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Investigating Economic Factors Affecting Air Pollution in Developing and Developed Countries; A Spatial Regime Model Approach

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Abstract

The relationship between the variables e.g. economic growth, energy consumption, foreign direct investment, and the growth of pollution are complex issues, and important for the countries, which are planning a sustainable development strategy. On the other hand, considering the effects of geopolitical spillover on environmental economic issues, this paper studies the effective economic factors on carbon dioxide emissions in the developing and developed countries over the period 1993–2016, by employing the approach of the spatial regime panel. Results show that there are spatial effects and spatial heterogeneity between the variables. Accordingly, in this paper, we employed the regression approach of the spatial regime panel. Results show that the how variables affect the spatial regimes varies, and countries that have the structure of the first or second regime have different effects in terms of size and significance of the coefficients. So that in the study of the effect of spatial autoregression variable in the developing countries in the first spatial structure regime, there are neighboring effects of carbon dioxide emissions; while in the second spatial structure regime, there is no neighboring effects in the dependent variable.

Keywords: Carbon Dioxide Emission, Economic Factors, Kuznets Theory, Spatial Spillover, Regression Panel of Spatial Regime;
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1. Introduction

The environmental economy generally addresses the relationship between the economy effects on the environment and the environmental effects on the economy. Economics and the environment are linked through two flows. On the one hand, the renewable and limited resources are moving from the environment to the economy and, on the other hand, most of the products wastes generated by economic activities are moving from the economy to the environment. When the flow of materials and waste exceeds the real capacity of the environment, the capacity of natural and environmental resources decreases. The rapid flow of limited resources into the economic cycle poses the risk that the limited resources reserves may be over more quickly [6].
When the flow of renewable resources into the economic cycle exceeds the rate of renewal of these resources, the resources efficiency reduces and the likelihood of their extinction increases. Excessive waste generation more than the environment's capacity increases the likelihood of natural resources erosion. The reduction and rapid erosion of limited resources will increase the utilization of renewable resources. In addition, the increase of the emission wastes more than the environment's capacity generally indicates that the economy is moving towards the environment more dependently [8].
Since 1990, researchers have frequently studied the effect of global warming on the economy. So that one of the bugs attributed to the classic and neoclassic growth theories is their focus on sustainable development and the achievement of economic growth, regardless of environment's degradation. Various factors such as economic, demographic, technological, welfare issues, and international trade affect carbon dioxide emissions, among which energy consumption (especially in the form of fossil fuels in industries that are closely related to economic growth and development) has a major contribution to it [14]. In addition to the relationship of economic growth with energy consumption, its relationship with environmental pollution has been empirically examined over the past two decades. Research in this field can be divided into three general approaches. Despite the effective economic performance of the past two decades, the environment's quality is getting worse day by day. Therefore, the relationship between environmental performance and macroeconomic variables is one of the most important concerns in different countries.
On the other hand, carbon dioxide emissions have external costs, which are mainly posed to the people who do not involve in its generation. External costs arise when economic activities of one or more groups affect other groups or countries [7]. Thus, it seems that with increasing carbon dioxide emission in one region, it also increases in other regions. The spatial distribution of carbon dioxide emission is described by using explanatory spatial data analysis (ESDA), which helps identify spatial regimes and other types of spatial instabilities. Due to the recent spatial changes in environmental pollution (carbon dioxide emissions) in the developing and developed countries, the existence of spatial regimes gets possible. When the spatial regimes are established and examined in different places of carbon dioxide emissions, the spatial econometric models are estimated based on the probable spillover caused by independent variables with respect to their direct and indirect effects. Thus, in this paper, factors affecting the carbon dioxide emissions in the developing and developed countries are studied based on the approach of the spatial regime panel.
The remainder of this paper is organized as follows. Section 2 presents the theoretical foundations and research background, and Section 3 introduces the research model. Section 4 addresses the empirical model and research variables, and Section 5 provides the research findings. Finally Section 6 concludes the paper.

