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An investigation of environmental Kuznets hypothesis in Asian Productivity Organization (APO) using three air pollution indicators

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ABSTRACT

The threat of climate change over the past decades has become more prominent among environmental experts. As a result, economists and environmental researchers are more likely to pursue environmentally-friendly economic growth. The present study examines the variables of open trade, population, GDP, and its square to study the Kuznets environmental hypothesis regarding carbon dioxide, methane, and nitrogen oxide emissions in three separate equations, which have, to the authors' best knowledge, been rarely addressed in the literature. The study period was from 1990 to 2016 conducted on 20 countries in the Asian Productivity Organization (APO). This hypothesis has not been studied regarding air pollution among APO members states. The panel ARDL method was used regarding the panel data applied for the structure of the research data. According to the results, the Kuznets environmental hypothesis was approved as reversed U for carbon dioxide and methane gases in the long run, but not for nitrous oxide. The short-term results also indicate the rejection of the Kuznets environmental hypothesis among the studied countries. The variable of trade had a negative correlation with the emission of all three greenhouse gases. Also, the earning elasticity estimated for CO_2, N_2O, and CH_4 at 0.4, 0.38 and 0.04, respectively show that the effect of GDP growth on CO_2 emissions is higher than that of N_2O and CH_4 emissions, indicating the importance of CO_2, which causes more air pollution than other greenhouse gases and will have an important impact on the quality of the environment. Therefore, it is recommended to consider more measures for curbing carbon dioxide than for other greenhouse gases to prevent its emissions.

1. Introduction

Global warming and climate change will lead to the melting of snow and ice, resulting in increasing water levels, changing rainfall patterns, increasing air temperatures, and reducing labor productivity. Therefore, the threat of climate change has become more widely considered by environmental experts and economists over the past decades. As a result, economists and environmental researchers are more likely to pursue environmentally-friendly economic growth (Alam et al., 2016). When an economy starts to develop, the environment is rapidly destroyed due to air pollution, deforestation, soil and water contamination, and other factors in the very first stage of economic growth. As the economy begins to grow, the income level escalates and its rate of decline decreases so that at a certain level of income, environmental degradation begins to decline and the quality of the environment improves. This relationship shows that the hypothesis of environmental degradation and income is a reversed U, which is recognized as the hypothesis of the Environmental Kuznets Ecosystem (EKC). Grossman and Krueger (1991) found Kuznets's inverse U-shaped relationship between pollution and economic development (Sinha and Bhattacharya, 2016). The EKC hypothesis explains that environmental degradation first increases with increasing economic growth and after it reaches the lower level, it decreases in the final stage considering the high level of income. This means that the EKC hypothesis suggests long-term economic growth brings welfare to the environment (Dinda, 2004). But, there are contradictory views on environmental protection and economic growth. Meadows et al. (1972) argue in *Growth Constraints* that economic growth leads to the sustainable growth of the environment and environmental protection reduces economic growth. However, Dasgupta and Heal (1979) in *Economic Theory and Quench Resources* present evidence that the relationship between economic growth and environmental protection is complementary. But, empirical experiences of the inconsistency of environmental growth did not reach any definitive consensus (Alam et al., 2016).

Developments in environmental perceptions in the world occurred first in the early 1970s by discussing the quality of the environment against economic growth. During this period, researchers believed that economic growth contrasts with the preservation of the environment quality, which led to the rise of business and environmental issues at the end

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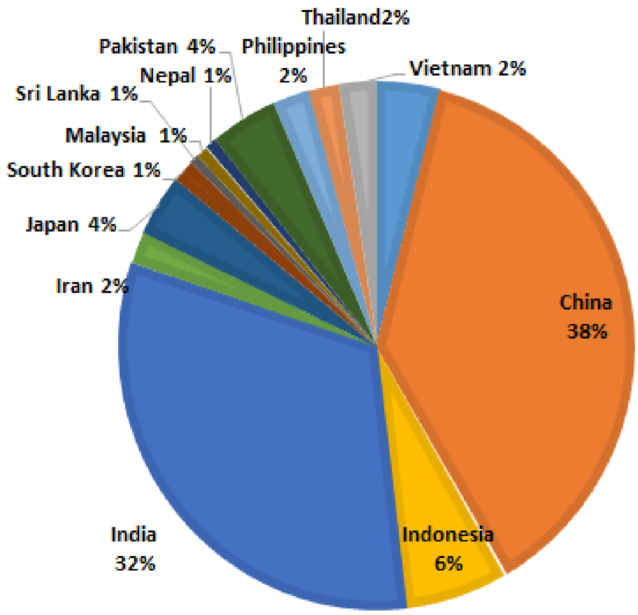
of this decade and prompted environmentalists to protest environmental conditions through the liberalization of trade. They believed that trade liberalization would increase economic activity, resulting in inappropriate use of resources and energy. Indeed, they believed that open trade plays a vital and effective role in the quality of the environment (Grossman & Kruger, 1991). In fact, they argue that the trade between countries has a positive impact on the environment because the quality of the environment is a normal commodity and trade liberalization can increase the demand for a healthy environment due to increased income in different countries. In this case, firms will be encouraged to move towards healthier and less polluting production ways and will increase supply as demand for the environment grows. On the other hand, some also believe that trade causes environmental degradation as it increases the scale of economic activity and increases the accumulation of environmental pollutants in developing countries and since the standards of environment in these countries is low, the expansion of trade, especially in developing countries, causes the environment to become more polluted (Mohammadi et al., 2016).

