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Environmental Sustainability in Selected OPEC Countries: Do the Influence of FDI and ICT Matter?

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ABSTRACT: Considering the undeniable role and importance of the environment in people's lives, the present study is designed to investigate the combined effect of information and communication technology (ICT) and foreign direct investment (FDI) on achieving environmental sustainability. Since the increasing emission of carbon in society and its destructive environmental effects on social economic aspects and even political tensions have become a challenge, the main question of the research is what strategies have governments, especially oil exporting countries, used in the past to reduce the level they have discovered pollution and what policies do they want to follow in the future? Among the policies undertaken by the OPEC oil exporting countries, has the action for foreign direct investment (FDI) and the development of information and communication technology (ICT) been effective in preventing harmful environmental effects? For this purpose, data on renewable energy consumption, the intensity of use of information and communication technology, foreign direct investment (FDI), and urbanization have been used as explanatory variables, and carbon dioxide (CO_2) emission as a dependent variable. The target countries selected are oil exporting countries (OPEC) for the period 2000 to 2020, and the analysis method used is panel VAR. The results showed that creating a shock in FDI, labor force, urban population, and renewable energy consumption decreases CO_2 while creating a shock in Gross capital formation increases CO_2. The impact of shock of ICT on CO_2 is also insignificant and can be ignored. The results of variance analysis also showed that urban population, labor force, and FDI variables have the largest contribution in explaining the behavior of CO_2; therefore, it is necessary to pay attention to FDI and try to increase the attraction of foreign direct investment to reduce CO_2 in OPEC countries.

JEL: C23, F43, F64

KEYWORDS: Environment, foreign direct investment, information communication technology, OPEC

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Introduction

The emission of carbon dioxide (CO_2) and the intensification of various industrial activities have become inevitable in the process of economic growth and development. The lack of control of greenhouse gases has become an important challenge worldwide, jeopardizing economic growth and sustainable development. The international effort of governments to reduce carbon emissions has become a big challenge for developing countries.[1] For this reason, governments seek to find suitable solutions to reduce the amount of pollution and adhere as much as possible to control and reduce the emission of carbon and polluting gases in the process of their economic growth and development. Since the beginning of the industrial revolution in the world, we have seen an increase in environmental pollution because of the high energy consumption in the complex process of product production, and this has led to an increase in the average concentration of carbon dioxide in the air and harmful changes in the global environment.[2,3] One of the most basic effects of carbon dioxide emissions and environmental pollution is endangering human health in society, and planners found a relationship between energy consumption and carbon dioxide emissions caused by economic growth and industrial activities.[4] In this way, the serious effects of energy-consuming activities have led to an increase in temperature and the pollution of the big cities of the world, which ultimately leads to damage to human health.[5]

In this regard, the reports of the World Health Organization (WHO) show that every year around 7 million people worldwide die because of diseases escalated by air pollution. Meanwhile, about 88% of the people living on the planet live in low and middle-income economies.[6] Today, the countries of the world are seeking to reduce the cost and make the price of their products competitive; the external consequences are harmful to society. So that the increase in pollution in the process of production and development has become inevitable and many economists believe, it is impossible to achieve economic growth and environmental sustainability simultaneously.[7] As a result, according to them, there is a close relationship between environmental quality and economic growth, and to improve the economic situation and get out of stagnation, the environment is sacrificed.[8] In this way, by accepting this belief, the first theories of economic growth ignored the importance of environmental sustainability and natural resources. Currently, many studies on the issue of economic development are done with an emphasis on environmental aspects such as pollution caused by economic activities because most of the activities are somehow dependent on the energy consumption caused by burning fossil fuels such as gasoline, oil, coal, and natural gas are used for

generating electricity, heating, transportation, that pollute the environment.[9] This is the reason why for developing countries, the challenge of the relationship between carbon emissions and economic growth is considered important and has attracted researchers and planners to regulatory and legal approaches to reducing carbon emissions.

Different studies have included a variety of factors in the pollution nexus, including different energy uses,[10,11] technological innovations,[12] population,[13] financial development,[14] urbanization,[15] and trade openness.[16] Recently, the studies of Pita et al[17] and Rahman et al[18] related to the influence of economic development indicators on the environmental quality of countries also confirm that the process of sustainable economic development in most developing economies, despite its many benefits in increasing social welfare, generally has problems, of which pollution is one of the most important. The environmental pollution issue is considered the most important issue in the world, many studies have been conducted on this issue; therefore the effect of many variables on the level of environmental pollution has been investigated and confirmed, while the question here is whether the effect of different variables on the level of environmental pollution is the same in all countries and regions. It is expected that the degree of impact of the environment from different variables will be different in different countries and regions; since countries with high oil resources generally pay less attention to saving fossil fuels than oil-importing countries due to easy and cheap access to oil. This also causes this group of countries to face more environmental issues than other countries. In other words, it seems that the importance of the issue of environmental pollution is more important for developing countries, especially crude oil countries, whose income is mainly dependent on oil extraction.

The OPEC member countries have neglected this key and important sector due to their high oil revenues and the lack of feeling the need for technology, and this is also the reason that despite the high income in this group of countries, the level of technology in these group countries is lower than developed countries. For this reason, it seems that the absorption of technology as well as foreign direct investment, which is one of the variables affecting the absorption of technology, is very important in this group of countries; therefore, the question that we seek to answer in this research is how the variables of the intensity of use of information and communication technology and foreign direct investment (FDI) in the short and long term affect the size amount of emissions.?

According to the priority of the issue for oil and crude oil-selling countries, we have chosen OPEC member countries as examples. It is noteworthy that the OPEC member countries are in the early stages of economic growth and development in terms of infrastructure and basic investment resulting from oil and gas exports, and environmental pollution caused by energy-dependent activities is considered the biggest problem of these countries. The time series data for the study is between 2000 and 2020, and the method used is panel data regression. It is worth mentioning for this study, it is also tried to examine the effect of variables that were less important in previous studies; therefore, the research aims to determine the impact of important variables such as information and communication technology (ICT), foreign direct investment (FDI), urbanization and renewable energy consumption on environmental sustainability in selected oil developing economies of OPEC member countries to examine the impact of variables Mentioned on environmental pollution, the gap in existing studies should also be covered to some extent. In summary, since the increasing emission of carbon in society and its destructive environmental effects on social economic aspects and even political tensions have become a challenge, the main question of the research is what strategies have governments, especially oil exporting countries, used in the past to reduce the level they have discovered pollution and what policies do they want to follow in the future? Among the policies undertaken by the OPEC oil exporting countries, has the action for foreign direct investment (FDI) and the development of information and communication technology (ICT) been effective in preventing harmful environmental effects?

