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*Research Article*

# Explaining Relationship between Carbon Footprint and Economic Growth with Emphasis on Welfare Index: Evidence from Panel Data for OPEC Countries

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**Abstract**
Considering oil-rich status of OPEC member countries, abundance of energy resource and its low cost, environmental quality is at low level due to production and extraction of energy resources. Iran is also a part of this collection, thus, the higher greenhouse gas emission in these countries makes more problems for the human beings and other creatures and control, and observation of standards in this regard becomes more important than ever. Therefore, the present study was conducted to investigate the relationship between carbon dioxide emissions and economic growth with emphasis on the social welfare index of OPEC member countries. To this end, the data of OPEC member countries from 2000 to 2014 were analyzed using the data panel approach. The results showed that CO2 emissions have a positive and significant relationship with the economic growth of OPEC member countries, which means that the higher the CO2 emissions, the higher the nominal growth. However, when the relationship between CO2 emissions and economic growth is calculated by emphasizing the welfare index, it shows that this effect is declining. It means that the effect of pollution on declining welfare ultimately reduces the rate of economic growth. Give. Therefore, countries should take a constructive step in improving economic growth and reducing pollution by improving the quality of the environment and creating a suitable foundation for realization of this goal, because one of the main goals of societies and governments is to improve the welfare of society.

**Keywords**: Carbon Dioxide, Economic Growth, Welfare Index, Panel Data

## Introduction

Economic growth emphasizes the expansion of economic activity, while economic development focuses on promoting the quality of economic growth, the sustainability of economic growth, and social welfare. Environmental concerns have shifted countries' attention from nominal growth to real growth (Padash and Ghatari, 2020; Long and Ji, 2019). Sustainable development and reduction of climate change are the principles of policy-making in many welfare states. However, environmental policies must address many of the other challenges faced by welfare states today, such as rising public debt, unemployment, social and economic conflicts, and population aging (Padash et al., 2015; Ottelin et al., 2018). On the other hand,

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today the volume of negative effects of polluting industries is so great that every unarmed eye realizes its consequences. Governments have changed direction in different ways and with different sensitivities. Many industrial companies also try to provide a platform to reduce carbon emissions, as a large share of carbon input and emissions comes from industrial production (Song et al., 2020; Jia et al., 2020; Liu, 2014). Due to the low cost of environmental pollution in developing countries, this phenomenon has intensified. Therefore, differences in environmental laws can have a significant impact on the trade balance of countries (Abessa et al., 2019; Garmestani et al., 2019; Glicksman et al., 2019; Padash and Ataee, 2019; Sawhney and Rastogi, 2014). With the emergence of carbon footprint in an open economy, international trade in the form of imports and exports allows all societies to consume goods that have been produced using foreign sources. As a result, the production of this type of goods is reduced. Therefore, it can have a significant impact on the economic growth of the country (Gholamipour Foumani et al., 2019). Carbon footprint (CFP) is a measure of the total carbon dioxide emissions that accumulate directly and indirectly from the entire life cycle of a product. CFP actually measures carbon dioxide or other greenhouse gases (Flores et al., 2020; Ratchawat et al., 2020; Chen et al., 2020; Zhou, 2020; Kitamura et al., 2020). Considering the environmental effects, this index can be a very attractive index for companies and organizations (Padash et al., 2016; Gholamipoor, 2018).

The pollution is associated with significant health problems. Low-income households are exposed to higher concentrations of pollutants due to their proximity to industrial and traffic pollution (Jiang et al., 2020; Viganò and Castellani, 2020). Numerous studies have been conducted in the United States to show that low-income groups are more exposed to pollutants for the reasons mentioned. Although there has been a significant improvement in recent years, almost 13% of homes in Europe suffer from damp problems. In parallel, many studies show that low-income populations are exposed to hazardous chemical agents indoors. The Federal Environment Agency of Germany reported in 2009 that children from low-income households were more vulnerable to gasoline hazards and had more lead in their blood than in similar high-income households. Low-income populations also use more chemicals, which poses a serious threat to their health (Kolokotsa and Santamouris, 2015). In the last two decades, economists and environmentalists have used cost-benefit analysis to conclude that an increase in energy consumption is valuable when it can increase economic growth and the benefits of economic growth outweigh the costs to the environment (Nikoo Eghbal et al., 2012). In fact, welfare states accept economic growth only as a prerequisite for dealing with social and economic problems (Kallis, 2011). There is a general consensus that the quality of the environment decreases with the growth of national income until the level of income increases to a certain degree, and then the process of economic growth by itself solves the problems arising in the early stages of development (Zhang and Zhao, 2014).