In general, Copeland and Taylor (2004) classified the effects of commercial liberalization on the environment into three categories including effects of scale, combination, and technology. The effect of scale that leads to economic growth has a negative impact on environmental quality. The effect of combination reflects a change in the composition of the product basket or, in general, is the change in the structure of the economy, and the effect of technology represents a change in production technology (Rezek & Rogers, 2008). In fact, the effect of the scale of trade liberalization will aggravate environmental degradation, the effect of technology will reduce the environmental degradation, and the effect of the combination will depend on the type of comparative advantage. At the most fundamental level, business and the environment are interdependent, because all economic activities are environmental-based. This is the basis for all the basic inputs (metals and minerals, forests and fisheries) and the energy needed for all stages of work. In fact, the effects of trade on the environment depend on the extent to which the environment and business goals can be complementary and mutually supportive.

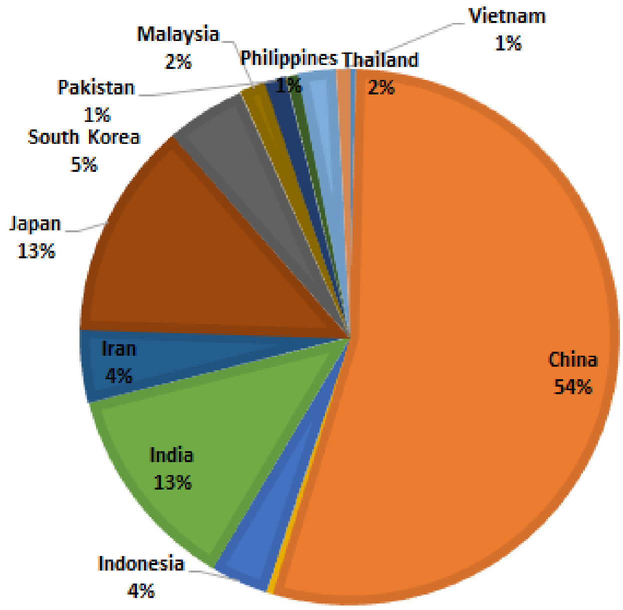
The main source of global warming is greenhouse gas (GHG) emissions (Suri and Chapman, 1998). The main GHGs include water vapor, carbon dioxide (CO_2), nitrogen oxide (N_2O), methane (CH_4), low-level ozone (O_3), and chlorofluorocarbons (CFC_s). These gases are components of the atmosphere and their lifetime (more than a decade) allows for their uniform and balanced distribution in the atmosphere and participation in greenhouse effects (Noroozi & Khosravi, 2010). Carbon dioxide is the most important GHG in the atmosphere after water vapor in infrared absorption and is responsible for 62 percent of the total Earth's energy and land generated by GHGs in the last decade. The second important gas, accounting for about 20% of the greenhouse effect, is methane whose atmospheric concentration is about 200 times lower than that of carbon dioxide. Methane is one of the most important GHG emissions, and almost 70% of methane emissions are related to human activities. Methane concentration has been doubled since the Industrial Revolution. The effects of this gas on the climate and the chemical composition of the atmosphere are reasons for concerns over the high growth of this gas in the last decade. After water vapor and carbon dioxide, this gas is the third most reactive component in the troposphere (Noroozi & Khosravi, 2010). Nitrogen oxide is responsible for about 6% of the greenhouse effect and its ability to absorb infrared radiation is 300 times greater than carbon dioxide. In other words, an N_2O molecule is about 300 times more capable of transmitting reflected light from the Earth than a CO_2 molecule. So, emissions of methane (the second most important GHG) and nitrogen oxide (the third most important GHG) directly contribute to climate change. Nitrogen oxide and methane warm the Earth 296 and 23 times more than carbon dioxide, respectively (Drabo, 2017).

The Asian Productivity Organization (APO) was established in 1961 following a decision by several countries to enhance the level of productivity, accelerate the process of economic development, and raise people's living standards in the member states. According to its constitution, APO is an intergovernmental, non-political, nonprofit, and non-partisan regional organization whose main goal is to accelerate economic development in the Asia-Pacific region by expanding and disseminating skills through increased productivity in the region. The purpose of APO is to contribute to the socio-economic development of member countries and to improve the life quality of people in those countries through the promotion of productivity under the spirit of mutual cooperation among the member states (Nasrollahniya et al., 2014). APO members include Bangladesh (1982), Cambodia (2004), the People's Republic of China (founding member), Fiji (1984), India (founding member), Hong Kong (1963), Indonesia (1968), Iran (1965) (Founding member), Japan (founding member), the Republic of Korea (founding member), Laos (2002), Malaysia (1983), Mongolia (1992), Nepal (Founding member), Pakistan (Founding member), the Philippines, Singapore (1969), Sri Lanka (1966), Thailand (Founding member), and Vietnam (1966).