2. Theoretical foundations and research background

Research on the variables that affect greenhouse gas emissions began from the 1980s and 1990s. These early studies mainly sought to investigate the relationship between environmental quality and macroeconomic variables. The main variables studied in this paper are GDP, trade, energy consumption, investment, population, research and development expenditures, urbanization, and transportation. Among them, the explanatory power and the presence of three variables of GDP, energy consumption, and foreign trade has been more important than other variables. Since the 1990s, the focus of studies has been on the inverted U curve. It has been argued that most developing countries are on the upside of this chart, and developing countries are mainly in the downside of this chart. The effect of GDP, trade, energy consumption, investment, population, research and development expenditures, urbanization, and transportation on greenhouse gas emissions have also been mainly predicted as positive.

Over the past decades, the relationship between economic growth and the environmental quality has attracted the attention of economists and ecologists. They often came to prove that when the income level was low, the environmental quality worsened, and when the income rose and exceeded the threshold, the pollution reduced. If the phenomenon exists, there is an inverse U-shaped relationship between the economic growth and the environmental effects, which is known in the environmental economics literature as the Kuznets environmental curve (EKC).

Furthermore, in recent years, what has concerned much attention is the negative side effects of globalization and free trade on the environment. So that by presenting the pollution haven hypothesis (PHH), the main role of trade and globalization in the transfer of pollutants from the developed countries to the less developed or developing countries has become more apparent [5].

Due to the theoretical foundations, the empirical literature in this regard is very broad. So that most of the studies have sought to identify the major variables that affect carbon dioxide emissions. Most of the variables studied in these research that affect carbon dioxide emissions include foreign trade, energy consumption, GDP, and foreign investment. Some other studies have tried to find that if there is an inverse U-shaped relationship between GDP and carbon dioxide emissions. Results for the developed countries have confirmed this relationship. Accordingly, in this section, studies related to the subject matter are presented.

Omri et al. [12] studied the relationship between per capita carbon dioxide emissions, per capita GDP, and energy consumption in MENA countries. Results showed that in all countries, per capita energy consumption had a positive effect on per capita emissions.

Burnett et al. [4], by using the spatial panel econometric model in the US over the period 1970–2008, confirmed the EKC hypothesis, and found the positive spatial spillover of economic growth and the negative spatial spillover of energy carriers.

Shenggang et al. [15] studied the effect of trade and foreign direct investment on carbon dioxide emissions in China's industrial regions by using the two-step GMM estimation. Results showed that the increase of foreign direct investment would exacerbate carbon dioxide emissions.

Zhao et al. [16] studied 30 provinces in China over the period 1991–2010 by using a panel spatial econometric model, and found that per capita production of provinces had a negative significant effect on carbon dioxide emissions, and the spatial spillover of pollution and energy shocks was positive.

Miguel et al. [11] studied the crime expansion based on the murders rate in the Mexican cities over the period 2005–2010 by employing the approach of the spatial regime panel. He found two regimes related to the states—one for the states exposed to joint operations and the other for the ones that are not exposed to—and estimated the econometric models for each regime in order to establish the spatial dependence between the states. Spatial regression results point to an important difference in

the concept, size, and sign of the effects of some variables based on each regime's properties.
Abdouli et al. [1] studied the effect of economic growth, direct investment, free trade, and energy consumption on the environment in 17 MENA countries by using the static and dynamic panel data methods. Results showed that there was an environmental Kuznets curve. Results also revealed that foreign direct investment would increase environmental pollution, and the rise of energy consumption would increase carbon dioxide emissions.
Wang et al. [18] studied the spatial effects of carbon dioxide emissions among China's provinces, as well as the effects of technology on air pollution over the period 1980–2014. Results showed that the spatial effects of carbon dioxide emissions have been confirmed in the studied period. The effects of technology have also reduced carbon dioxide emissions significantly in China.
Yang et al. [17] studied the spatial effects of different variables on carbon dioxide emissions in China over the period 1985–2015. Results indicated that there were positive and negative spatial effects of carbon dioxide emissions in the Chinese provinces. So that the industrialization structure variables have positive effects on carbon dioxide emissions, while the technology structure variables have negative spillover effects on carbon dioxide emissions.