Forster (1973) in a study examined the effect of pollution reduction policies on economic growth. In addition to the production function, he also related the utility function to the environment and showed that in this case even the level of equilibrium growth is much lower than the case where only the production function depends on the quality of the environment (Forster, 1973). Some of these studies have examined the impact of economic growth on the environment, known as Environmental Kuznets Curve (EKC) studies (Destek and Sarkodie, 2019; Sarkodie and Strezov, 2019; Dogan and Inglesi-Lotz, 2020). Based on these studies, in the early stages of economic growth, an increase in the production level leads to environmental degradation, but in the higher stages of growth, the demand for environmental standards increases and a positive relationship is established between production growth and environmental quality (Gorus and Aslan, 2019; Shahbaz et al., 2019; Asongu and Odhiambo, 2019). Therefore, based on the EKC hypothesis, there is an inverse U-shaped relationship between economic growth and environmental degradation. One of the major drawbacks of EKC studies is the lack of attention to the interaction between environmental quality and economic growth. In these studies, only the effect of economic growth on environmental quality is examined, while the quality of the environment in turn directly and indirectly affects economic growth (Hakimi and Hamdi, 2016). On the other hand, in the process of calculating GDP in different ways, we do not pay attention to the important point of how much the production of goods and services will cost the society. Many production plants produce soot, toxic gases, and polluting wastes and sometimes polluted effluents as a by-product or an external agent. Basically, the value of these side factors is negative, but at the same time, they are not considered in national accounts (Shakeri, 2015). Energy consumption and carbon dioxide emissions in Iran have increased significantly in recent decades, and Iran, an emerging economy, is one of the countries with the highest levels of carbon dioxide emissions in the world. According to statistics from the Carbon Dioxide Information Analysis Center (CDIAC), located at the U.S. Department of Energy's (DOE), Iran ranks eighth in terms of annual carbon dioxide emissions and seventh in 2010 with one step up in the world (Hosseini et al., 2019). As human development progresses, the increasing environmental degradation will lead to the deprivation of some families and communities. While higher incomes and better technologies are one of the keys to the welfare of societies, the other key is the development of the health of individuals in society, which can be influenced by the immediate and direct effects of pollutants and indirect and slower threats such as carbon dioxide emissions and external environmental effects (Gholamipoor Foumani, 2018).

Now the question arises, should income differences between countries matter? Undoubtedly, the answer is yes. High income levels reflect high living standards. Economic growth may to some extent increase pollution or promote individual ideals. However, ultimately, when a rich and developed country is compared with a less developed country, there are significant differences in their quality of life, living standards, and health (Ajamoglu, 2015). Concerns about global warming and environmental pollution are more acute in single-product countries such as OPEC member countries (including Iran), which are mainly dependent on the export of certain types of raw materials (Gholamipour Foumani et al., 2015).

Examining Iran's position in the world in terms of energy consumption and CO2 emissions, comparing energy intensity, energy per capita, and CO2 emissions per capita in the country with the global average, indicates that the country is not on the path of sustainable development and with the continuation of this process, an environmental crisis will be more probable than before. Therefore, the main question of the present study is whether carbon dioxide emissions, given the negative effects on household welfare index, can lead to real economic growth in OPEC member countries?

