Environmental Energy and Economic Research 2021 5(4): S022
DOI 10.22097/eeer.2021.287650.1200

Research Article

Environmental Pollution and Economic Growth based on the Theory of Environmental Kuznets Curve (EKC) in Iran's Provinces (1997-2017)

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Received: 25 April 2021 /Accepted: 12 August 2021

Abstract:
Despite the fact that economic growth provides the basis for the progress of societies, it increases pollution and, as a result, destroys the environment and reduces the welfare of societies. On the other hand, preserving and protecting the environment is one of the most important pillars of achieving sustainable development. Regardless of the environmental issue, natural and human resources will be depleted and will have dire consequences on the planet and even in human societies. The environment is considered as a factor, which affects and is affected by both economic growth and sustainable development. In developing countries, overproduction and economic growth generally lead to environmental degradation. In this study, the effects of reverse U-shaped and N-shaped curve of GDP on the surface variable with power two and three on the pollutant's emission volume is investigated. Also, nitrogen oxide, carbon monoxide, carbon dioxide, sulfur dioxide, sulfur trioxide using long-term panel econometric methods, including; panel unit root test, Kao co-integration test, FMOLS and DOLS for 30 provinces of the country over 1997-2017 were considered. As a result, estimates suggest that the environmental Kuznets assumptions are the same for all five pollutants, and as GDP increases, pollution first increases, then begins to decline after reaching the peak point, and finally continues to rise by increasing reproduction. In other words, the results of the estimates indicate the confirmation of the N-shaped relationship between the provinces of Iran.
Keywords: Environmental Pollution, Economic Growth, Kuznets Theory, Provinces of Iran

Introduction

Environmental pollution, greenhouse gas emissions and climate change in recent years have become the most important environmental concerns and the biggest global threat to the future years. In addition, one of the main and important challenges of countries' management is the issue of pollution and greenhouse gas emissions; therefore, countries are also seeking to organize these pollutions in the international arena in addition to national policies (Padash and Rajabzadeh, 2020, Padash et al., 2021). Due to the importance and role of environmental pollution in issues such as sustainable development and its adverse effects on quality of life, it has attracted the attention of economists in recent decades. Consequently, in order to increase the quality of life and welfare of society, reducing environmental pollution should be considered along with economic growth.

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There are other channels for health to have an impact on growth. For example, evidence suggests that when public health levels improve, fewer financial resources in later periods (than when there are not such health levels) for providing medical treatment, and this causes some of these resources to be released, leading to higher economic growth in other sectors of the economy (World Bank, 1997). However, the main goal of growth and development programs of the government is to maximize the welfare of society, ignoring the quality of the living environment in the process of economic growth can have a negative impact on the welfare of society. Therefore, if we neglect the environment due to economic growth or do not comply with environmental standards, the economy will be inefficient. Sustainable development was achieved when environmental degradation is prevented and protection programs are included in the agenda of governments. Thus, there is a favorable contrast between economic growth and environmental protection. The studies, which examine the impact of economic growth on the quality of the environment, based on environmental Kuznets theory. The importance of the Environmental Kuznets Curve is that it states that economic growth provides a tool for supporting the living environment and does not destroy the living environment (Perman et al., 2003).

Numerous studies have examined the relationship between economic growth and the living environment in Iran, but in this study, considering the time period selected for the provinces of Iran as well as the use of three pollution indicators, it was more practical results will be provided for policy makers and environmental planners.

The results of various studies have shown that environmental protection and economic growth are aligned with each other instead of contradicting each other because they both seek to maximize social welfare.

In order to more accurately study the EKC in Iran, an attempt has been made to use both time series data and all cross-sectional data as a panel for a long period of time (1997-2015) for 30 provinces of the country. Carbon dioxide (CO_2) is a greenhouse gas and generally used as a variable pollutant in studies, but sulfur oxide (SO_X) and nitrogen oxide (NO_X) will be also used in this study (Tavakoli et al., 2016; Mostafavi et al., 2020). The next difference is the use of the third-order equation for studying the Kuznets curve that most studies has only studied the second-order functions of the Kuznets curve. Thus, considering the importance of achieving sustainable development and the relationship between economic growth and production of air pollutants in sustainable development issues for economic policymakers, the results of this study can be used by managers at the national for effective protection of the environment and the promotion of environmental ethics. In addition, due to the calculation of the gross domestic product of the provinces of the country at a fixed price and the amount of air pollutants for the provinces, which is done in series-time for the first time in the country, the results of these calculations can be used by other researchers.

Theory Foundations

Over the past half century, environmental degradation along with the growing industrial production in developed countries has led to an increase in public awareness and reaction to the effects of destructive economic activity on the environment, so that in 1960s, popular protests began in some developed countries (Barghi Oskooi and Yavari, 2007). During this period, many experts considered economic growth and environmental protection to be in conflict with each other. However, in the late 1980s and early 1990s, with the introduction of the concept of sustainable development, economic growth along with emphasis on the preservation and quality of the living environment was considered.

this discussion has been the subject of much study and research. If the formation process of this field of study is examined, it will be found that in the last few decades, there have been two groups of thought in this field that have eventually become a third approach.
The first approach is choosing between economic growths and maintaining environmental standards, which means that economic growth, and consequently the increase in production and consumption, inevitably requires more raw materials and energy as production data and in turn increase the production of waste.