3. Research Model

In a situation where the determinant structure of the variable in question can be changed in the locations, structural conditions have different effects on the variable in different locations and lead to spatial regimes [10]. Spatial models are spatially heterogeneous. In other words, the variable is not stable in space. When this variable is identified by a separate distribution, spatial regimes can be presented for different locations. Spatial heterogeneity occurs when there is a location structural change in the data. In such cases, spatial regimes may be presented and characterized by varying either the parameters amount or the application forms. Spatial econometric models are estimated for each regime with regard to the potential spillover effects of the variable.
Structural stability test of the regression coefficients in spatial subsets is performed through Chow tests. The spatial switching regression or spatial regime model applies the spatial Chow test to diagnose structural instability in parameters across all regimes. A significant coefficient indicates changes in the variable across the spatial locations under study. The standard regime model is as follows:

$$\begin{bmatrix} y_i \\ y_j \end{bmatrix} = \begin{pmatrix} X_i & 0 \\ 0 & X_j \end{pmatrix} \begin{bmatrix} \beta_i \\ \beta_j \end{bmatrix} + \begin{bmatrix} \varepsilon_i \\ \varepsilon_j \end{bmatrix} \tag{3.1}$$

Where i and j represent the discrete spaces subsets or data regimes, and the null hypothesis test of $\beta_i = \beta_j$ is estimated in the Equation 3.1. The standard Chow test is as follows:

$$C = [(e_R' e_R - e_u' e_u)/K]\,[(e_u' e_u)/(N-2K)] \sim F_{(K,N-2K)} \tag{3.2}$$

Where e_R and e_u are the OLS residues of a finite model and an infinite model, respectively. N is the number of observations, and K is the number of regressors. When the spatial error terms are autoregressive, the above equation is not valid. The corrected version of the test is called the spatial Chow test [2]:

$$C_s = [e_R'(I-\lambda W)'(I-\lambda W)e_R - e_u'(I-\lambda W)'(I-\lambda W)e_u]\,/\sigma^2 \sim \chi_K^2 \tag{3.3}$$

Where λ is the estimation of ML for the spatial parameter, $\sigma^2$is the estimation for the error variance for the finite model (Lm test), the infinite model (W test), or both (LR test), and I is the matrix identification of $n \times n$.

In modeling the amount of carbon dioxide emission, the degree of pollution in a certain location may depend on the degree of pollution in neighboring areas. To calculate such an emission mechanism, for empirical analysis, spatial autoregression (SAR) is proposed. These models have different properties, which in some cases are added as a lagged dependent variable (spatial lag model), autoregressive spatial error term (spatial error model Error) or both in a similar regression model (SARAR Model). Another property of the SAR model is the lag of forecasted variables rather than response variables. In this case, other conditions in the model must be established for the parameters of predictive spatial lagged aoturegression (WX), whose the model is called spatial Durbin model (SDM). To save the space, the generation process, which is related to its direct and indirect effects for the lagged spatial model and SDM in terms of spatial regime models, is briefly presented. The generation process for the spatial lagged model is as follows:

$$y = \rho w y + X\beta + \varepsilon \tag{3.4}$$

$$y = (I_n - \rho w)^{-1} X\beta + (I_n - \rho w)^{-1}\varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 I_n)$$

Where y represents a vector of $n \times n$ of the dependent variable, w is the space-weighted matrix with elements of $w_{ij} = 1$ if the two spatial locations have a common boundary, and otherwise $w_{ij} = 0$. In this model, the parameters that are estimated are regular regression parameters (β, σ), and the additional parameter of $\rho$of the lagged dependent variable, is known as the spatial autoregressive coefficient. The error statement is assumed to have a normal distribution with mean zero and variance of $\sigma^2 I_n$.

In the case of SDM, the data generation process can be formulated as follows:

$$y = \rho w y + X\beta + wX\theta + \varepsilon \tag{3.5}$$

$$y = (I_n - \rho w)^{-1} X\beta + (I_n - \rho w)^{-1} wX\theta + (I_n - \rho w)^{-1}\varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 I_n)$$

The result of these models is that the change in the explanatory variable for a geographic unit can potentially affect the dependent variable in all other units. In other words, a spatial lagged property of the dependent variables allows us to establish the amount of spatial effects. The spatial regime model, which represents the regime, can be interpreted in a spatial lagged model as follows:

$$y = \rho w y + x_1\beta_1 + x_1 x_2 \beta_2 + \varepsilon \tag{3.6}$$

Where $x_1$is the continuous variable, and $x_2$is the livestock variable of the spatial regime (0.1).

