI_{it}$	-0.07	-2.8	0.025	0.005
$LGDP_{it}$	0.10	12.26	0.008	0.000
$LGDP^2{}_{it}$	-0.08	-13.66	0.005	0.000
LEN_{it}	0.66	26.55	0.024	0.000
$LIND_{it}$	0.04	4.91	0.008	0.000
LUR_{it}	0.37	2.39	0.015	0.017
LTR_{it}	-0.09	-1.41	0.063	0.159

Source: Research finding.

According to Table (4), for every percent of change in the independent variables, there is a corresponding percent change in the CO_2 emissions represented by the coefficient. The lagged coefficient of the dependent variable has positive and significant, suggesting that CO_2 emissions in the previous period have a positive effect on it in the current period. There is a negative and significant relationship between the e-government development index and CO_2 emissions. With an increase in the e-government development index by 1% in MENA countries, average CO_2 emissions decrease by an average of about 0.07%. This result is consistent with the findings of Ziolo et al. (2022) and confirmed views of Medaglia et al. (2021), Al Khouri (2013), Krishnan et al. (2013), Young Bum (2017), Jouzbarkand et al. (2011) and Ernst and Young (2003). However, it contradicts the views of Haigh (2004) and (Park et al. (2018). The findings shows that the increase of GDP leads to high carbon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of Per Capita Gross Domestic Product in the MENA countries increase carbon dioxide emission by 0.10 percent if there is a one percent increase in Per Capita Gross Domestic Product, indicting that Economic growth reduces environmental quality. As the economic growth is positive and significantly increases carbon dioxide however this study also tests the environmental Kuznets curve by taking the square of economic growth per capita. the results validated this hypothesis as the square term coefficient gives negative and significant results which are consistent with previous studies, such as Awan and Azam (2022), Allard

et al. (2018), Shehzad et al. (2022). The effect of energy consumption on carbon dioxide is shown positively by the coefficients. Thus, a rise in energy use increase carbon dioxide. The findings further show that when there is an increase in carbon dioxide emission with the use of a high amount of energy worsens environmental quality. More specifically, a 0.66 percent increase will occur in carbon dioxide if the use of energy increases by one percent. The findings confirm that energy use in the MENA countries harms environmental quality by producing pollution. This result aligns with Acheampong (2018), Liu and Bae (2018), Massagony and Budiono (2023), which verified the positive impact of energy consumption on CO_2 emissions. Also, the findings shows that the estimated coefficient of industrialization is positive and significant that's leads to high bon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of industrialization in the MENA countries increase carbon dioxide emission by 0.04 percent with a one percent increase in industrialization, this result aligns with Liu and Bae (2018), and Voumik and Ridwan (2023). According to Table (4), urbanization leads to high carbon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of urbanization in the MENA countries increase carbon dioxide emission by 0.37% if urbanization goes upward by one percent; consistent with findings from Liu and Bae (2018) and Sofuoğlu et al. (2023). Also, a negative relationship is indicated between trade openness and carbon emissions, however, this relationship is not a significant trade openness.

5. Conclusion and Policy Implications

The term "electronic government" or "e-government", used interchangeably as "digital government", is a concept that merges various disciplines. One of the popular definitions provided by the World Bank for e-government is: "the use by government agencies of information technologies (such as Wide Area Networks, the Internet, and mobile computing) that can transform relations with citizens, businesses, and other arms of government" (The World Bank, 2015). In a nutshell, many definitions provide the idea of offering government services supported by ICTs to the public. The main objective of e-government is to improve efficiency, reduce government cost and time (i.e., tangible outcomes), and achieve citizens' satisfaction and trust in government (i.e., intangible results) (Malodia et al., 2021). in terms of environmental issues, e-government can have a significant effect on maximizing the impact of actions addressing climate change and environmental protection. It also highlights the new opportunities, including remote monitoring

of water and air pollution as well as monitoring and optimizing the use of energy and natural resources, saving time on transactions and interactions, reducing costs associated with transportation, saving paper (Sapraz, 2023; Al-Khori, 2013). The current study employs dynamic panel data and the GMM approach to investigate the impact of e-government development and CO_2 emissions in 17 selected countries of the MENA region, including Iran, for the 2007-2022 period. The model estimation results show that the development of e-government has had a negative and significant effect on the emission of carbon dioxide emissions in MENA countries.

Based on these findings, some policy recommendations can be proposed to reduce CO2 emissions in MENA countries. this group of countries has been able to take steps toward environmental sustainability and reduce pollution by developing e-government. In the analysis of the cause of this result, it can be stated that the development of the e-government will save energy and reduce paper consumption by changing the economic and bureaucratic structures and the tendency toward non-physical factors and information. Also, developing e-government through the intelligent and optimal use of natural resources will create economic growth by reducing environmental damage. Therefore, the authorities in this group of countries must pay due attention to the implementation and improvement of e-government to reduce CO_2 emissions and help to improve environmental quality. Secondly, given that the relationship between CO2 emissions and economic growth validates an inverted U-shape curve, the economic growth level in MENA's economy seems sufficient to reach acceptable reductions in CO2 emissions after the indicated income levels. Third, there is a need to increase the use of renewable energy sources and promote energy conservation practices to reduce energy consumption. Moreover, MENA countries should seek cost-effective and domestic opportunities to meet its energy demand through energy diversification. Furthermore, it is also necessary that MENA countries take appropriate steps to regulate and optimize the industrial structure from a strategic point of view.

It is important to recognize that e-government alone cannot solve all environmental challenges. Access to ICT infrastructure, internet connectivity, and digital literacy are prerequisites for effective e-government implementation. In many regions, particularly in developing countries or rural areas, these resources may be limited. Furthermore, there may be concerns regarding data privacy, cybersecurity, and the reliability of electronic systems.

To evaluate the overall effectiveness of e-government in improving environmental quality, comprehensive research studies and case-specific assessments are needed. Factors such as context, governance frameworks, technological capacities, and public engagement strategies should be taken into account to draw accurate conclusions about the impact of e-government on environmental outcomes.

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