## Previous Experimental Studies

The first coherent theoretical study on the relationship between economic growth and the environment was presented in 1971 by D'Arge (1971), who showed the causal relationship between economic growth and environmental quality using the Harrod growth model (D'Arge, 1971). In fact, attention to the relationship between pollution emissions and economic growth dates back to the 1990s with the design of the Environmental Kuznets Curve (EKC) (Dogan and Inglesi-Lotz, 2020; Sarkodie and Ozturk, 2020; Suki et al., 2020; Chen and Taylor, 2020; Jin and Kim, 2020). This hypothesis shows that the relationship between the two variables of pollution and per capita income is ∩-shaped. In the early stages of growth, pollution increases at a declining rate, reaching its peak, and then decreases at an increasing rate, meaning that from the peak of the curve onwards, the economy refuses to reduce the use of materials and energy in the production process (Martinez- Zarzoso and Bengochea-Morancho, 2003). Zhang and Zhao (2014) stated that with rapid economic growth, China is facing a lot of pressure to reduce greenhouse gas emissions and income inequality. This study examines the impact of income inequality on CO2 emissions at the national and regional levels during 1995 to 2010 in China. The experimental results of this study have shown that income growth increases CO2 emissions and the effects of income growth on pollution vary across China. It was also found that the effect of income inequality on CO2 emissions in the eastern region is greater than in the western region. Finally, it was found that a fairer distribution of income helps control pollution. Sinha and Bhattacharya (2016) in an article using data from 2001 to 2013, found different forms of curves designed at different levels of political decision-making. In fact, after analyzing the data of both industrial and residential areas, it was found that emission levels are different for each class. For this reason, the policies adopted should be different for each specific group. In addition, the confirmation of Kuznets hypotheses reaffirmed the impact of accelerating economic growth on the environment. The study of Pablo-Romero and Sánchez-Braza (2017) was performed in two stages. In the first stage, the amount of carbon during the period 1995 to 2009 was calculated. In the second stage, the Kuznets environmental hypothesis was calculated between the amount of carbon and the total final demand was tested using the data panel model. The results show that the Kuznets hypothesis about the relationship between the carbon footprint and the final demand is not confirmed. It was also found that carbon footprint increases significantly with increasing demand. The traction of carbon footprint varies from country to country and is associated with increasing final demand.

The results of the study by Ottelin et al. (2018) have shown that government public services have led to a 19% increase in carbon footprint and a 38% increase in other materials' footprint. They also stated that the welfare state has important features that ensure carbon reduction among citizens. According to Long and Ji (2019): First, per capita consumption has decreased in some provinces and is a threat to social welfare and sustainability; Second, the "relative threshold effect" - the progress of social welfare is slower than the expansion of the economic scale - the amount of resource consumption and environmental pollution, especially water pollution and carbon emissions, will cause significant damage to welfare. Gholamipour et al. (2019) stated that with the emergence of carbon footprint in an open economy, international trade in the form of imports and exports will allow all societies to consume goods that are produced using resources from abroad. With the flow of goods and services between countries, carbon pollutants also flow virtually. The results of the analysis show that the status of carbon footprint has a significant and inverse effect on imports of the entire Iranian economy. It was also found that the reduction in carbon emissions is in line with the increase in this gas.

The situation of carbon footprint has a significant and inverse effect on the country's exports. Although the increase in carbon dioxide emissions has a positive effect on many economic sectors in Iran, including agriculture, industry and services, but in most sub-sectors of the energy sector, this effect is reversed. In such a way that it has an inverse effect on oil, gas and coal exports and it has positive effect only on the export of petroleum products. Considering the weight of each product in the country's export basket, the outcome of the impact of the carbon footprint on the country's exports is estimated to be inverse. The results of estimating the production function and the environmental pollution function (CO2 emission) simultaneously using the two-stage least squares (SLS2) method during the period 1971 to 2007 in the study of Behboudi and Sojoudi (2010) show that despite the positive effect of the environment on GDP growth, environmental pollution increases in the process of economic growth. The results also show the insignificance of the effect of credit spent on environmental protection on increasing the quality of the environment. Nikoo Eghbal et al. (2012) show that in all income groups there is a one-way causal relationship from economic growth to energy consumption. The results of the causal relationship from economic growth to the growth of carbon dioxide emissions show that in ML group this relationship is positive, while in MH and

H groups this relationship is negative. Furthermore, considering that the decreasing trend of carbon dioxide emission intensity relative to the increase in revenue in the three income groups confirms the Kuznets environmental curve, the accuracy of the Kuznets environmental curve using the DOLS technique in all studied countries is rejected and the N-shaped curve is confirmed. The results based on the coverage probability of variables in the model of Mehrara et al. (2016) indicate that the ratio of investment to production, population growth rate (with a negative sign), growth of imports of capital goods, growth of labor force and growth of imports of intermediate goods rank first to fifth in Iran's economic growth, respectively. On the other hand, no significant relationship is observed between the energy consumption and the growth of non-oil production in Iran due to the low probability of the presence of this variable in the model. Therefore, energy saving policies are not considered a threat to economic growth.