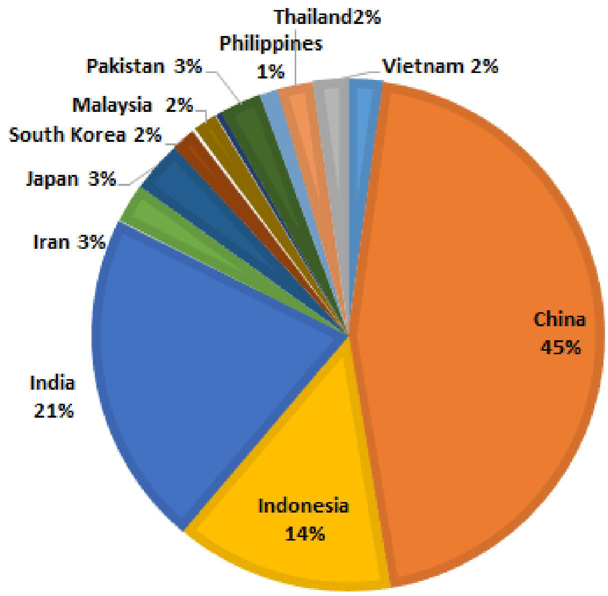
Figure (1) shows some economic statistics of these countries.



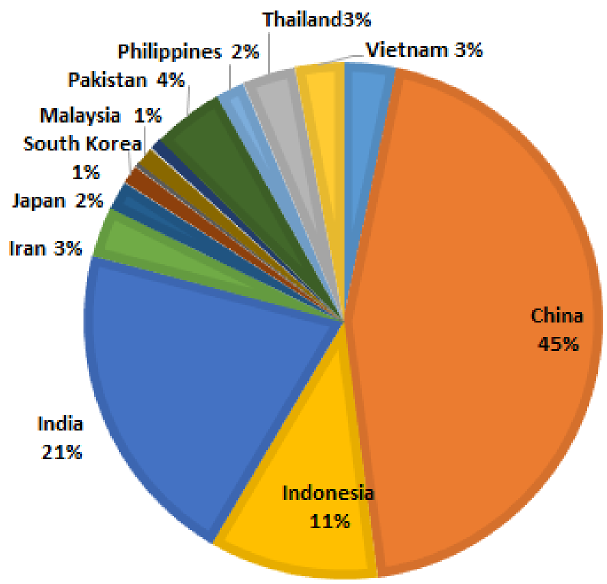
Total population



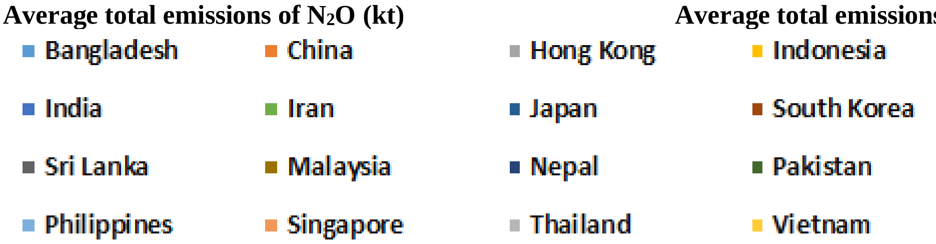
Average total emissions of CO_2 (kt)



Average total emissions of N_2O (kt)



Average total emissions of CH_4 (kt)