The model can be summarized as follows:

$$y = (I_n - \rho w)^{-1}(x_1\beta_1 + x_1 x_2 \beta) + (I_n - \rho w)^{-1}\varepsilon \tag{3.7}$$

Where y is the vector of the dependent variable, and w is the space-weighted matrix. In this model, the parameters σ, β and the additional parameter of ρrelated to the lagged dependent variable, which is known as the spatial autoregressive coefficient, are estimated.

4. The Empirical Model and Research Variables

In this study, carbon dioxide emission is presented as a function of GDP, energy consumption, trade liberalization, foreign direct investment, and research and development costs.

$$CO_2 = F(GDP, EN, Trade - Openness, FDI, R\&D) \tag{4.1}$$

This research is descriptive-analytical, and the data has been gathered by documentary studies and desk research. The data has been gathered in panels. The realm of this research includes all the two groups of developing and developed countries. The variables calculation is summarized in Table 1.

Table 1: The variables definition

Variable	Operational definition	Sign
logarithm CO2 emission	Per capita Carbon dioxide gas	LCO2
Logarithm of GDP	Per capita GDP at the constant 2010 price in dollars	LGDPP
Logarithm of energy consumption	Per capita Energy consumption of crude oil (kg)	LEC
Logarithm of research and development expenditures	research and development expenditures as a percentage of GDP	LRD
Logarithm of trade openness	Value of foreign trade as a percentage of GDP	LTRD
Logarithm of foreign direct investment	Foreign direct investment in constant 2010 price	LFDI
Logarithm of population	Number of people residing in each country	LPOP

The data are collected annually from the World Bank website over the period 2016–1993. It should be noted that 30 developed and developing countries have been selected as the sample. The countries has been selected based on data access and ranking by the World Bank and the International Monetary Fund. The statistical properties of the variables has been summarized in Table 2.

4.1. Stationarity test of research variables

Unit root tests in consolidated data were developed by Quah (1994). These studies were completed by Line, Levin, and Chow (1992) . Lane, Levin, and Chow (LLC) showed that in consolidated data, using the unit root test for these data had more test power than using unit root tests for each sector separately. Accordingly, in this research, in order to full study this property, the unit root test of Line, Levin, and Chow (1992) has been used.

The results of the variables' stationarity test are summarized in Table 3. As it can be seen, all the variables studied at the error level of 5% and 10% reject the null hypothesis of the presence of unit root and nonstationarity of variables. The statistical evidence shows that all data are at the level of stationarity, and do not need to be differentiated.

Table 2: Statistical characteristics of the variables under study

Countries	**Statistical measure**	LPOP	LFDI	LTRD	LRD	LEC	LGDPP	LCO2
Developing countries	Average	17.135	21.228	4.144	-1.138	7.107	8.370	11.236
	Mean	16.973	21.248	4.087	-0.974	6.992	8.392	11.398
	Maximum	21.044	26.396	6.090	0.963	9.997	11.194	16.147
	Minimum	13.125	13.592	2.750	-3.162	4.813	5.773	7.234
	Deviation	1.690	2.057	0.593	0.922	0.934	1.117	1.795
	Skewness	0.344	-0.238	0.647	-0.331	0.526	0.189	0.018
	Kurtosis	2.773	3.303	3.992	2.634	3.952	3.013	2.839
Developed countries	Average	16.482	22.831	4.322	0.395	8.254	10.311	11.722
	Mean	16.166	22.902	4.288	0.470	8.249	10.527	11.471
	Maximum	19.594	27.322	6.017	8.608	9.152	11.626	15.572
	Minimum	12.893	14.509	2.773	-1.603	7.396	7.431	8.591
	Deviation	1.470	1.836	0.534	0.643	0.394	0.761	1.564
	Skewness	-0.080	-0.519	0.066	2.348	0.183	-1.354	0.296
	Kurtosis	2.686	3.782	3.631	39.173	2.300	5.263	2.609