On the other side of this spectrum, there is a second approach. In this group, it is believed that the path of improving environmental quality is parallel to economic growth, and in order to improve environmental standards, we need to keep pace with economic growth. This is because, in principle, higher levels of income increase the demand for goods that use lower levels of raw materials, and increasing income increases the demand for environmental quality, which means accepting environmental protection standards and criteria.

The third approach, which was introduced in the early 1990s, has shown an inverse U-shaped relationship between economic growth and environmental pollution, which has been known as the Environmental Kuznets Transfer Hypothesis or Environmental Kuznets Curve (EKC) whose name, was derived from Simon Kuznets, the winner of the Nobel Prize (1955). According to EKC, in the early stages of economic growth, environmental degradation is high until it reaches its peak, and then in the higher stages of growth, the environment improves.
The situation of developed and developing countries can be shown according to the third approach in Fig. 1.

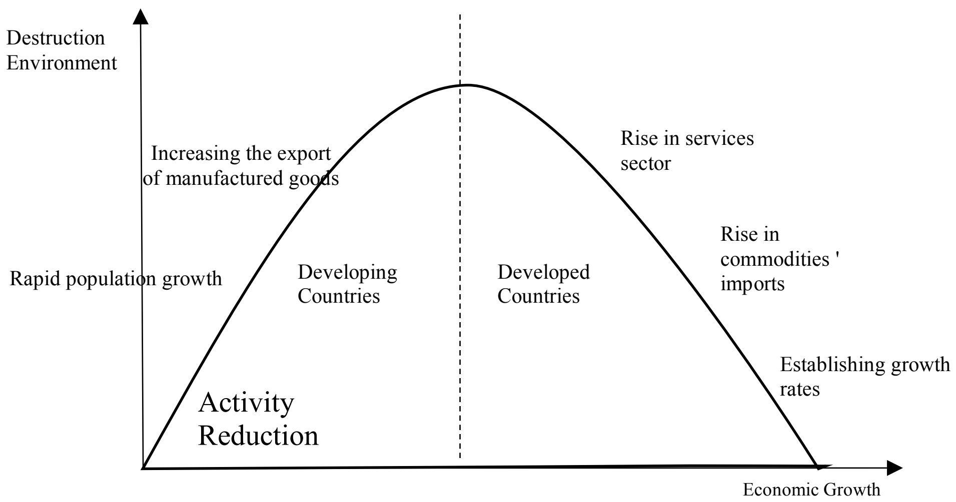

Figure 1. The relationship between economic growth and development and environmental degradation

As shown in figure 1. developing countries are located on an increasing slope of the curve. These countries are moving from an agricultural-based economy to an industrial economy. High population growth rates, rapid industrial growth, industrial exchanges, and an increase in the number of vehicles are all factors that increase energy consumption in these countries. However, the energy sector, despite playing a key role in the development process, also poses environmental problems, so that today one of the main challenges in the global dimension is derived from discussion of energy for sustainable development, industrial development, air pollution, atmosphere and climate change (Kijima et al., 2010; Abdallh and Abugamos, 2017).

Many econometric studies have tested the EKC hypothesis, most of which have used the reduced form of the equation of environmental Kuznets hypothesis. Thus, the quality of environment is a secondary or tertiary function of income. The considered model is estimated using various methods such as OLS and panel data with fixed or random effects, and so on. The general reduced form of the environmental Kuznets model is as follows:

$$y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x_{it}^2 + \beta_3 x_{it}^3 + \varepsilon_{it} \quad (1)$$

In Equation (1), y_{it} indicates the environmental quality index and x_{it} indicates income. ε_{it} is a model disruption sentence. The index t indicates the time and i is segment such as country, province or city. β_i is the value of the pattern parameters that must be estimated (Kijima et al., 2010, 1199).

Equation (1) provides important information about the relationship between environmental quality and economic growth, which were summarized below:

1- If $\beta_1 = \beta_2 = \beta_3 = 0$, it indicates that there is no relationship between the environmental quality (y_{it}) and the income (x_{it}) .
2- If $\beta_2 = \beta_3 = 0$ and $\beta_1 > 0$, the relationship between the environmental quality (y_{it}) and the income (x_{it}) is a uniform incremental relationship, or in other words, this relationship is linear with a positive slope.
3- If $\beta_2 = \beta_3 = 0$ and $\beta_1 < 0$, the relationship between the environmental quality (y_{it}) and the income (x_{it}) is a decreasing uniform relationship, or in other words, this is a linear relationship with the negative slope.
4- If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$, the relationship between the environmental quality (y_{it}) and the income (x_{it}) is the inverse U-shape, which is the EKC pattern. The return point on the curve is obtained by $X^* = \frac{-\beta_1}{2\beta_2}$. Figure 2 shows the inverse U relationship.