Theoretical Background

Climate changes indicate abnormal sustainability in the earth's atmosphere and its consequences in different parts of the globe. In other words, any change in the earth's climate can be due to a disturbance in the earth's heat balance, and of course, the main reason for this change is mainly human activities, which have caused a gradual increase in greenhouse gases. Among these gases, increasing the concentration of Co_2 contributes more to global warming; as noted by the researchers, about 56% of the greenhouse warming created during the last century is related to carbon dioxide gas. The increasing emission of carbon is a controversial issue in today's society and made it necessary to make reforms in the field of finance, energy, and economic development in such a way that implementing regulations, provides the ground for reducing CO_2 emissions in OPEC countries. Gowdy[19] points out, in any society, the social welfare of the people in that society should be placed among other national goals and the continuous increase in per capita income at the expense of social welfare, especially when we witness high destruction of the environment, leads to the weakening of the social contract theory. As a result, the focus of government policies should be to materially improve social welfare. Di Tella and MacCulloch[20] emphasized that the destruction of the environment through CO_2 emissions or any other means creates grounds for dissatisfaction with life and is a means of reducing human well-being and thus reducing life expectancy. This opinion was also raised by the empirical wisdom of Ang[21], who stated that there is relatively much evidence that environmental degradation not only negatively affects the

quality of life in society by reducing health but also by disrupting the quality of human capital. In the long run, national productivity is affected and, in this way, it affects the economy.

Due to the high importance of the deteriorating emission of CO_2, many studies have been conducted on this variable and the variables affecting it, which include different energy uses,[10,11] technological innovations,[12] population,[13] financial development,[14] urbanization,[15] and trade openness.[16] Recently, the studies of Pita et al[17] and Rahman et al[18] related to the influence of economic development indicators on the environmental quality of countries also confirm that the process of sustainable economic development in most developing economies, despite its many benefits in increasing social welfare, generally has problems, of which pollution is one of the most important.

The experience of developed and developing countries to achieve economic growth and sustainable development shows that carbon dioxide (CO_2) emissions constitute a large part of greenhouse gas emissions by these countries and the problem of reducing carbon emissions has become a big challenge. Economic activities, especially industrial and service activities in society have negative and positive external effects, and negative external effects are considered more vital due to leaving harmful social effects and slowing long-term economic growth. For this reason, examining the relationship between economic growth and the environmental degradation index seems very necessary for developing countries.[22,23] The main weakness of measuring GDP in countries that have natural gifts and underground resources is ignoring the reduction of natural resources and their waste in the long term, environmental pollution caused by the disposal of materials, and social costs including health because of occupational exposure to chemicals and radioactivity are weaker. In this regard, the goal of the economic planners is based on balancing economic growth with carbon emission, to a great extent, causing less damage to the environment. For the OPEC oil exporting countries, which have abundant natural resources, the challenges caused by the use of cheap energy in production and economic growth have made environmental changes created by increased concentration of greenhouse gases (GHGs) in the atmosphere, as one of the most important issues of the 21st century of these countries should be considered. Following, we will discuss the theoretical foundations of the most important variables affecting the stability of the environment, that is, the amount of CO_2 emission.

Information and communication technology and the environment

The importance of information and communication technology (ICT) to achieve the short-term and long-term goals of economic growth and development is undeniable. The role of information and communication technology in motivating the productivity of production factors is important in 2 aspects: First, in the production function of economic enterprises, ICT capital input is a role-playing and effective input for production. When talking about production input under the title of ICT, it refers to all kinds of tangible hardware technologies and intangible software technologies. The second approach refers to the complementary role of ICT in increasing the productivity of other production factors, such as improving the productivity and skill of human resources.[24]

Romero and Gramkow[25] pointed out in their study that increasing economic complexity using information communication technology reduces CO_2 emissions by 23% and leads to an improvement in environmental quality. Economic complexity is an important variable whose relationship with pollution has received much attention recently. It is believed that the more complex the economy, the less it pollutes the environment because it uses newer technologies. Caglar et al[26] and You et al[27] show that economic complexity has a negative and significant impact on environmental change. Normally, countries with a higher standard in the economic complexity index have the opportunity to export more complicated products and also have a higher gross domestic product (GDP), higher per capita income, and growth rates.[28-30] Information and communication technology (ICT) development can, directly and indirectly, increase economic growth. Magazzino et al[31] in a study investigated the relationship between information technology and environmental pollution. In this article, they examined and confirmed the relationship between the penetration of information and communication technologies (ICT), electricity consumption, economic growth, urbanization, and environmental pollution for 25 OECD countries in the period 1990 to 2017. Moreover, Magazzino et al[32] in a study investigated the relationship between ICT, electricity consumption, air pollution, and economic growth in European Union countries. For this purpose, they used data from a panel consisting of 16 European Union countries in the period 1990 to 2017. The results of this study showed that the use of information and communication technology and electricity consumption increases CO_2 emissions and improves GDP. Also, the results of this study showed that economic growth is an important driver of electricity demand because a 1% economic growth rate is associated with a 0.13% increase in per capita electricity consumption.

In this context, the question arises as to which economies benefit most from the development of ICT. Hanclova et al[33] point out that growth generated by ICT usage is less evident in Eastern Europe, which consists of most emerging economies. On the other hand, they suggest that priority should be given to investments from higher and middle-income countries, where higher marginal returns can be expected. Avgerou[34] indicates that investments in ICTs are successful only in economies that have the conditions for implementing and using the equipment efficiently. Bresnahan et al[35] examine the effect of

ICT and organizational change on the skill composition of labor demand and conclude that IT investment and organizational change, combined with changes in the products and services offered by the firm, lead to a shift in the demand for labor that favors skilled workers over unskilled workers. This result is taken as evidence that IT and organizational changes become more productive when implemented in an environment where skilled labor is relatively abundant.[36] Van Reenen et al[37] examined the impact of ICT capital on labor productivity using a firm-level dataset from 13 European countries for the period 1998 to 2008 and the results show that a 10% increase in ICT capital is associated with an increase in output of between 0.9% and 0.23%, confirming the importance of ICT for growth. However, some researchers pointed out the negative impact of ICT on the environment. Pandikumar et al[38] also suggests that social networks (SN) and search engines (SE) contribute to environmental problems that most people are not aware of social networks and search engine servers, which require a large number of data centers and IT infrastructure.