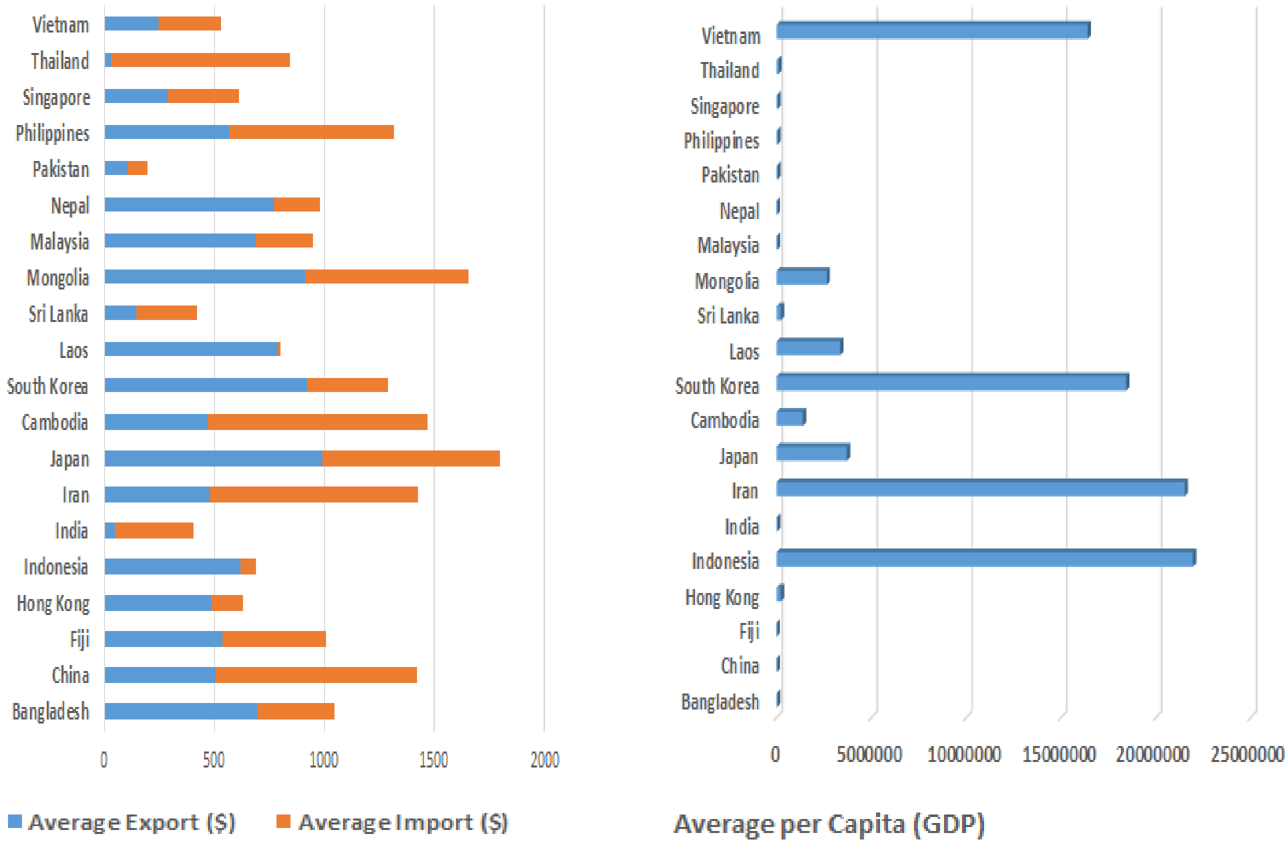


Fig 1. Economic index status for APO (1990-2016)

According to the statistics in Figure 1, the average highest and lowest CO_2 emissions during the study period are related to China and Laos among the 20 studied countries, respectively. Regarding the amount of N_2O and CH_4 emissions, the highest emissions are related to China and the lowest to Fiji. Therefore, it can be concluded that China has the largest share of all three gas emissions. In the case of economic variables, Singapore has the highest average exports and imports, and Japan has the lowest average exports and imports among 20 member countries during the period under review. The highest average GDP is for Indonesia and the lowest for Fiji. In terms of population, the highest average population among the 20 countries during the studied period is in China and the lowest in Fiji. But, what is certain is that the organization's main goal is to increase its productivity and economic development, but short-term productivity improvement should be done with caution as it may increase production costs in the long run and cause environmental degradation (climate and soil pollution) and climate change through GHG emissions (carbon dioxide, methane and nitrogen oxide) (Drabo, 2017). Economic growth is another important goal of this organization, which plays an important role. As previously mentioned, economic growth will be a major contributor to the pollution. Therefore, APO, according to what has been said, has been selected to examine the effect of the economic indicators of GDP (to investigate the Kuznets hypothesis), open trade, and human factor of the population on CO_2, CH_4, and N_2O emissions.

Many studies have been conducted on the environmental Kuznets curve (EKC), such as Amiri et al. (2016), Mehrara et al. (2012), Biabi et al. (2016), Amirnejad and Asadpour Kordi (2014), Alam et al. (2016) and Shahbaz et al. (2013). Lau et al. (2014) pointed out that in all of these studies on the environmental Kuznets hypothesis, carbon dioxide emissions were used to pollute the air. But, Drabo (2017) studied the environmental Kuznets hypothesis from 1986 to 2010 in 136 developed and developing countries. In this study, he examined the effects of economic growth, export, import, population, knowledge, and agricultural household expenditures on GHG emissions of CO_2, CH_4, N_2O, and the sum of CH_4 and N_2O in the agricultural sector and found that crop exports were an important source of GHG emissions. Also, Sinha and Bhattacharya (2016) and Sinha and Bhattacharya (2017) studied the Kuznets hypothesis for SO_2 and N_2O emissions in 139 cities in India between 2001 and 2013 separately in two industrial and residential areas. Their results showed that EKC was a reversed U-shaped curve for SO_2 and linear in the industrial area and residential area, respectively, but it was reversed U-shaped for N_2O in both industrial and residential areas.

The above studies on the environmental Kuznets hypothesis are examples of studies conducted in recent years. GDP and CO_2 emissions were used to study the hypothesis. In addition to these two variables, population and trade variables as well as other indicators including pollution, e.g., methane and nitrogen oxide, were considered in the present study in which they were estimated and compared in the form of three separate equations. Also, this study tried to use a relatively new method, Panel ARDL, for the estimation. In general, the environmental Kuznets hypothesis using population and open trade variables was explored for carbon dioxide, nitrogen oxide, and methane pollutions as three separate equations in long-run and short-run. Few studies have used these three pollution indicators and also few studies have addressed APO countries. The estimation of different pollution indicators in these countries with the Panel ARDL method is one of the contributions of the present research.