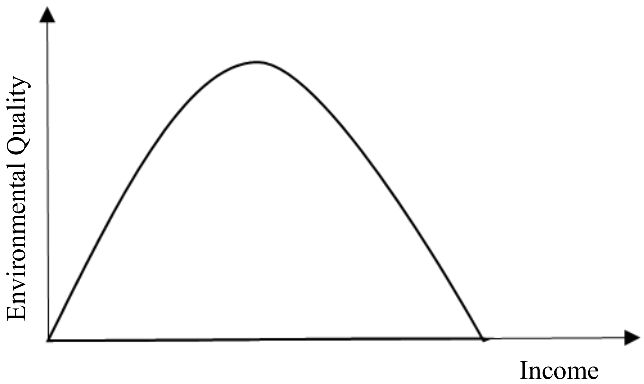

Figure 2. Reverse U-shape relationship between the environmental quality (y_{it}) and the income (x_{it})

5- If $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 = 0$, the relationship between the environmental quality (y_{it}) and the income (x_{it}) is U-shaped.
6- If $\beta_1 > 0$ and $\beta_2 < 0$ and $\beta_3 > 0$, the relationship between the environmental quality (y_{it}) and the income (x_{it}) will be N-shaped. In the three-order equations, the maximum and minimum points of the relation are obtained using the equation. Figure (3) shows the N relationship between environmental quality and income.
7- If $\beta_1 < 0$ and $\beta_2 > 0$ and $\beta_3 < 0$, the relationship between the environmental quality (y_{it}) and the income (x_{it}) will be reverse N-shaped (Dinda, 2004).

This equation provides an empirical explanation of the relationship between environmental degradation and income.

In addition, the results of using the reduced form are sensitive to the time period used, sample of selected countries, etc. (Grossman and Krueger, 1995; Hill and Magnani, 2002). Moreover, the results may be changed by selecting different factors in estimating the regression model (Borghesi, 2001).

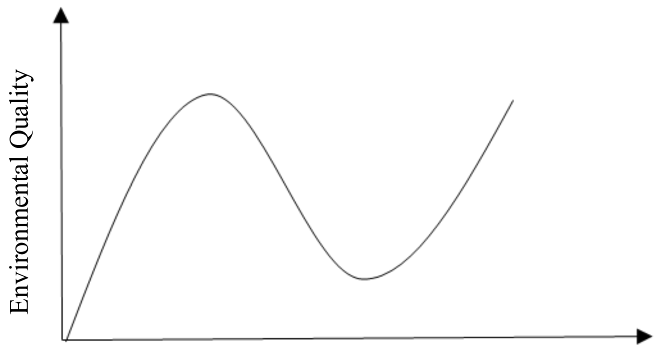

Figure 3: Reverse N-shaped relationship between the environmental quality (y_{it}) and the income (x_{it})

Literature Review

Liang and Yang (2018) examined the interrelationships between urbanization, economic growth and environmental pollution in three directions of urban planning in 30 provinces of China during the period 2006-2015 using the simultaneous equations. They paid at the same time. The results show that urbanization promotes economic growth through the accumulation of physical capital, knowledge of capital and human capital. This relationship between economic growth and urbanization is a reciprocal relationship from environmental pollution to urbanization and there is an inverse U-shaped relationship between economic growth and environmental pollution, and between urbanization and pollution.

In a study, Ouyang (2019) examined nonlinear relationships between environmental regulation, economic growth, and air pollution in OECD countries using panel threshold analysis. The results showed that with the increase in environmental policy strategies, the emission of pollutants first increases and then the meaningless correlation is established between them. The relationship between per capita GDP and pollution during the three stages of threshold model estimation is negative and significant (Ouyang et al., 2019).

Xie examined the Kuznets Environmental Relation between economic growth and smoke pollutants in 249 Chinese cities using semi-parametric spatial self-regression models in 2015. The results indicate a reversible U-shape relationship between economic growth and $PM_{2.5}$ concentration and confirm the Kuznets Environmental Hypothesis (Xie et al., 2019).

Shirmohammadi (2016), in his thesis entitled "Testing the Environmental Kuznets Hypothesis Test in the Framework of a Growth Pattern for the Iran Economy", examined the dynamic relationship between environmental quality and economic growth. In order to empirically analyze the model, the data of Iran economy during 1972-2012 and the parameters compatible with the Iran economy have been used. The results of the research show that with the increase of economic growth, the destruction of the environment increases and the Environmental Kuznets Hypothesis is incompletely true for the Iran economy.