Foreign direct investment and the environment

Foreign development investors are mostly invited by emerging developing countries, hoping that through these international activities, the positive experiences from developed economies will reach the domestic countries.[39] It is worth noting that FDI can have a negative impact in the early stages of development and transition to market economies.[40] When domestic firms are less productive relative to foreign ones and firms with below-average productivity are forced to quit the market, the industry benefits from the increase in productivity. However, when the most productive firms leave the market, FDI inflows in such cases are harmful to the recipient country[41] (p. 22). FDI not only provides the financial resources needed for economic development but also generates positive productivity effects (externalities) for host countries. On the other hand, FDI can help open up and industrialize the economy.[42] The impact of industrialization on economic growth and pollution depends on the degree of openness of the economy and international trade is seen as a means to improve environmental quality because it allows dirty domestic production to be replaced by imports from international markets.[43] Thus, improvements in production techniques lead to lower emissions due to continuous technological progress.[44]

The predominant problem in developing countries is the lack of sufficient investment and the low level of available technology. There is a widespread belief that Foreign Direct Investment can solve this problem, in the way that an increase in FDI is correlated positively with an increase in a specific region's growth rate[41] (p. 22). Magazzino and Mele[45], also studied and confirmed the existence of a causal relationship between foreign direct investment and economic growth.

Bokpin[46] studied the impact of foreign direct investment (FDI) on environmental sustainability in Africa and the results of the study showed that FDI has had a lasting negative effect on the environment. Blanco et al[47] examined the relationship between foreign direct investment (FDI) and CO_2 emissions; using a sample of 18 Latin American countries for the period 1980 to 2007. They found that causality runs from FDI in environmentally intensive industries to CO_2 emissions per capita. Roman and Padureanu[48] showed that FDI and capital endowment are correlated positively with GDP in Romania over the period 1995 to 2004. Melnyk et al[41] studied the effect of foreign direct investment on economic growth and the results show a significant impact of FDI on the economic growth of host countries. Rafindadi et al[49] also investigated the impact of FDI inflow and energy consumption on environmental pollution in the Gulf Cooperation Council (GCC) during the period from 1990 to 2014 and concluded that FDI inflow is detrimental to the environment, while energy consumption has a positive impact on the environment and both factors are significant in determining the level of carbon emissions in the atmosphere. In other studies, higher disposable income, national investment, and FDI variables are found to have a significant effect on energy consumption in the GCC countries.[50,51] Among the most recent studies conducted in the field of the relationship between CO_2 emissions and foreign direct investment, the study of Balli et al[52] can be mentioned. In this study, the existence of a relationship between CO_2 emissions and foreign direct investment for the countries of the Asia-Pacific Economic Cooperation (APEC) was confirmed.

Energy consumption and the environment

While the carbon growth nexus is related to the relationship between economic growth and energy consumption,[53] enormous studies are clear that energy consumption plays an important role in economic growth that increases carbon emissions.[11,15,54] In general, economic complexity and production technology affect energy consumption and thus the environment.[55] In this regard, Magazzino[56] studied the relationship between CO_2 emissions, energy consumption, and economic growth in Italy over the period 1970 to 2006. The results show that CO_2 emissions, energy consumption, and economic growth are co-integrated. Apergis and Danuletiu[57] pointed out that there is a long-run positive causality between renewable energy and real GDP both for individual regions. The empirical studies in recent years provide strong evidence that the interdependence between renewable energy consumption and economic growth shows that renewable energy is important for economic growth and development. The story may be different in the member countries of OPEC. One of the advantages of the member countries of OPEC is the large amount of cheap and constant energy that can promote economic growth. In their study, Iwata et al[58]

partially confirmed the effect of energy consumption on carbon dioxide emissions. The environmental effect of renewable energy usage instead of fossil fuels is obvious.[59] Fossil fuels are the main source of greenhouse gas production and also the main source of many different pollutant streams.[60] High energy consumption in residential construction led to an increase in greenhouse gas emissions that may also result in increased pollution.[61] In this context, Sandanayake et al[62] studied the impact of the energy consumption of the construction sector on environmental emissions such as CO_2 and the results showed that the construction sector plays a significant role in energy consumption and environmental emissions. Moreover, Murshed et al[63] explored the relationship between nuclear energy, renewable energy, and carbon dioxide emissions in the G7 countries and concluded that although nuclear energy consumption is important in mitigating carbon dioxide emissions and carbon footprints in the long run, renewable energy consumption degrades the environment in the G7 countries.

Rafindadi et al[64] examined the impact of electric energy development on the economic growth of France; using ARDL tests and the vector error correction method (VECM) during 1961 to 2015. The results of the causality test indicate a 2-way causal relationship between financial development and economic growth and a one-way causal relationship between trade and economic growth in France; where an increase of 1% in financial development, electricity consumption, capital, export, and import leads to an increase of 0.02%, 0.27%, 0.18%, 0.15%, and 0.18% respectively in economic growth.

Rafindadi and Mika'Ilu[65] investigated the impact of energy consumption on the stability of developed financial market transactions in the United Kingdom; using the ARDL test and the vector error correction method (VECM) to analyze the Granger causality approach for the period 1970 to 2013. The results showed that the relationship between the developed financial market and energy consumption has an inverted U-shaped pattern, that is, the energy demand increases with the development of the financial market and begins to decrease after reaching the peak of the market. They found a negative impact on energy consumption; as an increase of 1% in economic growth, leads to a decrease in energy consumption by 0.5%.

Rafindadi and Usman[66] examined the short-term and long-term causal effects of globalization and energy consumption on the environmental degradation of South Africa; using a fully modified ordinary least squares (FMOLS) and conventional cumulative regression (CRR) model for the years 1971 to 2014. The results indicate an upward Environmental Kuznets Curve (EKC), which is associated with the excessive use of fossil fuel energy in South Africa. The results of the causality test showed the existence of a one-way causal relationship between energy consumption to environmental degradation and a 2-way causality between economic growth and globalization; as 7.96% and 0.80% of energy consumption and globalization lead to environmental degradation by 72.52% and 1.39%, respectively.