2. Methodology

2.1. Environmental Kuznets Curve (EKC)

EKC states that there is a relationship between environmental pollution and economic growth (Chowdhury & Moran, 2012), which may be U-shaped or inverse U-shaped, N-shaped or inversed N-shaped, or even linear (Canas et al., 2003). This relationship, as previously stated, was named after the Nobel winner, Simon Kuznets who found an inverse U-shaped relationship in the form of income inequality and income hypothesis in the 1960s. Figure 2 shows the relationship between environmental degradation and income as inverse U. According to this diagram, environmental degradation increases in the early stages of economic growth but begins to decrease after reaching the maximum level of pollution.

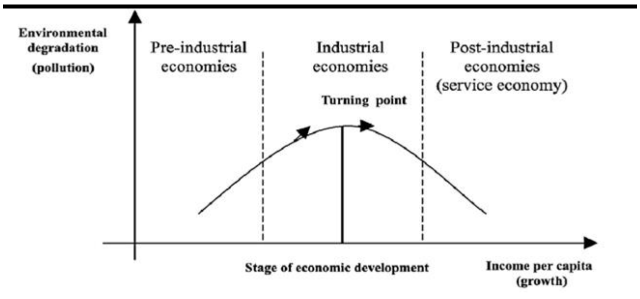


Fig 2. Environmental Kuznets curve (EKC)

The empirical analysis of EKC can be described as a simple theoretical model proposed by Andreoni and Levinson (2001). Many economists before Andreoni and Levinson tried to analyze this hypothesis through microeconomics. The common view of all of them was related to the concept of this curve and the argumentation of all of them was based on the problem of maximizing the utility of a consumer. They argued that the utility function consists of two components, including the utility derived from the use of standard goods and the inappropriateness caused by pollution from consumption, so that

$$U = U(C, P) \qquad \textbf{(1)}$$

$$Uc > 0, \; Up < 0$$

in which C is the consumption of private goods, P is pollution, and U is the quasi-concave utility function for the consumption of private goods and contamination. In this equation, the consumption of goods increases the utility of the consumer on the one hand and reduces it due to contamination on the other. Finally, by using the maximization and Lagrange's rule, equation (2) can be obtained (Mohammadbagheri, 2010) as follows

$$P^*(M) = \frac{\alpha}{\alpha+\beta} M \left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha} \left(\frac{\alpha}{\alpha+\beta}\right)^{\beta} M^{\alpha+\beta} \qquad (2)$$

in which P is pollution and M is income. Equation (2) shows the relationship between income and pollution. Based on this equation, the form of pollution function and the relationship between income and pollution depend on the slope of the equation and the values of α and β.

$$\frac{\partial P^*}{\partial M} = \frac{\alpha}{\alpha+\beta} - (\alpha+\beta)\left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha} \left(\frac{\alpha}{\alpha+\beta}\right)^{\beta} M^{\alpha+\beta-1} \qquad (3)$$

According to equation (3), if the activities conducted to reduce pollution had a constant return to scale, then β + α, the slope of the curve ($\frac{\delta P*}{\delta M}$), and the contamination curve will be a positive line. Since 0≤β and 0≤α, then P^* increases with increasing M (Fig. 3a). If the efforts and activities to reduce pollution show lower yields than the scale, 1> β + α, and the curve are relative to the convex source (Fig. 3b). Finally, if pollution reduction activities had ascending returns, the curve will be concave relative to the base (Fig. 3c). In this case, up to a certain income level, the increase in income leads to further pollution and then reduces pollution, which is the same environmental Kuznets hypothesis (Lotfipour et al., 2012).

Therefore, according to what was said, an environmental Kuznets hypothesis model is used to achieve the study aims. But as stated, various factors affect GHG emissions, which have been used in this study by using various theories and various empirical studies, including the studies of Drabo (2017), Wang et al. (2015), and Biabi et al. (2016). In addition, the available information about factors affecting GHG emissions is theoretically considered as a regression equation (4):

$$Y = f\,(GDP.GDP^2.TRADE.POP) \qquad (4)$$

in which Y is the dependent variable that shows the GHG emissions of CO_2, N_2O, and CH_4, and explanatory variables including, GDP per capita, and second-generation GDP per capita, TRADE OPEN that is derived from the sum of exports and imports on GDP, and POP is the population. However, as stated, the present study is for the 20 APO member countries for a period of 23 years, so the regression model (1) is estimated as a panel and therefore the main model for estimating model (5) will be as below:

$$Y_{it} = f\left(GDP_{it}.GDP_{it}^{\ 2}.TRADE_{it}.POP_{it}\right) \quad (5)$$

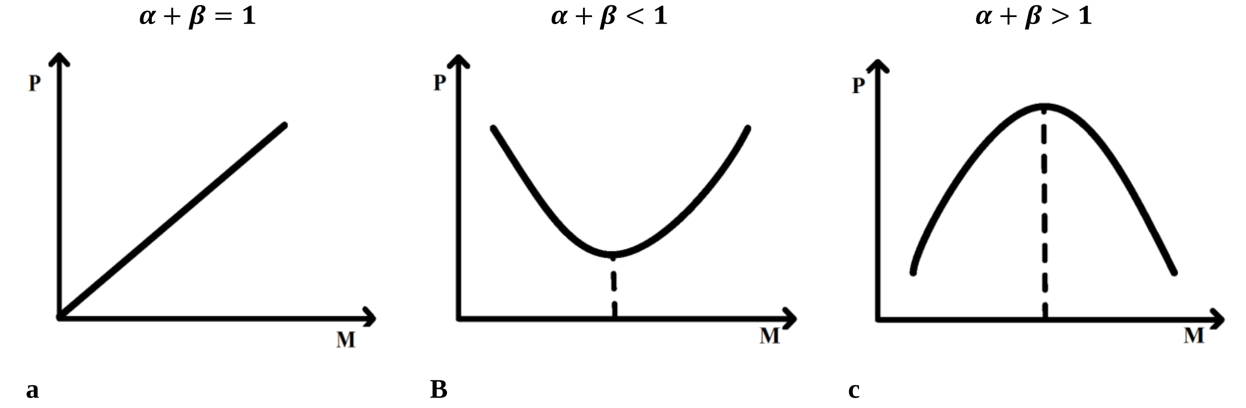


Fig 3. Contamination graph

in which *I* is the number of sections equal to 20 (the number of studied countries) and *t* is the time, which is equal to 23 years (the period considered). With the introduction and explanation of the functional form of the model of factors affecting GHG emissions, short-term and long-term relationship between variables was investigated in the form of self-explanatory analysis (ARDL) in the framework of the panel. The use of traditional econometric methods in empirical studies is based on the assumption of static (variables). The studies carried out in this field indicate that many macroeconomic series do not assume this assumption and most of the variables are non-invariant. Therefore, according to the theory of co-integration in econometrics, it is necessary to ensure the variability and non-existence of variables. In experimental studies, the Dickey-Fuller and Phillips Paron tests are generally used to test the reliability of time series variables. However, if the data is in the panel form, special panel tests such as Levin Lane Chow (LLC) or Shin Boys (IPS) should be used. By examining the statics of variables, steps should be taken systematically to model the relationship between the variables. The choice of the ARDL method is based on this study. In the ARDL pattern, the variables in the template can be I(0) or I(1), but they cannot be I(2), so this problem should be investigated by performing static tests. The ARDL model was first developed by Pesaran and Pesaran (1997) and then expanded by Pesaran and Smith (1998), Pesaran and Shin (1999) and Pesaran et al (2001). Due to the limitations of using methods Granger parasites and ECM-correction models, these people have tried to achieve better results in analyzing long-term and short-term relationships between variables by overcoming the deficiencies of the above methods (Siddiki, 2000). The advantage of using the ARDL method over other methods is that regardless of the static nature of the variables in the model of type I(0) and I(1), one can also examine the relationship between the variables (Pesaran and Pesaran, 1997). Also, in the case of small samples, this method has a high explanatory power than other methods (Pesaran & Shin, 1999). Therefore, estimations of the ARDL method are cost-effective and efficient for avoiding problems such as self-affiliation and intrusion. The method also estimates long-term and short-term relationships between the dependent variable and other explanatory variables at the same time (Siddiki, 2000). In other words, it is necessary to investigate whether the short-term dynamic relationship tends toward long-term equilibrium (Noferesti, 1999). For this purpose, in PANEL models, Kao, Pedronio, and Fisher's coherency tests are used. These tests indicate that a coherent relationship exists between the model variables. After confirming the long-run relationship by the co-experimental tests of the long-term relationship, equation (5) is corrected as equation (6):

$$Y_t = \gamma_0 + \gamma_1 GDP_t + \gamma_2 GDP^2{}_t + \gamma_3 TRADE_t + \gamma_4 POP_t + u_t \quad (6)$$

Also, in the ARDL model, if there is a coincidence between the variables in the model, a relationship can be made between short-term fluctuations of variables and long-term equilibrium values. This is possible through the error correction pattern. The general form of the error correction model for equation (5) can be expressed as equation (7).

$$\Delta Y_t = b_0 + \sum_{i=1}^{n} a_{1i}\Delta Y_{t-i} + \sum_{i=1}^{n} b_{1i}\Delta GDP_{t-i} + \sum_{i=1}^{n} b_{2i}\Delta GDP^2{}_{t-i} + \sum_{i=1}^{n} b_{3i}\Delta TRADE_{t-i} + \sum_{i=1}^{n} b_{4i}\Delta POP_{t-i} + \partial ecm_{t-1} u_t \quad (7)$$

In Equation (4), the first-order difference ∂ measures the modification velocity of the desired parameter or the velocity of approaching the long-term equilibrium value, and ecmt-1 is the waste sentence that is obtained from the estimation of the long-run relationship (3). In this study, data were collected from 1990 to 2016, all provided by the

World Bank, and the model was estimated by the Eviews 9 software package.

3.Results

To illustrate the variables used in the study, their statistical properties are shown in Table 1 in which the minimum, maximum, and mean values and standard deviation of the variables are summarized.