Moradian (2017) in his thesis entitled "Estimation of parametric and non-parametric estimation of the Environmental Kuznets Curve (case study: Iran)", has confirmed the environmental Kuznets hypothesis in Iran and its provinces. In this study, in order to investigate the relationship between per capita income and pollution in Iran, a period of 1991-2014 has been selected. The results of the parametric estimation of panel data using the FGLS method emphasize the Environmental Kuznets Hypothesis for the provinces of Iran.

Nahidi Amir Khiz et al. (2018) studied the effect of economic growth on environmental pollution in the Iran economy over 1986-2016 using the self-explanatory model with extensive pauses. The results of estimation of the model indicate that there is a positive relationship between per capita income and environmental pollution variables and a negative relationship between Per capita income square and environmental pollution variables. Therefore, the environmental Kuznets hypothesis has been valid in Iran.

In order to more accurately study the EKC in Iran, time series data and cross-sectional data were used as a panel for a long period of time (1997-2015) for 30 provinces of the country. Carbon dioxide (CO_2) is a greenhouse gas and generally used as a variable pollutant in studies, but sulfur oxide (SO_X) and nitrogen oxide (NO_X) will be also used in this study. The next difference of this study is in the use of the third order equation is for the study of the Kuznets curve; the notable point is that most studies have only studied the second-order functions of the Kuznets curve.

Materials and Methods

The use of econometric methods in estimating pattern coefficient using time series data is based on the assumption that pattern variables are stationary. If the time series variables used in estimating pattern coefficients are non-stationary, although there may be no significant relationship between pattern variables, the regression R^2 determination coefficient may be very high.

In addition, the presence of non-stationary variables in the pattern makes the usual t and F tests not valid. The critical quantities resulting from the distributions of t and F are such that they provide the possibility of further rejection of the H_0 hypothesis by increasing the sample size. By rejecting the H_0 hypothesis, it is erroneously concluded that there is a strong and significant relationship between the variables of the model. Although regression is obtained, the result is nothing more than a spurious regression. A common feature of a spurious regression is the presence of a high R^2 determination coefficient (close to one) and a low Durbin-Watson statistic (close to zero) (Nofresti, 1999).

Unit root tests are divided into two categories as follows:

A) Tests that examine the common unit root process for hybrid data and the coefficients of autoregressive (AR) are the same between different sections like the Levin, Lin and Chu (LLC) test and the Breitung test (Olayungbo, 2011; Mohan et al., 2007; Dreger and Reimers, 2005).

B) Tests that examine a separate unit root process for hybrid data across sections, and the coefficients of autoregressive (AR) vary across sections such as tests of Im, Pesaran and Shin (IPS), Fisher-ADF and Fisher-PP (Shirvani et al., 2020; Adhikari and Chen, 2012, Fei et al., 2011; Nirmala et al., 2011; Harris et al., 2010; Apergis and Loomis, 2010).

In this study, the durability of variables is first examined using unit root and panel tests. Then, the covariance relationship between the variables and the existence and absence of spurious regression are evaluated using the Kao co-integration test. Finally, the coefficients of the variables will be estimated by using the fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) methods.

Dynamic Ordinary Least Squares (DOLS)

Stock and Watson (1993) proposed a method for estimating the relationship between variables with random trends by modifying the ordinary least squares method and called it dynamic

ordinary least squares (DOLS). This is because OLS estimates have a non-normal distribution, and as a result, statistical inference based on calculated t-statistics can be misleading.
Kao and Chiang (2000) developed the DOLS method for panel data and showed that using this method could lead to estimators with an asymptotic distribution with a mean of zero. They used Monte Carlo studies and showed that DOLS is a good way to correct endogenous and self-correlation problems. Ignoring endogenous can lead to simultaneous error in estimating coefficients. Another advantage of DOLS is that it can be used in small specimens, prevent simultaneous bias and has an asymptotic distribution.

Due to endogenous problems, estimates of DOLS lead to deviations from regression, the DOLS estimator eliminates this deviation and bias by increasing the pauses and simultaneous values in constant regression. The DOLS estimator can be represented as Equation (2):

$$y_{it} = \acute{z}_{it-1}\beta + \sum_{j=-p1}^{j=p2} c_{ij}\Delta z_{it+j} + \nu_{it} \quad (2)$$

where, c_{ij} is the pause coefficient of the first order difference variables.

The DOLS method performs better in symmetrical and asymmetric panel data. Adding the anterior and posterior values of the first-order difference of the explanatory variables significantly reduces the estimation error through DOLS by reducing the asymptotic bias caused by endogenous of the explanatory variables. The anterior and posterior values are added to the model in order to eliminate the correlation between the regression error component and the explanatory variables. The DOLS method can also be used in cases with different collective degree of explanatory variables.