Rafindadi and Ozturk[67] concluded that there is a long-term and short-term positive correlation between energy consumption and economic growth in South Africa during 1970-2011, and the higher energy consumption entailed greater prospects of economic growth and the society's welfare. The results of the Granger causality analysis showed the existence of a 2-way relationship between energy consumption and financial development and the financial development has a positive and significant effect on energy consumption; that is, a 0.1% increase in financial development leads to a 0.26% increase in energy consumption in the long term and a 0.35% increase in energy consumption will be associated with a 1% increase in economic growth.

Rafindadi[68] indicates that energy consumption is the main cause of environmental destruction in Japan. Exports reduce CO_2 emissions, but imports lead to increased environmental destruction. Energy consumption, export, and import contribute 33.55%, 1.03%, and 7.13% respectively in Japan's economic growth after the crisis period. Rafindadi[69] showed that financial development stimulates energy demand and reduces CO_2 emissions in Nigeria during 1971-2011; while economic growth reduces energy demand and increases CO_2 emissions. The results of the causality analysis showed a 2-way causal relationship between energy consumption and financial development, and the same result was found for the financial development and CO_2 emissions relationship. Similarly[70]) showed that in the long term, economic growth has a negative relationship with energy consumption in the United Kingdom. The results of the causality test show a 2-way causal relationship between energy consumption and trade openness and a one-way relationship between economic growth and energy consumption. Also, in the short term, there is a 2-way causal relationship between economic growth and energy consumption. The results showed that a 1% increase in economic growth causes a 0.54% decrease in energy consumption. Also, a 1% increase in trade openness and the ratio of capital to labor causes an increase of 0.98% and 3.39% in energy consumption in the UK, respectively. Finally, it was found that energy consumption has a role of 43.42% in the UK's economic growth prospects.

Urbanization and the environment

Generally, in the process of industrialization, the expansion within the city is constantly increasing and pollution is increasing. In the 19th century, Wagner analyzed data on public sector spending in many European countries including Japan, and the United States. His theory consisted of 3 distinct components. First, it noted that as the economy grew, complexity increased. This required the constant provision of new laws

and order along with the development of legal institutions. Second, emerging the trend of urbanization and the increasing externalities associated with the growing urbanization rate. The final component underlying Wagner's Law is the high-income elasticity of demand for goods supplied by the public sector.[71] Thus, one of the complicated phenomena discussed in the concepts of environment, economics, and sociology is the expansion of urbanization. In recent years, the production system of countries has changed significantly.[72] Building a smart city can reduce CO_2 emissions by improving productivity and reducing energy consumption; therefore, the importance of the housing sector is quite clear due to its significant impact on economic growth and greenhouse gas emissions.[22,73] Urbanization occurs when workers migrate from agriculture to cities to work in industry. When the value added by industry is higher than that of agriculture, urbanization can lead to economic growth. Most of the empirical studies indicate the fact that no country has ever achieved a middle-income rank without urbanizing, and none has achieved high income without dynamic intelligent cities that are centers for entrepreneurship.[74] In this relation, Sharma[75] also examined the determinant factors of carbon dioxide emissions with particular reference to urbanization in 69 countries using a dynamic panel data model for the period 1985 to 2005 and found that is detrimental to CO_2 emissions in high, middle, and low-income regions.

Method

To investigate the impact of shocks to the explanatory variables on the size of CO_2 emissions; the panel VAR method is used for this purpose. In other words, considering that the purpose of the study is to investigate the impact of shock in explanatory variables on the dependent variable and considering that the Panel VAR model is one of the best and most common methods to investigate the impact of shock, for this reason in this study Panel VAR method is also used. In this study, the Panel VAR method is used to estimate the research model. This method is a combination of the vector auto-regression model approach and panel data. In this method, all model variables will be endogenous. This issue allows us to examine neglected individual heterogeneities as well.[30,76] The PVAR model includes the conventional VAR method, that is, all variables are assumed to be endogenous and dependent, but the data is of panel type. A panel model includes n inputs or units; which can be the country, sectors of the economy or industries, companies, etc. In the general form, a VAR model for an ith unit (where $i = 1, 2, \ldots, N$) is written as equations (1) and (2):

$$\begin{aligned} y_{i,t} = \sum_{j=1}^{N}\sum_{k=1}^{p} A_{ij,t}^{k} y_{j,t-k} + C_{it}x_t + \in_{i,t} = A_{i1,t}^{1} y_{1,t-1} \\ + \ldots + A_{i1t}^{p} y_{1t-p} + A_{i2,t}^{1} y_{2,t-1} + \ldots + A_{i2,t}^{p} y_{2,t-p} \\ + \ldots + A_{iN,t}^{1} y_{N,t-1} + \ldots + A_{iN.t}^{p} y_{N.t-p} + C_{i.t}x_t + \in i_{.t} \end{aligned} \quad (1)$$

$$y_{i,t} = \underbrace{\begin{pmatrix} y_{j1.t} \\ y_{i2.t} \\ \cdot \\ \cdot \\ \cdot \\ y_{in.t} \end{pmatrix}}_{n\times 1} \quad A_{ij,t}^{k} = \underbrace{\begin{pmatrix} a_{ij,11,t}^{k} & a_{ij,12,t}^{k} \cdots & a_{ij,1n,t}^{k} \\ a_{ij,21,t}^{k} & a_{ij,22,t}^{k} \cdots & a_{ij,2n,t}^{k} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ a_{ij,n1,t}^{k} & \alpha_{ij,n2,t}^{k} \cdots & a_{ij,nn,t}^{k} \end{pmatrix}}_{n\times n} \quad (2)$$

$$C_{it} = \underbrace{\begin{pmatrix} c_{i1,1,t} & c_{i1,2,t} \cdots & c_{i1,m,t} \\ c_{i2,1,t} & c_{i2,2,t} \cdots & c_{i2,m,t} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ c_{in,1,t} & c_{in,2,t} \cdots & c_{in,m,t} \end{pmatrix}}_{n\times m} \quad x_t = \underbrace{\begin{pmatrix} x_{1,t} \\ x_{2,t} \\ \cdot \\ \cdot \\ \cdot \\ x_{m,t} \end{pmatrix}}_{m\times 1} \quad \varepsilon_{i,t} = \underbrace{\begin{pmatrix} \varepsilon_{j1,t} \\ \varepsilon_{i2,t} \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_{in,t} \end{pmatrix}}_{n\times 1}$$