According to Table 1, the CO_2 emission was higher than N_2O and CH_4 emissions in member countries during the study period indicating the high contribution of CO_2 to GHG emissions. Before the model is estimated, first the variability of all variables has to be checked to ensure the lack of aggregation of variables from order II, namely I(2), because with the variables I(2) in the model, the ARDL method can no longer be used. Therefore, in this study, two famous tests of the single root in panel patterns, including Levin et al. (1993) and Im et al. (2003), have been used. The null hypothesis in these tests is based on the existence of a single root. Tables (2) and (3) summarize the results of these two tests for the logarithms of variables examined at the level and after the first difference, assuming that there are time variables and *y*-intercept separately.

According to Table (2), only the variable of N_2O release is stable at the level and the remaining variables are unstable, and the results of the root test by one differencing are expressed in Table 4.

Based on Tables (2) and (3), except for the variable of N_2O, which is at the stable level, the remaining variables are at an unstable level and are fixed by one differencing. Therefore, according to the results, none of the variables are I(2). After assuring the reliability of the variables, the co-integration of Kao was used to determine whether the variables are related to each other in the long run, and the results are shown in Table (4). The null hypothesis in this test is the lack of co-integration or long-term relationship.

According to the results of the Kao test in Table (4), the value of ADF for each of CO_2, N_2O, and CH_4 was significant at the 1% level. Therefore, according to the Kao test results, the long-term relationship between CO_2, N_2O, and CH_4, and the other variables of the model was confirmed. In other words, the null hypothesis regarding the absence of coexistence or long-term relationships was refuted. After proving the existence of coexistence in the model using the Kao coherence test, the long-term relationship was estimated. As stated, the Panel ARDL method was used in this study, and the Schwarz-Basin (SBC) criterion was employed to determine the optimal interruption. The results of the long-run estimation are shown in Tables (5) and (6).

Regarding the long-term results for CO_2 emissions in Table 6, except for the variable of population, the remaining variables were significant at the 1% level. Also, given the sign and square of the variable of GDP, it can be concluded that in the long run, the environmental Kuznets hypothesis is reverse Ud among the 20 studied countries during the 23-year period. The comparison of the absolute magnitude of the coefficient of variations of the logarithm of GDP per capita and the coefficient of variations of the logarithm of GDP per capita shows that in the first half of the Kuznets curve, the relationship between GDP production and CO_2 emission was a positive, upward and steep trend (about 2.56), but in the second half, the Kuznets curve was downtrend and continued with a slight slope (about 2.07). Over the years (1990-2016), the elasticity of CO_2 emissions relative to GDP variations was estimated at 0.4, i.e., assuming that other conditions are constant, as GDP per capita increases by 10%, average CO2 emissions will increase by 4% over the studied period. Also, the return point of the environmental curve is where the per capita income in APO countries would be US$ 86876662.64. In other words, on average, when APO member countries earn a real per capita income of US$ 86876662.64, the increase in per capita income would not increase CO_2 emissions and from that point onwards, along with growth and development (GDP per capita), CO_2 emissions will reduce and will lead to environmental sustainability. In addition, as the results show, EKC for CO_2 emissions in APO member countries will be realized at the per capita income of US$ 86876866662.864 and according to Figure (1), the maximum per capita income is US$ 31152839.4 and is less than per capita income at the return point of EKC, the return point of the curve is not within the sample. Therefore, it is concluded that the APO countries have not yet reached the point of return. The variable of open trade has a negative relationship and its coefficient is 0.023 and since the model is a logarithmically one, a 1% increase in trade could reduce CO_2 emissions by 0.223%. Also, according to short-term results, none of the variables was significant. But, the importance short-term estimation of error correction coefficient of ECM (-1) is that is is equal to 0.39 indicating that the short-term model converges to a long-term model after 2.5 years.

Table 6 shows the estimation of the long-term model for CH_4 emission. According to these results, U-inversion has been established for this GHG. Like carbon dioxide, the variable of population is not significant, but the remaining variables are significant at a confidence level of 1% and 5%. Also, by comparing the absolute magnitude of logarithm variance coefficient of GDP per capita and logarithm variance coefficient of per capita GDP as the results of CO_2 emission, it shows that in the first half of EKC, the relationship between gross production per capita and production of CH_4 pollution was positive and ascending with a slope of 0.57, but in the second half, EKC is downward and continues with a slight slope (about 0.02). The elasticity of CH_4 emission variations versus GDP variations is 0.04. That is, assuming that the other conditions are constant, the CH_4 emission is moderately increased to 0.4% during the study period if GDP per capita increases by 10%. Also, the return point for the environmental curve is US$ 1544174.47. In other words, on average, when APO member countries receive this per capita income, higher per capita income will increase CH_4

emission from that point on. With the increase in per capita GDP, the amount of CH_4 will be reduced. In addition, according to the results, EKC return point for CH_4 in the APO countries will be achieved at the per capita income of US$ 1544174.47. Since according to Table 1, the maximum per capita income is US$ 31152839.4 and is higher than the per capita income at the return point of EKC, so for the methane, the return point is the curve in the sample. Therefore, it is concluded that some of the APO countries have returned to the point of return. By examining the data of these countries during the studied period, eight countries from 20 countries including Vietnam, Mongolia, Liu, South Korea, Cambodia, Japan, Iran, and Indonesia have reached the point of return to EKC curve and earned more than the return point. Also, according to the trade outcomes, a 1% increase in trade will reduce methane emissions by 0.226%. According to the results of the short-term estimation of CH_4, it is found that GDP and its gross variables are significant at the 10% level, which according to the sign of these variables, can be concluded that the Kuznets environmental hypothesis of short-term methane GHG is not supported. According to the result, the error correction coefficient equals 0.46, which indicates that after approximately two periods of short-term equilibrium, it converges to long-term equilibrium.