The results obtained from the study of Momeni et al. (2016) indicate that the country is moving further away from the path of sustainable development, because Iran is in a deplorable situation in terms of water resources and as a country with the short of water might lose its fertile lands much sooner. Given that natural resources are being destroyed, domestic production at any cost and in exchange for environmental degradation, lack of government intervention and the lack of mandatory standards for optimal energy consumption in the field of production, distribution and transmission and reduction of pollutant emissions in production processes as well as the lack of organizational oversight of the energy consumption in highly polluting industries accelerates this destruction and plunges the country into irreparable environmental crises. Among the many studies conducted, a very limited number of studies have attempted to examine the relationship between environmental quality and economic growth, and the vast majority of studies have examined the impact of economic growth on environmental quality. The present study tries to explain the relationship between carbon footprint and economic growth in oil-rich countries by using growth models commensurate with the Iranian economy. This study also tries to consider the welfare of households, which is naturally affected by the quality of the environment. In this way, to provide solutions for sustainable growth and also to show that a threshold effect of environmental protection is necessary to achieve sustainable growth. In other words, the end result of environmental protection must be large and large enough for economic growth to be on a sustainable path.

## Methodology

In this research, the researcher has used the combination of time-series and cross-sectional methods. Cross-sectional and time series analysis, or in other words, panel data, is one of the practical topics of econometrics; In such a way that it examines and analyzes a number of countries, enterprises, households, etc. as sections over time. Panel data provides a very information-rich environment for the development of estimation methods and theoretical results. In many cases, researchers can use panel data for cases that cannot be examined only in time series or only cross-sectionally. The standard shape of this model is as follows:

$$Y_{it} = \alpha_i + \beta X_{it} + \epsilon_{it}$$

Where, k is an explanatory variable (excluding the intercept) in $X_i$. Depending on the state of α, there are three cases: Case 1: If there is no difference between the sections, then α enters the model as the average of all sections. In this case, the OLS method will provide efficient and consistent estimates of α and β. Case 2: If there is a difference between the different sections, the difference between the sections is shown in $\alpha_i$, which is assumed to be constant over time. This method is called fixed effects model. Case 3: if it is assumed that the difference between the sections is random and not constant over time, another method called random effects is used to estimate the model.

## Data and unit-root test in panel data

For experimental analysis, time series data related to OPEC member countries during the period 2000-2014 were used. The Organization of the Petroleum Exporting Countries (OPEC) is an oil cartel consisting of Algeria, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, Ecuador, Angola and Venezuela. The main purpose of this organization is to coordinate and integrate the oil policies of the member countries and determine the best way to ensure their collective or individual interests, to design ways to ensure the stability of oil prices in the international oil market in order to eliminate harmful and unnecessary fluctuations, to have a special attention to oil-producing countries and to the need to provide a stable income for oil-producing countries, to supply oil to consuming countries in an efficient, cost-effective, and permanent manner with appropriate and fair returns for those investing in oil industry. In this study, information concerning indexes is collected from statistics and data of World Development Indicators (WDI). If the time series variables used to estimate the model parameters are non-stationary, the probability that the obtained regression is false is very high, in which case the use of t and F statistics would be misleading. Therefore, to prevent false regression, the data are first tested for stationarity state. In the stationarity test, what matters is the strength of the unit root tests. Most researchers agree that as the sample size increases, the strength of the tests increases and their results can be trusted. However, the main problem with long-term time-series data collection is that it is often not possible for researchers (especially in less developed countries). On the other hand, in countries where this is possible, the test results will be biased due to possible structural changes and failures. Therefore, it is better to use panel models, as described above, to evaluate the strength of the tests, instead of simply emphasizing time series, which is obtained by combining time-series data in different groups. This not only solves the problem of lack of observations, but also prevents the possibility of being caught in the trap of structural changes and failures. Panel data has many advantages over cross-sectional or time-series data. Increasing confidence in estimates, explaining more advanced models, and reducing the problem of collinearity between variables are the most important advantages of this method.