Where, $y_{i,t}$ represents an n×1 vector that contains n endogenous variables of unit i at time t; While the variable $y_{ij,t}$ is the jth exogenous variable of unit i. $A^{k}_{ij,t}$ is an n*n matrix of coefficients that is the response of unit i to the kth interval of unit j in period t. For the matrix $A^{k}_{ij,t}$, the coefficient $a^{k}_{ij,lm,t}$ gives the reaction of variable l from unit i to the kth interval of variable m from unit j. x_t is an $m\times 1$ vector of exogenous variables and C_{it} is an n×m matrix related to the endogenous variables of these exogenous variables. For C_{it}, the coefficient $c_{ij,t}$ gives the reaction of endogenous variable j from unit i to exogenous variable lth. Finally, $\varepsilon_{i,t}$ represents an n×1 vector of residuals for unit variables i with the following properties (equations (3) and (4)).

$$\Sigma_{ii,t}\left(0, \sim \mathcal{N}\varepsilon_{ii,t}\right) \quad (3)$$

$$\Sigma_{ii,t} = E\left(\varepsilon_{i,t}\varepsilon`_{i,t}\right) = E\begin{pmatrix} \varepsilon_{i,1,t} \\ \varepsilon_{i,2,t} \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_{i,n,t} \end{pmatrix}\left(\varepsilon`_{i,1,t}\varepsilon`_{i,2,t}\ldots\varepsilon`_{i,n,t}\right) = \underbrace{\begin{pmatrix} \sigma_{ii,11,t} & \sigma_{ii,12,t} & \sigma_{ii,1n,t} \\ \sigma_{ii,21,t} & \sigma_{ii,22,t} & \sigma_{ii,2n,t} \\ \sigma_{ii,n1,t} & \sigma_{ii,n2,t} & \sigma_{ii,nn,t} \end{pmatrix}}_{n\times n} \quad (4)$$

Where, it is assumed that $\varepsilon_{i,t}$ has no autocorrelation; So $E(\varepsilon_{i,t}, \varepsilon_{j,s}) = \Sigma_{ii,t}$, while $E(\varepsilon_{i,t}, \varepsilon_{i,s})=0$ and $t \neq s$. Note that the generalization of the variance-covariance matrix for the residual VAR is allowed to be period-specific, which represents a general form of variance heterogeneity. For each variable for unit ith, the dynamic equation in period t includes a set of $k = Nnp+m$ coefficients for estimation, which implies that $k = Nnp+m$ coefficients are estimated for all units.

Following the study of Abdouli and Hammami[77] regarding the impact of FDI inflows and economic growth on the environment in MENA countries, the objective of the present study is to investigate the effect of ICT and FDI on achieving environmental sustainability in a group of 14 OPEC member countries. The reason behind choosing a study period of 2000 to 2020 was the availability of data for such a group of countries. The dependent variable in this study is carbon dioxide (CO_2) emissions from the combustion of fossil fuels, gas fuels, and gas flaring. The main independent variable in this study is ICT, which is measured in terms of cell phones and the Internet user rate. On the other hand, globalization in this study includes both the financial aspect (foreign direct investment) and the trade aspect (imports and exports of raw materials). The selection of ICT variables is in line with recent literature inspired by: Annamalaisamy and Jayaraman[78]; Awad and Albaity[79]; Amavilah et al[80]; Tchamyou and Asongu[81]. The number of individuals using the Internet (Percentage of the population) is used as an ICT policy variable. Other independent variables include labor force, capital formation, and renewable energy consumption as a share of total energy consumption, urbanization rate, and foreign direct investment (referred to[82,83]). Based on the Cobb-Douglass growth model equation, GDP is generally introduced as a function of the labor force and capital formation. In addition, many other variables affect GDP directly and indirectly. Inspired by Marmara[74] and Amiri and Reif's[84] studies, a panel regression model has been introduced as follows in equation (5) to examine the evolution of CO_2 emissions per unit of GDP over time and to assess the factors affecting this variable in OPEC countries over the period 2000 to 2020. The approach followed in this section is due to the work and efforts of Canova and Ciccarelli[85]. By modeling on N units, the modified model is shown as equation (5).

$$XO_{2it} = \alpha + \beta_1 \Lambda\Phi_{it} + \beta_2 K_{it} + \beta_3 YP_{it} + \beta_4 IXT_{it} + \beta_5 \Phi\Delta I_{it} + \beta_6 PE_{it} + \varepsilon_{it} \quad (5)$$

Where CO_2 represents CO_2 emissions (kg per PPP $ of GDP) as the dependent variable, LF represents total labor force, K represents the Gross capital formation (Percentage of GDP), RE represents Renewable energy consumption (Percentage of total final energy consumption), UR represents Urban population (Percentage of the total population), ICT represents Individuals using the Internet (Percentage of the population), and FDI represents Foreign direct investment, net inflows (Percentage of GDP). The data related to CO_2 emissions has been collected from Climate Watch (Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute. Available at: https://www.climatewatchdata.org/ghg-emissions. See NY.GDP.MKTP.PP.CD for the denominator's source). Data on FDI, Gross capital formation, Labor force, and Renewable energy consumption have been collected from the World Bank, data on Individuals using the Internet from the International Telecommunication Union and data on urban population have also been collected from the United Nations World Urbanization Prospects.

Results

To estimate the model, the stationarity of the variables must be checked first. If the variables are not stationary, it leads to a spurious regression problem and the process of the econometric technique is not suitable for regression estimation leading to biased and misleading estimates.[86] Before checking the constancy of the variables, the descriptive statistics of the article are presented first. The descriptive statistics of the variables can be seen in Table 1.

In a very brief comparison, it is remarkable that the average CO2 emission in OPEC member countries is 0.32, while this ratio is 10.94 for high-income countries, 0.21 for less developed countries, 0.3 for low-income countries, and the global average for all countries. It is 4.27. The average urban population (percentage of the total population) in OPEC member countries is 68%, while this ratio is 77% for high-income countries, 28% for low-income countries, and the global average for all countries is 49%.

It is noteworthy that the average foreign direct investment, net inflows (% of GDP) in OPEC member countries is 2.79%, while this ratio is 2.48% for high-income countries and 1.62% for low-income countries. And the global average for all countries is 2.42%. The number of the labor force, total, on average in the period under review (average between 1990 and 2021) in OPEC member countries is close to 9 million people, while this number is about 565 million people for high-income countries, for countries with low-income, more than 1 billion people and the global average for all countries is close to 3 billion people (World Bank).

To avoid spurious regression, it is necessary to examine the stationarity of variables. If the research variables do not have non-stationary forms, the diagnostic tests of the model should be examined. If the investigated model has no problems in terms of diagnostic tests, it is possible to investigate the impact of shock in the explanatory variables on the number of CO_2 emissions.