Determining the spatial adjacent (neighborhood) in econometric models

In research work, we are usually faced with data in which spatial aspects are discussed and should be determined. One of the sources of spatial information is adjacent and neighborhood, which reflects the relative position in the space of one observation unit region compared to other such units. The criterion of adjacent and neighborhood will be based on the information obtained from the map of the study community and based on this information, it can be determined which areas are neighboring or adjacent. To determine the neighborhood, there are different methods in which the quadratic matrix W represents the different definition of neighborhood relationships between the studied areas. Among these methods, the following methods can be mentioned:

If $W_{ij} = 1$ is defined for elements with a common side immediately with the right or left of the area under study, it is called "linear neighborhood". If $W_{ij} = 1$ is defined for elements with a common side with the area under study, it is called "face-like neighborhood". If $W_{ij} = 1$ is defined for elements with a common vertex with the area under study, it is called "elephant-like neighborhood". If $W_{ij} = 1$ is defined for two existing areas immediately in the right and left of the study area, it is called "two-way linear neighborhood". If $W_{ij} = 1$ is defined for two regions on the right, left, north, and south of the study region, it is called "two-way face-like neighborhood". In this study, the face-like neighborhood is used to examine all areas with a common border.

Suppose you consider the matrix W for five regions (Equation (3)):

$$W = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix} \quad (3)$$

Note that W is a symmetrical matrix, and according to the contract, the matrix on the main diameter always has zero elements. As it is symmetrical, if the sum of each row is one, then the sum of the corresponding columns is also one. Now reverse the matrix W to have a matrix that the sum of its rows is one, and this is shown as the "standardized first order" neighborhood matrix, matrix c (Equation (4)):

$$c = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} \\ 0 & 0 & \frac{1}{2} & 0 & \frac{1}{2} \\ 0 & 0 & \frac{1}{2} & \frac{1}{2} & 0 \end{bmatrix} \quad (4)$$

If the product of the matrix c and the vector of the observations of a number of variables in the five regions, called the vector y, is used, the motivation for standardization can be observed. This product matrix $y^* = cy$ shows a new variable equivalent to the average observations of neighborhood areas.

Introducing the model

In this study, the theoretical basis of the environmental Kuznets curve based on Krueger and Grossmann model (1991) was used. In that case, to study the linear and nonlinear effects of economic growth (specifically per capita GDP as an indicator of economic growth) on pollution in 31 provinces over 1997-2017 in 5 different equations of pollutants including carbon monoxide (CO), (CO_2) as a greenhouse gas, sulfur dioxide (SO_2), sulfur trioxide (SO_3), nitrogen oxide (NO_X) are considered. It was tried to determine FMOLS and DOLS of these relationships by using panel econometric methods. The purpose of selecting and separating five different pollutants in separate equations is to carefully examine the rate of economic growth on each of these

Pollutants, to find what extent economic growth has been able to increase or decrease pollutants in the provinces of Iran.

In addition, due to the presence of a spatial component in the studied data and according to the proximity and proximity of the provinces to each other, the effect matrix is formed and multiplied by the dependent variable and is in the model as an environment spatial effect (Based on the study of He, 2015). For this purpose, equations (8) to (12) are defined based on the studies of Ottow et al. (2018), Ouyang et al. (2019) and Xiang et al. (2019):

$$LCO_{2it} = C + \beta_1 LGDP_{it} + \beta_2 LGDP_{it}^2 + \beta_3 LGDP_{it}^3 + \beta_4 LPOP_{it} + \beta_5 LUR_{it} + \beta_6 LSIP_{it} + \varepsilon_{it} \quad (5)$$

$$LNO_{Xit} = C + \beta_1 LGDP_{it} + \beta_2 LGDP_{it}^2 + \beta_3 LGDP_{it}^3 + \beta_4 LPOP_{it} + \beta_5 LUR_{it} + \beta_6 LSIP_{it} + \varepsilon_{it} \quad (6)$$

$$LSO_{2it} = C + \beta_1 LGDP_{it} + \beta_2 LGDP_{it}^2 + \beta_3 LGDP_{it}^3 + \beta_4 LPOP_{it} + \beta_5 LUR_{it} + \beta_6 LSIP_{it} + \varepsilon_{it}(9) \quad (7)$$

$$LSO_{3it} = C + \beta_1 LGDP_{it} + \beta_2 LGDP_{it}^2 + \beta_3 LGDP_{it}^3 + \beta_4 LPOP_{it} + \beta_5 LUR_{it} + \beta_6 LSIP_{it} + \varepsilon_{it}\ (9 \quad (8)$$

$$LCO_{it} = C + \beta_1 LGDP_{it} + \beta_2 LGDP_{it}^2 + \beta_3 LGDP_{it}^3 + \beta_4 LPOP_{it} + \beta_5 LUR_{it} + \beta_6 LSIP_{it} + \varepsilon_{it} \quad (9)$$

CO_{2it}: amount of carbon dioxide emissions in ton
NO_{Xit}: amount of oxidant nitrogen emissions in ton
SO_{2it}: amount of sulfur dioxide emissions in ton

SO_{3it}: amount of sulfur trioxide emissions in ton
CO_{it}: amount of carbon monoxide emissions in ton
L indicates the desired variable logarithm.