## Explaining production function

In this part of the research, the researcher tries to design and estimate an appropriate model that can reasonably explain the changes in the variables. Then, the data are analyzed and the hypotheses are tested based on the data panel model. Initially, to avoid regression fallacy and to ensure the data stationarity, the statistical properties of the data were examined in terms of stationarity or the existence of a unit root. Then, Chow and Hausman test was used to select the appropriate model.

The production function used is the Cobb Douglas production function with a constant return to the production scale in which the elasticity of substitution is one. This function is defined as follows:

$$Y = AL^{\alpha}K^{\beta}G^{\gamma} \tag{1}$$

Where, Y: product produced, A: total factor productivity, K: private capital input, G: public capital, and parameters $\alpha$ ‹$\beta$ and $\gamma$ denote the elasticities of production to labor force, private capital and public capital, respectively. The strength of this general function of Cobb Douglas function as the representative of the total production function is the separation of private and public investment (Mahdavi, 2000, p. 8). In Barro model (1990), in terms of the main factors of production, it is assumed that the government increases production just by producing public goods. The existence of public goods produced by the government will increase production in the enterprise, and therefore the Cobb Douglas production function form for the enterprise will be as follows:

$$Y = AL^{1-\alpha}K^{\alpha}G^{1-\alpha} \quad ; 0<\alpha<1 \tag{2}$$

This equation implies that the production will have a constant return to scale for the L and K inputs. In this model, it is assumed that the government has a balanced budget and government expenditures are provided as follows at the tax rate of GDP:

$$G=t.Y \tag{3}$$

In this equation, it is assumed that t and Y/G are constant over time. Thus, profit of economic enterprises will be as follows after tax:

$$L_i.[(1-t).Ak_i^{\alpha}G^{1-\alpha} - w - (r+\delta).k_i \tag{4}$$

Where, r: interest rate, δ: capital depreciation rate, w: wage rate, r+δ: capital lease rate at which:

$$k_i = {}^{K_i}/_{L_i} \tag{5}$$

In a fully competitive market, the wage rate after tax is equal to the final output of labor force and the capital lease rate (r + δ) after tax is equal to the final output of capital. If $k_i$ = K, then the lease or capital ratio will be:

$$r+\delta = (1-t).\left(\frac{\partial y_i}{\partial K_i}\right) = (1-t).\alpha A.k^{-(1-\alpha)}G^{1-\alpha} \tag{6}$$

Thus, Equations (2) and (3) can be rewritten as follows:

$$G = tAL^{1/\alpha}k \tag{7}$$

Substituting the above equation into Equation (3):

$$r+\delta = (1-t).\left(\frac{\delta y_i}{\delta K_i}\right) = \alpha A^{1/\alpha}(Lt)^{(1-\alpha)/\alpha}(1-t) \tag{8}$$

By placing the value of r from Equation (5) in Equation (4), the following equation is obtained:

$$\gamma = \left({}^{1}/_{\theta}\right)[\alpha A^{1/\alpha}(Lt)^{(1-\alpha)/\alpha}.(1-t) - \delta - p] \tag{9}$$

In this equation, the effect of tax on growth can be presented. So that (1-t) shows the negative effect of tax and $(t)^{(1-\alpha)/\alpha}$ reflects the positive effect of tax on economic growth. In Equation (9), as mentioned, $(Lt)^{(1-\alpha)/\alpha}$ shows the positive effect of government expenditures on economic growth and the term (1-t) shows the negative effect on economic growth. (Barro and Sala-I-Martin, 1995). In this model, which is also clear from its relations, it cannot be state with certainty that government expenditures cause an increase in production and economic growth, but it depends on the volume and scope of government activities. Now, according to the theoretical foundations presented above, it can be accepted that in addition to the factors of labor force and capital, government expenditures also affect economic growth, the impact of which is not already known in any country. To test and present an empirical growth model for the country's economy, the following relation can be written according to the "Barro"'s production function:

$$\text{Ln}(y) = \text{Ln}(A) + (1-\alpha)\,\text{LnL} + \alpha\,\text{Ln}(K) + \gamma\,\text{LnG} \tag{10}$$