First, the stationarity of the variables is examined. Table 2 shows the results of the stationarity of variables with the help of Levin, Lin, and Chu (LLC). The results indicate that all variables are at a stationary level. It should be noted that the stationary test of Im, Pesaran, and Shin also shows similar

Table 1. Descriptive statistics of the variables.

STATISTICS	CO_2	FDI	ICT	K	LF	RE	UR
Mean	0.32	1.75	20.7247	26.2356	10151769	22.9884	67.1800
Median	0.31	1.07	7.3760	25.1593	6477441	2.0450	69.5800
Maximum	1.11	24.01	99.6529	59.3409	67373495	90.1300	100.0000
Minimum	0.11	−10.72	0.0000	−12.8801	284337	0.0000	12.9780
Std. Dev.	0.12	3.25	27.5308	9.1899	13102153	32.5917	22.4470
Skewness	2.12	1.96	1.4432	0.5457	2.320739	1.0683	−0.7990
Kurtosis	14.37	13.61	4.0522	4.2545	8.204906	2.3758	3.2330
Jarque-Bera	2165.51	1880.61	138.8179	40.6694	715.3303	72.8779	45.7040
Sum	114.12	618.14	7315.826	9261.18	3.58E + 09	8114.92	28218.3
Sum Sq. Dev.	5.29	3721.8	266796.8	29728.2	6.04E + 16	373901.6	211122.6
Observations	294	294	294	294	294	294	294

Source: Research findings.

Table 2. The results of the unit root test (Levin, Lin, and Chu Test).

VARIABLE	LEVEL	TEST STATISTICS	PROB
CO_2	I(0)	−2.78	.00
FDI	I(0)	−5.38	.00
K	I(0)	−1.95	.02
ICT	I(0)	−41.33	.00
RE	I(0)	−2.43	.00
LF	I(0)	−2.78	.00
UR	I(0)	−5.85	.00

Source: Research findings.

results. The results of the stationary test presented in Table 2 indicate the stationary of all variables at the level.

After making it certain that all variables are stationary, in the next step, it is necessary to determine the optimal number of lags in the model. The results of the optimal lag test show that the lag length is selected as 1 according to the AIC, SC, and HQ (Table 3).

To estimate the panel vector autoregression (PVAR) model and before estimation, there is also a need to check the stability of the model; for this reason, we will continue to examine the stability of the model. It is noteworthy that in a panel vector autoregression model, the model is stable if all modules of the covariance matrix are strictly less than one. Establishing the stability condition is very important because establishing this condition guarantees that the panel vector regression model under consideration will be invertible. The stability test results are shown in Table 4. The condition of stability is established in the considered model.[87-89]

Table 3. Determining the optimal lag of the estimation model.

NUMBER OF LAGS	THE MODEL UNDER REVIEW		
	AIC	SC	HQ
0	6.81	6.93	6.06
1	−6.46**	−5.48	−6.06
2	−6.32	−4.48	−5.57
3	−6.25	−3.55	−5.16
4	−6.24	−2.68	−4.80
5	−6.40	−1.98	−4.61
6	−6.23	−0.95	−4.09
7	−6.09	0.04	−3.60
8	−6.03	0.95	−3.20

Source: Research findings.

Table 4. Checking the stability condition of the VAR model.

THE MODEL UNDER REVIEW	
ROOT	MODULUS
0.99	0.99
0.92-0.02i	0.92
0.92 + 0.02i	0.83
0.83 + 0.02i	0.83
0.55	0.55
0.05	0.05

Source: Research findings.

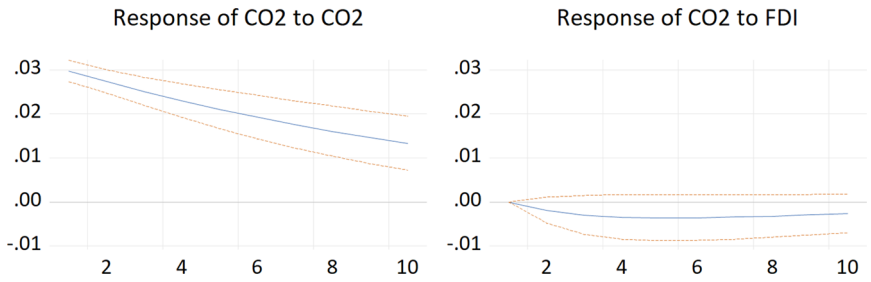

Figure 1. Co_2 responses to shocks created by CO_2 and FDI.
Source: Research findings.

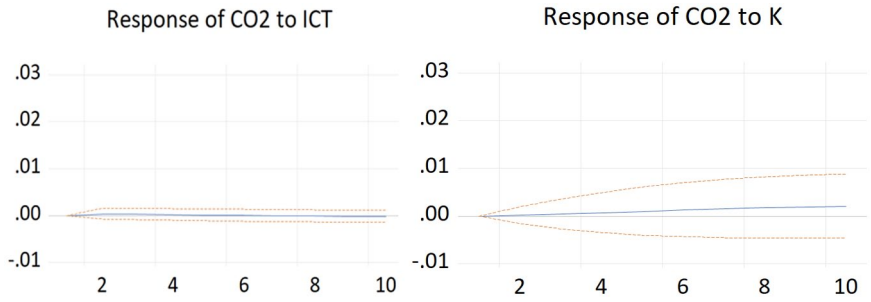

Figure 2. Co_2 responses to shocks created by ICT and K.
Source: Research findings.

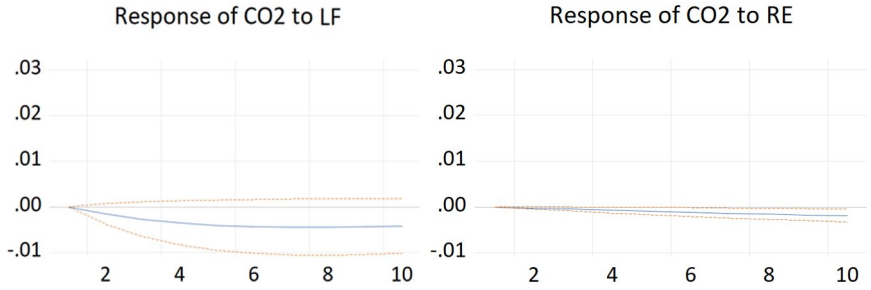

Figure 3. Co_2 responses to shocks created by LF and RE.
Source: Research findings.