Important note regarding the calculation of pollutant emissions is that since the statistics of air pollutant emissions in the energy balance of different years have been reported only for the whole country and there are no statistics for the provinces, the statistics of air pollutants emission for the provinces of the country over 1997-2017 have been calculated in this study. To calculate the emission of air pollutants in the provinces of the country, it is assumed that at the provincial and national levels, the same type of technology has been used to create an equal amount of air pollution for the production of each unit.

After calculating the statistics of different sectors in four sectors of agriculture, industry, transportation and services, the province's share in the pre-separation period and the province's share after separation have been used to calculate the numbers of provinces that have been separated during the period. Finally, the statistics obtained for the emission of pollutants for different parts of each province have been summed together to obtain the amount of emission of each type of pollutant separately by the provinces.

$LGDP_{it}$: Logarithm of real GDP per capita at the fixed price of the base year of 2011 in one thousand Rials per person.
$LGDP_{it}^2$: The second power of logarithm of real GDP per capita at a fixed price in the base year of 2011 to determine the U-shape relationship of the environmental Kuznets hypothesis
$LGDP_{it}^3$: The third power logarithm of real GDP per capita at a fixed price in the base year of 2011 to determine the N-shape relationship b of the environmental Kuznets hypothesis
$LPOP_{it}$: Logarithm of the population of each province in thousand people
LUR_{it}: Logarithm of urban population in thousand people
$LSIP_{it}$: The logarithm of the product of the neighborhood matrix in the dependent variable (pollution) that is estimated to examine the spatial environmental effects in the model.
Also, C: Intercept, ε_{it}: Error sentence.

It is worth mentioning that the data used to estimate the models were extracted from information related to 30 provinces of the country (except Alborz province due to incomplete statistical information) over 1997-2017.

Table (1) provides a summary of the descriptive statistics of the variables used in this study. Jarque-Bera statistic with the freedom degree of two and the chi-squared distribution examine the normality of the hypothesis. The null hypothesis of this test indicates that it is normal. Therefore, if the probability is less than 0.05, the null hypothesis will be rejected. In the data studied in this study, although the probability of Jarque-Bera statistic for all variables is less than 0.05% (rejecting the hypothesis of the normal distribution of data), considering the sample size of this study, which is 630 data for each variable, the data have a normal distribution according to the central limit theorem.

The skewness equals the normalized third torque. Skewness is actually a measure of the existence or asymmetry of a distribution. Skewness is zero for a completely symmetrical distribution, is positive for an asymmetric distribution with a slope to higher values and is negative for an asymmetric distribution with a slope to smaller values. The data studied in this study are all skew to the right.

The elongation equals the normalized fourth torque. In other words, it is a measure of the sharpness of the curve at the peak point. For example, real GDP per capita and population have an elongation of 2.78 and 2.81, respectively, which are less than the normal distribution elongation (the value of the normal distribution elongation is less than 3), and other variables have an elongation more than the normal distribution elongation.

Table 1. The results of descriptive statistics of the variables used in the research

Variables	Average	Middle	Max	Min	Scale deviation	Squatting	Stretching	Chark-Bra	Probability
Nitrogen oxide	46000.06	20726.3	528913.3	3758.78	74420.90	3.7	18.71	7998.020	0.000
Carbon monoxide	255627.5	111459.	3151725	12430.5	455501.3	4.38	23.86	13445.33	0.000
Carbon dioxide	13902320	6250258	183213035	1060196	23033806	3.90	19.95	91420981	0.000
Sulfur Dioxide	37719.43	17037.1	362887.6	3517.17	57288.10	3.14	12.77	3543.976	0.000
Sulfur Tri-oxide	508.5457	227.53	12524.35	26.30	916.28	5.99	59.97	88990.42	0.000
G.D.P	146.837	1132.13	8171.480	274.26	113.735	2.78	11.99	2936.07	0.000
Population	2328.475	1567.30	13422.37	493.47	2275.355	2.81	12.34	3125.255	0.000
Urban	1595.645	954.14	12260.43	221.40	2026.52	3.56	16.95	6451.401	0.000

Reference: Statistical Center of Iran and Findings of study

Result and Discussion

The results of panel unit root test

Before estimating the model, it is necessary to examine the durability of the variables used in the model as well as the co-integration between the variables. In order to evaluate the durability of the variables, the panel unit root tests of Levin, Lin and Chu (LLC) (2002), Im, Pesaran and Shin (IPS) (2003), Phillips and Perron (1988) and Dicky Fuller (ADF) (2001) have been used. The results of these tests are presented in Table 2. The null hypothesis of these tests indicates the non-durability of the variables.