Source: Research findings

Table 3: Residual test results at the level of research variables

	Developing countries		**Developed countries**	
Variable	**Statistic**	**Probability**	**Statistic**	**Probability**
LCO2	-1.68	0.04	-3.26	0.00
LGDPP	-15.59	0.00	-2.70	0.00
LGDPP 2	17.25	0.00	-2.78	0.00
LEC	-1.92	0.02	-4.07	0.00
LRD	-1.53	0.06	-1.66	0.04
LTRD	-2.42	0.00	-11.19	0.00
LFDI	-6.54	0.00	-8.03	0.00
LPOP	-13.08	0.00	-8.27	0.00

Source: Research findings

5. Research Findings

5.1. Test for the spatial panel regression

Before estimating the spatial regression model, we need to verify the existence of spatial correlation between the variables. For this purpose, the Moran's I-statistic and the Lagrange coefficient test have been used to identify the spatial correlation patterns between the variables. Results of this test for the two models of developed and developing countries are summarized in Table 4.

As shown in this table, the values of the test statistic indicate that the null hypothesis of the absence

Table 4: Diagnostic test to confirm the use of the spatial model

Model	Type of test	Value of statistic	Probability of test
Developing countries	Moran's I-statistic	6.96	0.000
	Lm test of spatial lag	47.42	0.000
	Lm test of spatial error	52.82	0.000
	LM-Robust test of spatial lag	4.16	0.041
	LM-Robust of spatial error	9.55	0.002
Developed countries	Moran's I-statistic	6.52	0.000
	Lm test of spatial lag	41.47	0.000
	Lm test of spatial error	44.79	0.000
	LM-Robust test of spatial lag	27.11	0.002
	LM-Robust of spatial error	30.42	0.026

Source: Research findings

of spatial correlation pattern between the error terms in the model is rejected at the 99% confidence level, and the presence of the spatial correlation pattern is accepted between the variables. In addition, results of the two LM and LM robust tests in the Table 4 indicate the better fit of the spatial panel than the normal panel (OLS).
The test of the fixed effects of time and place by applying the spatial Hausman test is shown in Table 5, whose results confirm the fixed effects rather than random effects. Results show that the null hypothesis of nonsignificance of the fixed effects of time and place cannot be accepted. Therefore, due to the both effects significance, according to Baltagi et al. [3], the spatial model used in this research is the bilateral fixed effects model.

Table 5: Testing the presence of time and location fixed-effects of the spatial model

Hausman test	Null hypothesis of the test	Value of statistic	Probability
Developing countries	Location fixed-effects are not commonly significant	32.14	0.000
	Location fixed-effects are not commonly significant	62.54	0.000
Developed countries	Location fixed-effects are not commonly significant	40.31	0.000
	Location fixed-effects are not commonly significant	78.54	0.000

Source: Research findings

The results of the Wald test for these statistics are summarized in Table 6 for examining the type of model in this section.
As can be seen, for both developed and developing countries, the SDM model has a better condition than SAC, SAR, and SEM models. Because in both tests, the null hypothesis that $\theta = 0$ and $\theta = -\beta\lambda$ is rejected at the error level of 5% and 10%, and thus, the SDM model cannot be diminished to SAC, SAR or SEM modes. In order to estimate the model, as stated before, all SDM models related to

Table 6: Diagnostic test to confirm the use of the spatial model

Model	Type of test	Parent statistic	Probability
Developing countries	$\theta = 0$	41.44	0.00
	$\theta = -\beta\rho$	41.41	0.00
Developed countries	$\theta = 0$	15.39	0.017
	$\theta = -\beta\rho$	11.14	0.084

Source: Research findings

the spatial, time, and sectors fixed effects have been presented.

5.2. Estimation of the regression of the spatial regime panel

In the study of the spatial regime, as described in the empirical model, spatial heterogeneity creates spatial regimes. Thus, the difference between the spatial regimes in coefficients effect may be observed. The way to deal with spatial heterogeneity models is based on studies using models of geographic weighting or spatial regime. Yet, in this paper, the spatial regime approach used by Anselin et al. [2] has been employed. To address the subject matter, the spatial Chow test has also been applied. Results of the spatial Chow test are shown in Table 7. It should be noted that the Chow test shows that the null hypothesis that the model is in the form of a single-regime spatial is rejected, and the hypothesis of the presence of asymmetric effects in space is accepted. It is possible to create a model with two spatial regimes.