Considering that the stability condition is also established in the model under review; therefore, in the following, impulse response and variance decomposition are examined.

Analysis of impulse response functions

One of the attractive applications of Panel VAR models is the possibility of examining shocks created by each variable and its impact on other variables. In other words, in Panel VAR models as well as VAR models, the coefficient obtained in the model is not capable of economic interpretation and does not show reliable information. In this type of model, impulse response functions as well as the results of variance decomposition can contain important information.[87,90] For this purpose, in the following, the issue of what impact the creation of a shock in the explanatory variables can have on CO_2 (the dependent variable in the model examined in this study) is examined. In the following, the results obtained from the impulse response functions (shocks caused by the explanatory variables) have been illustrated in Figures 1 to 4.

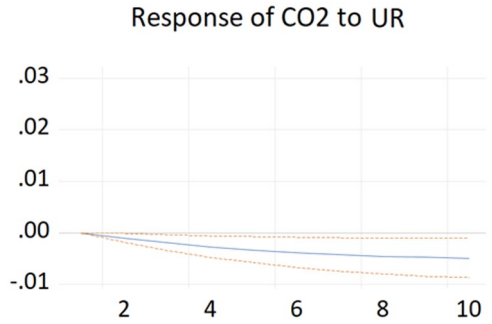

Figure 4. Co_2 responses to shocks created by UR.
Source: Research findings.

CO_2 response to shock in CO_2. The reaction of CO_2 to its CO_2 shocks is positive and decreases over time. Of course, this effect does not become zero even after 10 courses; therefore, a positive shock in CO_2 causes an increase in CO_2.

CO_2 response to shock in FDI. The reaction of CO_2 to the shock in FDI is negative. As it is clear in Figure 1, by creating a shock

in FDI, the amount of CO_2 should decrease significantly. It is worth considering that although the effect of the shock created in FDI on CO_2 decreases over time, this effect does not completely disappear even after 10 periods; therefore, FDI is known as an important and influential variable on CO_2.

To explain the result, it should be mentioned that with the increase in the attraction of foreign direct investment, it is expected that technology will also enter the country. With the introduction of new technology and the use of new methods that have less pollution, it is expected that the amount of CO_2 emissions will also decrease. It is also believed that by increasing the attraction of foreign direct investment, economic growth, and subsequent per capita income will also increase. In this situation, institutions and organizations related to the environment by establishing appropriate environmental laws and regulations, as well as taking into account the financial ability of economic enterprises to cover the costs associated with changing technology toward environmentally friendly technology, as well as paying duties and taxes Take steps to reduce CO_2 emissions.

CO_2 response to shock in ICT. The reaction of CO_2 to the shock in ICT is positive. As it is clear in Figure 2, by creating a shock in ICT, the amount of CO_2 should increase. It is worth considering that the impact of the shock created in ICT on CO_2 is insignificant and disappears completely after a few periods; therefore, the shock in ICT does not have a long-term effect on CO_2. To explain the result, it should be mentioned that ICT can provide a powerful tool for environmental protection because the improvement in the ICT situation reduces the need for natural materials in the environment. More use of ICT can reduce the amount of waste entering the environment.

CO_2 response to shock in K. The reaction of CO_2 to the shock created in K is positive. As it is clear in Figure 2, by creating a shock in K, the amount of CO_2 should increase. It is worth considering that the effect of the shock created in K on CO_2 is significant and after 10 periods this is still in place and does not disappear. The improvement of gross capital formation can lead to the expansion of economic activities. Expansion of economic activities can also increase CO_2 emissions.

CO_2 response to shock in LF. The reaction of CO_2 to the shock created in LF is negative. As it is clear in Figure 3, by creating a shock in LF, the amount of CO_2 should decrease. It is worth considering that the effect of the shock created in LF on CO_2 is significant and after 10 periods this effect is still maintained and does not disappear. To elaborate on the obtained result, it is worth mentioning that the increase of LF can be considered as one of the fields of technological improvement. With the improvement of technology, we expect the size of CO_2 emissions to decrease.

CO_2 response to shock in RE. The reaction of CO_2 to the shock created in RE is negative. As it is clear in Figure 3, by creating a shock in RE, the amount of CO_2 should decrease. It is worth considering that the impact of the shock created in RE on CO_2 is still there after 10 periods and does not disappear. To explain the obtained result, it is worth mentioning that renewable energy is known as clean energy; therefore, it can be expected that increasing the use of renewable energy can be effective in reducing CO_2 emissions.

CO_2 response to shock in UR. The reaction of CO_2 to the shock created in UR is negative. As it is clear in Figure 4, by creating a shock in UR, the amount of CO_2 should decrease. It is worth considering that the impact of the shock created in UR on CO_2 is still there after 10 periods and does not disappear. To explain the obtained result, it should be mentioned that the increase of UR, similar to the increase of LF, can be one of the fields of technology improvement. As technology improves, we expect CO_2 emissions to decrease.

Variance decomposition

The contribution of the variables in the model is determined by the changes of each of the variables over time. In this study, the variance decomposition of the prediction error was used. The purpose of calculating the variance analysis index is to determine the relative contribution and importance of the momentum caused by each variable in its changes compared to the changes of other variables. The results of the variance decomposition of the prediction error for the studied variables in 10 years are given in Table 5.

As illustrated in Table 5, in the first period of the study, 100% of the error variance in CO_2 was explained by that variable and the contribution of other explanatory variables was zero. According to the obtained results, from the second period to the 10th period, the share of CO_2 decreased from 99% to 92%, which has the largest share in the explanation of CO_2. Among explanatory variables, LF and UR have the largest contribution to explaining CO_2. The share of these variables has been increasing during the period and has reached more than 5% in the 10th period. After the mentioned variables, there is FDI, the contribution of this variable in explaining CO_2 was more than 1.5%. It is noteworthy that the contribution of other variables in explaining CO_2 is insignificant and can be ignored.

Conclusions

In the process of economic growth and development and the increase in industrial activities, the emission of carbon and greenhouse gases has become inevitable, and the lack of control of carbon emissions has become an important challenge worldwide, jeopardizing economic growth and sustainable development. The international effort of governments to reduce carbon emissions has become a big challenge for developing countries

Table 5. Variance decomposition analysis.