Table 2. The results of panel unit root test (considering intercept)

Variables	Break length	Test statistics LLC	Test statistics IPS	Test statistics ADF	Test Statistics PPF
LCO_2	0	-2.8611* (0.0021)	2.2677 (0.9883)	3685.97 (0.9919)	3685.97 (0.9995)
$D(LCO_2)$	1	-7.4192 (0.0000)	-7.7827 (0.0000)	183.574 (0.0000)	199.999 (0.0000)
LNO_X	0	-2.7868 (0.0027)	2.0333 (0.9790)	33.6598 (0.9976)	31.8737 (0.9989)
$D(LNO_X)$	1	-13.3149 (0.0000)	10.7179 (0.0000)	229.709 (0.0000)	238.568 (0.0000)
LSO_2	0	1.4897 (0.0931)	-1.2154 (0.1121)	62.5067 (0.3873)	52.6687 (0.7380)
$D(LSO_2)$	1	-3.7251 (0.0000)	-10.2903 (0.0000)	218.506 (0.0000)	221.951 (0.0000)
LSO_3	0	14.5492 (1.0000)	12.4688 (1.0000)	6.3622 (1.0000)	8.0833 (1.0000)
$D(LSO_3)$	1	4.7566- (0.0000)	-8.8590 (0.0000)	183.502 (0.0000)	205.845 (0.0000)
LCO	0	5.1479- (0.0000)	-0.7703 (0.2205)	66.1870 (0.2720)	99.411 (0.0010)
D(LCO)	1	-16.1912 (0.0000)	-13.5029 (0.0000)	289.096 (0.0000)	352.895 (0.0000)
LGDP	0	-5.5566 (0.0000)	-1.8395).0329(0	75.6847 (0.0834)	67.2791).2421(0
D(LGDP)	1	-11.3956 (0.0000)	-8.3241).0000(0	207.267 (0.0000)	296.275 (0.0000)
LPOP	0	-14.8334 (0.0000)	5.4147- (0.0000)	382.973 (0.0000)	647.869 (0.0000)
LUR	0	-35.3994 (0.0000)	-25.7498 (0.0000)	1460.03 (0.0000)	1401.03 (0.0000)

* The above numbers are test statistic coefficients related to variables and numbers within parentheses are their probabilities.

Examination of the calculated statistic values and the probability of their acceptance show that the variables of logarithm of population and urbanization are at the stable level and have a constant mean, variance and self-covariance structure. Therefore, the null hypothesis, which indicates non-durability of variables at 95% confidence level, is rejected. The other variables were not at the stable level, but they become stable by differencing once.

The results of the panel co-integration test

In order to avoid the existence of spurious regression in estimates, the co-integration between the dependent variable and the independent variables should be examined. For this purpose, to test and establish a long-term equilibrium relationship between the variables of the model, the Kao co-integration test (1999), which is based on the Engle-Granger, is used. The zero hypothesis of this test indicates the absence of co-integration.

Table 3. Results of the Kao co-integration test

ADF Statistics	T test Statistics	Probability level
Carbon dioxide equation	-6.533	(0.0000)
carbon monoxide equation	-3.8050	(0.0000)
Nitrogen-oxide equation	-4.3447	(0.0000)
Sulfur dioxide equation	-5.2214	(0.0000)
Sulfur trioxide equation	-2.3540	(0.0093)

According to the results of Table 3, the existence of co-integration between the pattern variables will not be rejected, and the null hypothesis, which indicates co-integration, is confirmed. Therefore, the existence of a long-term equilibrium relationship and the absence of spurious regression between pattern variables will also be confirmed.

Results of estimation by dynamic ordinary least squares method (DOLS)

Another method for determining coefficients over the long time is the dynamic ordinary least squares method. In this section, the estimated coefficients obtained from estimating five pollution equations have been presented.

According to Table 4, the effects of real GDP per capita on the emission of various gases have been increasing and significant, so that with an increase of one percent in real GDP per capita, emissions of carbon monoxide, carbon dioxide, nitrogen oxide, sulfur dioxide and sulfur trioxide increase by 12.90, 21.44, 27.93, 54.55, and 36.86%, respectively. The highest coefficient of this reducing effect is related to the relationship between real GDP per capita and sulfur dioxide gas and the lowest one is related to carbon monoxide emissions.

With the increase in the second power of real GDP per capita, the emission of various greenhouse gases has been decreasing and significant, so that with the increase of one percent in the second power of real GDP per capita, the emission of carbon monoxide, carbon dioxide, nitrogen oxide, sulfur dioxide and sulfur trioxide reduces by 1.79, 2.88, 3.80, 7.54, and 4.40%, respectively. The highest coefficient of this effect is related to the relationship between the second power of real GDP per capita and sulfur dioxide gas and the lowest one is related to carbon monoxide emissions.

With increasing in the third power of real GDP per capita, the emission of various greenhouse gases has been increasing and significant, so that with an increase of one percent in the third power of real GDP per capita, the emission of carbon monoxide, carbon dioxide, nitrogen oxide, sulfur dioxide and sulfur trioxide increase by 0.08, 0.12, 0.16, 0.34, and 0.18%, respectively. The highest coefficient of this effect is related to the relationship between the third power of real GDP per capita and sulfur dioxide gas and the lowest one is related to the emission of monoxide gas.