The above model is written as follows to estimate the contribution of each factor to production and predict the growth, where $\varepsilon_t$ is part of the model error.

$$\text{Ln}(y) = \text{Ln}(A) + (1-\alpha)\,\text{LnL} + \alpha\,\text{Ln}(K) + \gamma\,\text{LnG} + \varepsilon t \tag{11}$$

## Household welfare function

In the literature on household welfare functions, a variety of criteria have been developed by Dasgupta, Sen, and Start (1970), Shiynski (1972), Sen (1974), Yetzhaki (1979), Shurokz (1983), Kakwani (1984), Dagum (1990 and 1993). , Mekapdehi (2001, 2003 and 2004), etc.

However, Amartya Sen's welfare function is very important due to strong theoretical foundations and the introduction of welfare axioms. The Social Welfare Index shows the relationship between per capita income and the degree of inequality in income distribution. In 1974, Sen proposed this function as a function of social welfare.

$$WLF=\mu(1-G) \quad (13)$$

WLF is social welfare, μ per capita income, and G is the Gini coefficient. In addition to using the Gini coefficient as one of the criteria for income distribution, this index also uses the real per capita income criterion as one of the most important criteria for welfare. Therefore, due to the existence of two very important criteria that play an important role in the welfare of societies, it is one of the most common indicators for assessing the social welfare of societies.

## Final model

In the final model, the relationship between the volume of carbon dioxide gas as an indicator of carbon footprint and the household welfare index is explained. This model is adapted from the studies of Lu et al. (2010), Zhang and Zhang (2018) and Bashir Muhammad (2019):

$$Ln\hat{y}_t = \beta_0 + \beta_1 LnCO2_t + \beta_2 Ln(CO2 * WLF)_t + \beta_3 Ln\hat{y}_{t-1} + \beta_4 \sum ctrl_t + u_t \quad (14)$$

$\hat{y_t}$: Fitted amount of production in the economy
$\hat{y_t}$: Fitted amount of production in the economy
$\widehat{y_{t-1}}$: Production of the previous period in the economy
CO2: carbon dioxide emissions
WLF: Household Welfare Index
Ctrl: control variables, such as inflation rate, foreign direct investment.

## Findings

*Unit-root test in integrated patterns*

In this research, the common test in this field, namely Levin-Lin-Chu test, is used. Null hypothesis in this test states that there is a unit root. Therefore, rejecting the null hypothesis means that there is no unit root and the variables are stationary. The results of this test are summarized in Table 1. It is observed that all variables are stationary at zero level.

**Table 1**. Results of unit-root test LLC (with intercept and trend)

| Variable | Symbol | Statistics | Probability | Test Result |
|---|---|---|---|---|
| carbon dioxide emission (kiloton) | Co2 | -4.76 | 0.00 | Stationary at zero level |
| Carbon dioxide emissions * Welfare index | Co2*WLF | -219.65 | 0.00 | Stationary at zero level |
| Production in the economy in US dollars in the previous period (fixed price in 2010) | $Y_{t-1}$ | -4.61 | 0.00 | Stationary at zero level |
| Inflation rate | Inf | -2.79 | 0.00 | Stationary at zero level |
| foreign direct investment | FDI | -4.53 | 0.00 | Stationary at zero level |
| Fitted amount of production in the economy | Y | -10.96 | 0.00 | Stationary at zero level |
| GDP (fixed price in 2010) | GDP | -.6.17 | 0.00 | Stationary at zero level |
| government expenditures | G | -6.18 | 0.00 | Stationary at zero level |
| Labor force | l | -3.74 | 0.00 | Stationary at zero level |
| Capital | k | -16.16 | 0.00 | Stationary at zero level |

## Estimation of production function

To determine the presence or absence of separate intercept for each country, firstly, the Limer test should be examined and a selection should be made between cumulative and non-cumulative data (fixed effects or random effects). The result of the F (Limer) test confirms the model estimation by the fixed effects method. That is, the obtained F is greater than the table F, so H0 hypothesis on the equality of intercepts is not supported. Then, using Hausman test, the calculated chi-square statistic confirms the random effects method in the model.