Results show that the effect of variables on spatial regimes varies, and countries that have the structure of the first or second regime have different effects in terms of size and the coefficients' significance. So that in the first spatial structure regime in the developing countries, there are neighboring effects of carbon dioxide emission in the spatial autoregression variable, while in the second spatial structure regime, there are not neighborhood effects in the dependent variable.

Also, in studying the effects of GDP and the squared of this variable in all studied models, both spatial structure regimes, the Kuznets theory has been accepted. So that with the rise of the economic growth, in the first stage, the amount of greenhouse gas emissions will increase, and after the economic development, it will decrease in accordance with the aforementioned theory. In addition, in this estimation, the spatial effects of GDP and its squared has been accepted in the first spatial structure regime, which shows that Kuznets theory is confirmed in the spatial structure. So that the effects of the inverted U structure of the economic growth of the neighboring countries' on their environmental degradation have been confirmed, while this theory has been rejected in the second spatial regime. In other words, in the countries that have the second spatial structure regime, the neighboring effects of Kuznets theory are not confirmed.

Results show that in all three models, the foreign direct investment variable has a positive significant effect on the first spatial structure regime of the developing countries. But in the second spatial structure regime, it has been significant only in the fixed effect model of this coefficient. In other words, by increasing investment in host countries and the increasing the production and economic growth, along with the lack of legislation in support of environmental structures, foreign direct investment have had a damaging effect on the environment, and has led to an increase in carbon dioxide emissions in the developed countries. In addition, results show that the neighboring effects of foreign direct investment has not been significant in different models, and only in the model of time fixed effects and the second spatial structure regime, it has negative effects on carbon dioxide emission.

In studying the effect of energy consumption variable, as can be seen in the theory of economic growth, increasing energy consumption, due to the effects of pollution and environmental degradation, has a positive significant effect on carbon dioxide emission. Since energy consumption is one of the most important factors affecting the environmental pollution, this issue has been confirmed in both spatial structure regimes. The spatial effects of energy consumption variable in the first spatial structure regime have been confirmed in the two cross-sectional fixed effects and time–cross-sectional fixed effects models. In other words, the increase in energy consumption in neighboring countries rises the carbon dioxide emission in the countries that are in the first spatial structure regime. While in countries with the second spatial structure regime, this is confirmed only in the cross-sectional fixed-effects model.

Table 7: Estimation of spatial models for developing countries

Model	**Spatial cross-sectional fixed-effects**				**Spatial time fixed-effects**				**Spatial time–cross-sectional fixed-effects**			
Regime	**First regime**		**Second regime**		**First regime**		**Second regime**		**First regime**		**Second regime**	
Variable/ Parameter	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
ρ	0.247***	3.55	0.057	1.15	0.498***	7.65	-0.037	-0.43	0.096	1.31	0.006	0.11
LGDPP	0.629**	2.38	5.035***	15.64	6.685***	12.95	5.224***	6.14	0.880***	3.22	4.361***	12.47
LGDPP2	-0.05***	-3.11	-0.29***	-15.08	-0.408**	-14.80	-0.33***	-6.52	-0.06***	-3.99	-0.26***	-12.99
LEC	0.992***	14.90	0.954***	11.69	1.330***	11.69	1.308***	10.35	0.931***	13.76	0.888***	10.76
LRD	0.030	1.40	0.119***	4.80	0.126*	1.91	0.012	0.16	0.022	1.02	0.089***	3.53
LTRD	-0.046	-0.91	0.015	0.42	-2.01***	-22.05	-0.79***	-7.08	-0.049	-0.98	-0.020	-0.52
LFDI	0.021***	2.78	0.005	0.61	0.316***	11.97	0.353***	11.13	0.016**	2.05	0.004	0.47
LPOP	-0.003	-0.72	-0.004	-1.11	0.004	0.16	-0.017	-0.83	-0.004	-0.92	-0.005	-1.25
W*LGDPP	0.071***	3.07	-0.13***	-4.83	0.406***	10.07	0.318***	5.68	0.030	1.22	-0.07***	-2.46
W*LGDPP2	-1.14***	-3.12	2.351***	4.81	-7.66***	-11.52	-5.45***	-5.65	-0.603	-1.55	1.212***	2.24
W*LEC	0.485***	3.36	0.353***	3.21	-0.284	-1.10	0.228	1.31	0.453***	3.12	0.175	1.51
W*LRD	0.109***	5.90	0.064**	2.04	0.149**	-2.18	0.46***	-4.53	0.096***	5.13	0.010***	0.32
W*LTRD	0.009	0.15	-0.028	-0.79	1.649***	10.82	0.156	1.33	-0.027	-0.41	-0.100	-2.40
W*LFDI	0.013	1.37	0.018	1.59	-0.057	-1.26	-0.19***	-4.94	0.008	0.83	0.010	0.88
W*LPOP	0.002	0.35	-0.003	-0.57	0.034	1.11	0.031	1.19	0.000	0.03	-0.004	-0.84
R^2	0.81				0.86				0.57			
Chow Test	175.79***				225.55***				107.59***			