Table 4. Results of estimating pollution equations by DOLS method (dependent variable: greenhouse gas emissions)

Variables	Carbon mono oxide equation	Carbon dioxide equation	Nitrogen oxide equation	sulfur Dioxide equation	sulfur Trioxide equation
Logarithm of real GDP per capita	12.9090 (0.0000)	21.4498 (0.0000)	27.9302 (0.0000)	54.5522 (0.0002)	36.8640 (0.0011)
Logarithm of real GDP per capita**2	-1.7905 (0.0000)	-2.8831 (0.0000)	-3.8079 (0.0000)	-7.5495 (0.0002)	-4.4004 (0.0050)
Logarithm is a real GDP per capita**3	0.0828 (0.0000)	0.1243 (0.0000)	0.1686 (0.0000)	0.3415 (0.0001)	0.1747 (0.0153)
Population logarithm	4.9729 (0.0000)	1.3055 (0.0151)	1.8662 (0.0055)	4.4698 (0.0169)	3.5172 (0.0034)
Urban logarithm	3.2461 (0.0000)	1.5506 (0.0006)	1.7743 (0.0025)	3.1731 (0.0401)	7.5661 (0.0000)
Log (matrix adjacent to the emission of pollution)	0.0060 (0.0343)	0.0141 (0.0479)	0.0219 (0.0401)	0.1055 (0.0000)	0.0879 (0.0278)
Estimation and correct tests					
R-squared	0.9950	0.9959	0.9935	0.9791	0.9703
Adjusted R-squared	0.9907	0.9931	0.9891	0.9615	0.9497

* Above numbers are tests statistic coefficients related to variables and numbers within parentheses are their probabilities.

Considering the significance of the second and third powers of economic growth in the study of the environmental Kuznets curve, it can be said that the clarification of these relations in all provinces and the selected period establishes the N-shaped relationship. This is the normal cycle, which has been able to balance the economic growth, energy consumption and environmental protection.

As results, the environmental Kuznets curve using the DOLS technique as well as specifying the second and third-order relations of economic growth in 30 provinces of the country during 1997-2017 have approved the N-shaped curve.

With the increase in population and urbanization, the level of emissions of selected greenhouse gases has increased. The highest level of increase in pollution caused by population growth is related to sulfur trioxide gas and the highest level of increase in pollution caused by urbanization growth is related to sulfur trioxide gas. On the other hand, by comparing the estimated coefficients, it is clear that in the case of carbon dioxide and sulfur trioxide, increasing urbanization more than population growth has caused pollution. However, in the case of carbon monoxide, carbon dioxide and nitrogen oxide gases, population growth more than urbanization has caused pollution.

It could be concluded, by the increasing in the spatial effect of pollution (product of the neighborhood matrix by the amount of pollutant emissions), the volume of pollution in the provinces has increased over the selected period. Furthermore, indicating the effectiveness of pollution of neighboring provinces on each other so that the share of the spatial effect of sulfur dioxide gas is more than other gases and the share of carbon dioxide gas is less than the rest. This indicates the high scattering effect of pollution and transmission to neighboring provinces. The test coefficients of R^2 and $\bar{R}^2$ indicate the high power of explanatory and dependent variables.

Conclusion

In this study, an attempt was made to investigate the reverse U-shaped and N-shaped effects of GDP in the form of three different forms of this variable on the surface with power two and three on the pollutants emission volume including nitrogen oxide, carbon monoxide, sulfur dioxide, sulfur trioxide and carbon dioxide as a greenhouse gas. For regressions used long-term panel econometric methods, including; panel unit root test, Kao co-integration test, FMOLS and DOLS for 30 provinces of the country over 1997-2017.

Estimates suggest that the environmental Kuznets assumptions are the same for all five variables, and as GDP increases, pollution first increases, then begins to decline after reaching the peak point, and finally continues to rise by increasing reproduction. According to the results of estimating the N-shaped curve has been approved. Moreover, the existence of two variables of population and urbanization in the model has caused positive. This means that the expansion of urbanization has increased the consumption of fossil fuels and, as a result, has exacerbated air pollution.

Finally, by multiplying the neighborhood matrix by the amount of pollution, and the results were such that increasing pollution in each province will increase air pollution in neighboring provinces.

Therefore, in order to prevent the damage of the environment and its destruction, in addition to the environmental costs, the following measures are appropriate:

- Considering the positive pollution growth rate of the Iran economy, it is necessary to take measures to reduce the growth rate of pollution in order to approach the sustainability of the ecological system. In this regard, it can be suggested to encourage producers to use clean technologies in order to achieve, cut government subsidies to polluting industries and industries that do not meet environmental standards, use renewable energy sources instead of polluting energy sources in public affairs. In addition, use appropriate environmental tax structure along with environmental laws. Furthermore, more human capital (net capital) instead of physical capital (polluting capital) as well as raise the level of productivity of physical, human and natural capital, etc.
- Considering the increase in population and urbanization, measures should be taken to promote public culture towards the living environment.

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