**Table 2**. Chow test

| Fixed effects method | Critical value | Degree of freedom | Estimated probability |
|---|---|---|---|
| Cross-section F | 2.59 | 11.165 | 0.00 |
| Cross-section Chi-square | 28.76 | 11 | 0.00 |

**Table 3**. Hausman test

| Fixed effects method | Critical value | Degree of freedom | Estimated probability |
|---|---|---|---|
| Cross-section random | 0.846 | 3 | 0.83 |

Given that the initial value of the Durbin-Watson is a large distance from the number 2, it indicates the problem of autocorrelation of error terms. To solve this problem, the AR component enters the model and the results of the analysis are as follows:

**Table 4**. Estimation of fitted production function

| Variable | Coefficient | T statistics | Probability |
|---|---|---|---|
| C | -1.28 | -6.69 | 0.00 |
| L | 1.00 | 13.81 | 0.00 |
| K | -0.02 | -0.83 | 0.40 |
| G | -0.20 | -6.80 | 0.00 |
| AR(1) | 0.13 | 43.75 | 0.00 |
| AR(2) | -0.03 | -1.77 | 0.07 |
| Adjusted R-squared= 0.77 | | R-squared= 0.75 | |
| F= 30, 24 | | prob= 0.00 | |
| D.W=2.03 | | | |

Based on the results shown in the table above, production in OPEC member countries has a significant and positive relationship with labor force and a negative and significant relationship with government expenditures. However, it has no significant relationship with capital.

The adjusted coefficient of determination is 75%, which indicates the acceptable explanatory power of the independent variables, i.e., more than 75% of the changes in the dependent variable can be justified by the independent variables. After investigating the significance of the partial regression coefficients individually, the significance of the whole regression should be examined. The value of F statistic is more than its value in the table and despite the probability of being equal to zero, the whole regression is statistically significant. Considering the Durbin-Watson statistics of 1.95 and also the integrated nature of model, lack of autocorrelation of error terms and the model soundness can be claimed. The purpose of estimating the production function is to obtain the $\widehat{Y}$ values. After obtaining fitted production or fitted economic growth, the amount of social welfare should be calculated using the following equation and available data: WLF=μ(1-G)

The calculated values of the welfare index multiplied by the amount of CO2 emissions as an independent variable along with the amount of economic growth ($\hat{Y}$) fitted as a dependent variable are included in the following model and finally the relationship between carbon footprint and economic growth with an emphasis on the welfare index in OPEC member countries was estimated:

$$Ln\hat{y}_t = \beta_0 + \beta_1 LnCO2_t + \beta_2 Ln(CO2 * WLF)_t + \beta_3 Ln\hat{y}_{t-1} + \beta_4 \sum ctrl_t + u_t$$

To determine the presence or absence of separate intercepts for each country, the Limer test was performed, which according to the results, the data panel method was accepted at the level of 95% and above.

The Hausman test was used to determine whether the difference of intercepts was random or fixed. The results of this test are given in Table 6.

**Table 5**. Chow test

| Fixed effects method | Critical value | Degree of freedom | Estimated probability |
|---|---|---|---|
| Cross-section F | 11142.41 | 11.136 | 0.00 |
| Cross-section Chi-square | 1041.14 | 11 | 0.00 |

**Table 6**. Hausman test

| Fixed effects method | Critical value | Degree of freedom | Estimated probability |
|---|---|---|---|
| Cross-section random | 14.61 | 5 | 0.01 |

According to the results of this test, the model with fixed effects was estimated, and the estimation results are as given in Table 7. Given that the initial value of the Durbin-Watson is a large distance from the number 2, it indicates the problem of autocorrelation of error terms. To solve this problem, the AR component enters the model and the results of the analysis are as follows:

**Table 7**. Estimation of fitted production function

| Variable | Coefficient | t-statistics | Probability |
|---|---|---|---|
| C | 3.20 | 33.45 | 0.00 |
| Log co2 | 0.02 | 2.09 | 0.03 |
| Log co2*SWI | 0.001 | 2.80 | 0.00 |
| Log $Y_{t-1}$ | 0.0001 | 0.03 | 0.97 |
| Log inf | 0.004 | 1.74 | 0.08 |
| Log FDI | 0.002 | 0.82 | 0.40 |
| Adjusted R-squared= 0.99 | R-squared= 0.99 | | |
| F= 7.8225, | Prob= 0.00 | | |
| D.W= 1.95 | | | |

Based on the results shown in the table above, the economic growth of OPEC member countries has a significant and positive relationship with the amount of carbon dioxide emissions. The increase in environmental pollution stems from two reasons. First, in the early stages of economic growth, due to the high priority of national production and the level of employment, natural resources and energy are widely used to achieve high economic growth. Second, given low per capita incomes, businesses are unable to meet pollution reduction costs. Welfare index also has a positive and significant relationship with economic growth. Nevertheless, no significant relationship was found between the production of the previous period and economic growth in these countries. The adjusted coefficient of determination was calculated as 99%, which indicates the high explanatory nature of the independent variables, i.e., more than 99% of the changes in the dependent variable can be justified by the independent variables. After investigating the significance of the partial regression coefficients individually, the significance of the whole regression should be examined. The value of F statistic is more than its value in the table, and despite the probability being equal to zero, the whole regression is statistically significant. Considering the Durbin-Watson statistics of 1.95 and also the integrated nature of model, it can lack of autocorrelation of the error terms and the model soundness can be claimed.

## Conclusion and recommendations

Economic growth emphasizes the expansion of economic activity, while economic development focuses on improving the quality of economic growth, the sustainability of economic growth, and social welfare. Environmental concerns have shifted the focus of countries from nominal growth to real growth. The level of economic development of countries and the observance of environmental standards are among the factors affecting the relationship between economic growth and carbon dioxide emissions. Accordingly, in the present study, using the data panel method, the relationship between carbon dioxide emissions and economic growth with emphasis on the social welfare index of OPEC member countries from 2000 to 2014 was investigated. The results of the estimate showed that $CO_2$ emissions with an intensity of 0.02 have a positive and significant relationship with the economic growth of OPEC member countries. This means that the higher the $CO_2$ emissions, the higher the nominal growth. However, when the correlation between $CO_2$ emissions and economic growth was calculated with an emphasis on the welfare index, it was found that this effect has decreased to 0.001, which means that the effect that pollution has on the reduction of welfare ultimately reduces the rate of economic growth. Quality of life and level of social welfare in countries is one of the most important criteria for development. Accordingly, one of the most important goals of economic policy makers is to increase social welfare. In the present age, different countries view science, technology and innovation as key sources of competitive advantage as well as essential tools for improving people's living standards. Many manufacturing plants use technologies that produce soot, toxic garbage, and polluting wastes, and sometimes contaminated effluents, as a by-product or an external agent. Basically, the value of these side factors is negative, but at the same time, they are not taken into account in national accounts and only the main products of factories are measured. Environmental quality can be one of the factors affecting public health in society. As observed in this study, environmental pollution has reduced social welfare and thus slowed economic growth in the countries studied. Basically, clean air and environment free from toxic gases and bio-pollutants, is itself an important and main goal and in the new conditions of urban and industrial production has threatened the air, water and living environment; Contaminants must be externalized to the external agent of the enterprise. Internalization of these factors by firms reduces pollution. Because internalization means creating a situation in which firms pay for their own actions on pollution. In this case, the commodity production of firms may decrease, but if we consider the clean environment as a very valuable public good, in this case, real GDP may be higher than when external factors were not internalized for the firm. The countries must take a constructive step in improving economic growth and reducing pollution by improving the quality of the environment as well as creating a suitable ground for realization of this goal, because one of the main goals of societies and governments is to improve the welfare of society. Achievement to this important goal can be accelerated by improving the quality of the environment and economic growth. Therefore, the first step to reduce environmental degradation is to consider the policies to control pollution from fossil fuels to reduce carbon dioxide emissions and strategies for the efficient and rational use of energy inputs in various sectors of the economy. Since carbon dioxide emissions also depend on energy consumption in some way, it seems necessary to take measures to improve the energy consumption pattern and increase energy efficiency.

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