PERIOD/VARIABLE	1	2	3	4	5	6	7	8	9	10
S.E	0.02	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.07
CO_2	100	99.54	98.79	97.89	96.93	95.97	95.03	94.12	93.25	92.43
FDI	0.00	0.22	0.53	0.84	1.10	1.31	1.47	1.60	1.68	1.74
ICT	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.02	0.05	0.08	0.13	0.19	0.26	0.34
LF	0.00	0.15	0.43	0.78	1.15	1.53	1.87	2.19	2.46	2.70
RE	0.00	0.00	0.01	0.02	0.04	0.07	0.11	0.15	0.21	0.27
UR	0.00	0.06	0.21	0.42	0.69	1.00	1.34	1.71	2.09	2.48

Source: Research findings.

around the world, and to do so, they have created binding measures on the world stage for governments. For this reason, governments seek to find suitable solutions to reduce the amount of pollution and adhere as much as possible to control and reduce the emission of carbon and polluting gases in the economic growth stages.

This study aimed to examine the combined impact of Information and Communication Technology (ICT), Foreign Direct Investment (FDI), and other macroeconomic variables including Economic Complexity and Urbanization Rate on Environmental Sustainability (CO_2 emissions) in developing economies of OPEC member countries.

The research results show that foreign direct investment is one of the most important and influential variables in environmental pollution. It is noteworthy that creating a shock in foreign direct investment both in the short term and in the long term can be effective on the amount of environmental pollution. Balli et al[52] also confirmed the existence of a relationship between FDI and CO_2 for the Asia Pacific Economic Cooperation (APEC) countries. The results obtained in this study are contrary to the results obtained in the study by Wang and Zhang[91]. In their study, they confirmed a negative relationship between FDI and CO_2 in China. It seems that the level of development of the country affects the obtained result. Less developed countries can reduce pollution by entering and absorbing FDI due to the introduction of new technology that has less pollution. It seems that foreign direct investment (FDI) in improving productivity, especially in the oil sector of these countries, has led to the deployment of technologies in industries to prevent energy waste and pollution. Although attracting foreign direct investment is important and can be very important and effective in stimulating the economic growth and development of countries, measures should be taken to attract foreign direct investment to industries that cause less pollution. In other words, although the attraction of foreign direct investment is very important from an economic point of view, its environmental consequences should also be taken into account. The results of this research also showed that renewable energy and labor can be effective both in the short term and in the long term on the amount of environmental pollution.

It is noteworthy that energy consumption in the world is increasing due to the desire for economic growth, and as a result, the emission of greenhouse gases, especially carbon dioxide, which also has harmful environmental effects, can have an increasing trend due to the consumption of fossil fuels. It seems that there is less desire to use renewable energy in oil-rich countries due to easy access to cheap fossil fuels, and the share of renewable energy in the total energy consumption in these countries is small. Despite the relatively small share of renewable energies in the energy supply of oil-rich countries, the results of this study showed that creating a shock in renewable energies can affect the level of environmental pollution in oil-rich countries both in the short term and in the long term. Chen et al[92] also confirmed the negative relationship between the use of renewable energy and CO_2 emissions in selected countries (97 countries) between 1995 and 2015. It is noteworthy that the impact of these variables on the level of environmental pollution is less than foreign direct investment. Based on the results of this research, the increase in gross capital formation causes an increase in environmental pollution. It is worth mentioning that the effect of this variable on the amount of environmental pollution is significant.

Recommendation and limitation

OPEC countries should try to increase the attraction of foreign direct investment by creating incentives. Creating tax incentives and providing guarantees to reduce investment risk in OPEC member countries is one of the most important proposals to attract foreign direct investment.

Paying special attention to renewable energies: considering that OPEC member countries generally have access to cheap and abundant energy and the majority of energy consumption in these countries is related to fossil fuels, which cause significant pollution; therefore, it is recommended that these

countries also pay attention to renewable energy and plan to reduce the consumption of fossil energy and replace renewable energy instead of fossil energy. The use of renewable energy and the adoption of clean technologies in the tourism sector and the production of goods and services play an important role in reducing CO_2, but it is confusing from an economic point of view. Since renewable energy uses energy sources that are continuously replenished by nature, it not only ensures a sustainable energy supply in the economy, but the use of renewable energy will be cost-effective in the long run; therefore, paying special attention to renewable energies in OPEC member countries, in addition to the positive impact it brings to reduce environmental pollution, can also bring positive economic effects even in the long term.

In the context of adopting policies and solutions to reduce adverse environmental effects, it is recommended to use green energy technologies at the industrial level, promoting the use of energy-efficient devices, and including laws on the use of this type of energy, so that steps can be taken to reduce or stop energy loss and save. Also, government officials in OPEC countries can adopt a penalty-based approach, to encourage the prudent use of energy and the use of clean energy in these countries, which not only helps to save costs but also leads to Maintaining and increasing the well-being of citizens through the reduction of CO_2 emissions. Moreover, applying tax policies for centers that consume energy above the standard of environmental pollutants, or in another way, subsidies can be paid for industrial centers that do not have a history of releasing environmental pollutants. It should be noted that the quality of fossil fuels should also be standardized in the minimum acceptable quality range for industrial use. Low energy prices are equivalent to high energy consumption, and this in turn leads to the release of large amounts of CO_2 and other pollutants in society; therefore, it is important to ensure that domestic energy prices reflect global market prices. The study advocates policy measures that will drive massive foreign direct investment into the renewable energy sector. Finally, it can be said that energy is a part of the production factor in the contemporary era and a basic tool to achieve sustainable economic growth.

In summary, this study was conducted for OPEC member countries and the obtained results practically show an average of the influence of the explanatory variables on the size of CO_2 emissions in OPEC member countries. Due to differences between countries, the results obtained may not apply to individual countries and therefore, it is recommended that each country separately examines the effect of different variables on CO_2 emissions. Although there is a lot of similarity between OPEC member countries, these countries are not completely similar to each other. To ensure the findings of the research, it is suggested that this study be conducted for different regions and other groups and countries similar to each other, so that if the results are similar to this research, the results obtained can be trusted, or if different results are obtained, with Conducting further checks reduced the error obtained in the results as much as possible.

Authors' Contributions

All authors have an equal share in preparing the manuscript.

Availability of Data and Materials

Data are available on request after publication.

Consent for Publication

All authors have seen and approved their consent for publication.

Ethics Approval and Consent to Participate

Ethical considerations, including plagiarism, informed consent, misconduct, data fabrication, and double publication, etc. are approved and completely observed by the authors.

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