Source: Research findings; ***, **, and * show the significance of coefficients at 1%, 5%, and 10% level.

Results of the studying the open trade variable in the developing countries can play a role in reducing carbon dioxide emission due to its effects in previous studies, its increasing the development of technology, and the use of competitive and commercial advantages. This has been confirmed in the time fixed-effects model in both spatial regimes. Moreover, results show that only in the first spatial structure regime, the time fixed effects model of this variable in greenhouse gas emission is significant. The research and development expenditures variable has a positive significant effect on carbon dioxide emission in the time fixed-effects model in the developing countries of the first spatial structure regime. While, this effect is positive in the time–cross-sectional fixed effects in the second spatial structure regime. The spatial effects of this variable on carbon dioxide emission have been significant in most models in the first and second spatial regimes.

Results of estimating the SDM regime for the developed countries are summarized in Table 8. As can be seen, the spatial Chow test shows that considering the spatial structure in different regimes is more efficient than the simple SDM model. So that the null hypothesis that there is no difference between the structure of spatial regimes is rejected.

Results show that in the developed countries, there are the spatial autoregression effects of carbon dioxide emission only in the first spatial regime, and in the second spatial structure regime, there are the spatial autoregression effects only in the cross-sectional fixed-effects model.

In terms of the effects of per capita GDP, results confirms the Kuznets theory for the developed countries in the first spatial structure regime. Thus, the Kuznets theory has been confirmed in the countries of the first spatial regime. In studying the neighborhood effects and the spatial spillover, the Kuznets theory has been confirmed in both spatial regimes. Thus, there is a spatial spillover of the Kuznets theory in the developed countries in both regimes.

Table 8: Estimation the spatial models for developed countries

Model	Spatial cross-sectional fixed-effects				Spatial time fixed-effects				Spatial time–cross-sectional fixed-effects			
Regime	**First regime**		**Second regime**		**First regime**		**Second regime**		**First regime**		**Second regime**	
Variable/ Parameter	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
ρ	0.331***	2.44	0.131*	1.62	1.228***	16.23	0.078	1.11	0.308***	2.11	0.026	0.30
LGDPP	-2.025	-1.30	0.093	0.26	3.333***	3.62	-0.116	-0.72	-1.305	-0.79	0.169	0.47
LGDPP2	0.083	1.14	0.002	0.09	-0.158**	-3.64	-0.025**	-3.02	0.048	0.62	-0.004	-0.21
LEC	1.436***	15.25	1.102***	14.60	0.922***	8.92	1.500***	30.93	1.448***	14.83	1.103***	14.24
LRD	-0.19***	-4.98	-0.491***	-62.74	-0.30***	-10.25	-0.43***	-31.91	-0.21***	-5.33	-0.489***	-61.02
LTRD	0.010	0.17	0.122***	4.70	0.176***	4.64	0.110***	3.61	-0.023	-0.39	0.115***	4.20
LFDI	0.001	0.16	0.004	1.37	-0.002	-0.29	-0.02***	-3.60	0.002	0.44	0.005	1.56
LPOP	0.979***	6.70	1.313***	11.79	1.137***	69.89	1.128***	96.59	0.920***	5.54	1.273***	11.16
W*LGDPP	3.287**	2.75	-0.076	-0.10	1.989**	2.18	2.839***	7.22	3.342**	2.75	-0.448	-0.59
W*LGDPP2	-0.147**	-2.51	-0.016	-0.40	-0.125**	-2.78	-0.16***	-8.08	-0.153**	-2.56	0.00005	0.001
W*LEC	0.626***	3.27	0.224*	1.68	0.965***	7.17	0.581***	6.12	0.636***	3.02	0.379***	2.51
W*LRD	0.008	0.15	0.079*	1.81	0.444***	6.92	0.080**	2.54	-0.033	-0.59	0.028	0.60
W*LTRD	0.136**	2.59	-0.012	-0.26	0.141**	2.61	0.124***	3.10	0.143**	2.57	-0.014	-0.26
W*LFDI	0.003	0.51	0.000	0.07	-0.022	-1.85	-0.019**	-2.28	0.006	0.92	0.003	0.56
W*LPOP	-0.022	-0.11	0.255	1.19	1.214***	13.50	-0.038	-0.47	-0.030	-0.13	0.277	1.19
R^2	0.89				0.99				0.88			
Chow Test	801.17***				480.55***				895.39***			

Source: Research findings; ***, **, and * show the significance of coefficients at 1%, 5%, and 10% level.

As mentioned before, one of the environmental degradation criteria is the destructive effects of energy consumption that results in greenhouse gas emissions. Results of studying this variable in the developed countries show that in both spatial regime structures, the effect of energy consumption on carbon dioxide emission is increasing (Table 8). This has been confirmed in the spatial spillover effects of this variable on the greenhouse gas emissions of neighboring countries. So that this variable effect has been positive and significant in the first and second spatial regimes of all models.

The foreign direct investment variable has had a negative significant effect on greenhouse gas emission only in the second spatial regime of the time fixed-effect model. While in this model, the spatial spillover effects of foreign direct investment on carbon dioxide emission is negative.

The effects of open trade variable in different models have been various in significance. Yet, the significant models in this estimation show that the open trade variable in both spatial regimes has

a negative significant effect. Thus, the effect of this variable can explain the theory. While, in the second spatial regime, the time fixed-effects of this variable have a positive significant effect on greenhouse gas emissions.
In most of the models, the population growth variable, along with the economic theory, has significant effects on carbon dioxide emission. In addition, the spatial spillover effects of the population growth variable have occurred only in the first regime and the time fixed-effects model, while in the second spatial regime, the effects of spatial spillover of the population growth variable have not had a significant effect on carbon dioxide emission.

6. Conclusion

In this paper, factors affecting carbon dioxide emissions were studied based on the spatial regression regime in the developed and developing countries. The initial reviews by applying the spatial effects test confirmed the presence of spatial effects in the studied data. In addition, by applying the Hausman test, the fixed effects was confirmed for the countries under study. Moreover, results of studying the spatial regression confirmed the presence of spatial effects between the variables, and also indicated that the studied variables had spatial effects and spatial correlation. So that the increase in carbon dioxide emission in each country has a positive significant effect on the emission of this gas in the neighboring countries. There are also spillover effects between different regions in terms of other variables such as per capita GDP, foreign direct investment, open trade, research and development expenditures, and population. It should be noted that the effect of variables varies in spatial regimes, and countries of the first or the second spatial structure regime have different effects in terms of size and significance of the coefficients. So that in the study of the effect of spatial autoregression variable in the developing countries in the first spatial structure regime, there are neighboring effects of carbon dioxide emissions; while in the second spatial structure regime, there is no neighboring effects in the dependent variable. Yet, in the developed countries, there are the spatial autoregression effects of carbon dioxide emission only in the first spatial regime, and in the second spatial structure regime, there are the spatial autoregression effects only in the cross-sectional fixed-effects model.
Accordingly, based on what has been said, given the significance of spatial effects of the geographic distance and the economic factors, the countries under study can cooperate with each other to regulate air quality control. The type of the relationship between each of the factors of the environmental quality leads to the implementation of sound policies in terms of energy conservation policies and foreign policies to improve the environment quality. Also, if these factors affect the environmental pollution, the orientation of these factors in different countries can be regulated, which will make these economic factors applied more efficiently.

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