Table 1. Statistical characteristics of the variables

Variables	Min.	Max.	Mean	Std. dev.
CO_2	212.686	10020745	457619.6	1203283
N_2O	329.9578	587166.4	49783.16	104464.5
CH_4	635.201	1752290	140539.9	289901.5
GDP	4947.548	31152839.4	4510395.728	7986061.202
TRADE	1.46129E-09	0.021	0.002	0.004
POP	728626	1350695000	168839834	339671177

Table 2. Unit root tests result of variables in the level

	Without trend				With trend			
	LLC		IPS		LLC		IPS	
variables	P-value	t-statistic	P-value	t-statistic	P-value	t-statistic	P-value	t-statistic
LCO_2	0.13	-1.125	0.94	1.58	0.175	-0.932	0.366	-0.341
LN_2O	0.001	-3.07***	0.01	-2.03***	0.001	-2.99***	0.008	-2.39***
LCH_4	0.46	-0.096	0.99	3.05	0.13	-1.01	0.3	-0.51
LGDP	0.837	0.983	1	6.98	0.03	-1.86**	0.01	-1.26
$LGDP_2$	0.958	1.73	0.1	7.52	0.367	-0.33	0.92	1.44
LTRADE	0.99	2.06	0.98	2.21	0.53	-1.61	0.68	0.48
LPOP	1	7.58	1	33.1	0.000	18.93***	0.000	-11.89***

** $p < 0.05$.

*** $p < 0.01$.

Table 3. Unit root tests result of variables in the first-order difference

	Without Trend				With Trend			
	LLC		IPS		LLC		IPS	
variables	P-value	t-statistic	P-value	t-statistic	P-value	t-statistic	P-value	t-statistic
$DLCO_2$	0.000	-7.25***	0.000	-8.35***	0.000	-5.96***	0.000	-6.51***
$DLCH_4$	0.000	-6.76***	0.000	-9.03***	0.000	-6.55***	0.000	-8.54***
DLGDP	0.000	-6.44***	0.000	-6.94***	0.000	-5.95***	0.000	-5.07***
DLGDP2	0.000	-6.21***	0.000	-6.73***	0.000	-6.04***	0.000	-5.76***
DLTRADE	0.000	-7.07***	0.000	-8.15***	0.000	-5.52***	0.000	-6.9***
DLPOP	0.000	-9.29***	0.000	-6.09***	0.000	-1.93***	0.000	-10.15***

*** $p < 0.01$.

Table 4. Kao test results for CO_2, N_2O, and CH_4

	t-statistic	P-value
CO_2	***-3.67	0.000
N_2O	***12.58	0.004
CH_4	***-2.272	0.011

*** $p < 0.01$.

Table 5. Panel ARDL results (1, 1, 1, 1, 1) for CO_2 emissions

Variables	Coefficient	Std. dev.	t-statistics	P-value
LGDP	2.56***	0.43	5.93	0.000
$LGDP_2$	-0.07***	0.02	-3.34	0.000
LTRADE	-0.101***	0.04	-2.498	0.013
LPOP	-0.019	0.214	-0.09	0.928
Results Error Correction ECM (-1)				
DLGDP	-1.625	18.631	-1.625	0.105
$DLGDP_2$	1.437	0.91	0.437	0.151
DLTRADE	-0.257	0.09	-0.257	0.797
DLPOP	-0.375	5.527	-0.375	0.707
C	-5.46	0.021	-5.46	0.000
ECM(-1)	-0.39	0.063	-6.14	0.000

*** $p < 0.01$.

Table 6. Panel ARDL results (1, 1, 1, 1, 1) for CH_4 emission

Variables	Coefficient	Std. dev.	t-statistics	P-value
LGDP	***0.57	0.13	4.284	0.000
$LGDP_2$	***-0.02	0.006	-3.057	0.002
LTRADE	**-0.026	0.013	-2.017	0.044
LPOP	0.001	0.059	0.03	0.975
Results Error Correction ECM (-1)				
DLGDP	*-16.293	9.468	-0.17	0.086
$DLGDP_2$	*0.568	0.334	1.709	0.098
DLTRADE	0.081	0.068	0.095	0.342
DLPOP	1.413	4.757	0.297	0.776
C	***2.649	0.568	4.663	0.000
ECM(-1)	***-0.457	0.083	-5.47	0.000

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

Table 7. Panel ARDL results (1, 2, 2, 2, 2) for N_2O emissions

Variables	Coefficient	Std. dev.	t-statistics	P-value
LGDP	***-2.68	0.47	-5.6	0.000
LGDP2	***0.1	0.17	6.247	0.000
LTRADE	***-0.313	0.52	-5.996	0.000
LPOP	***1.615	0.19	3.111	0.002
Results Error Correction ECM (-1)				
DLGDP	-4.224	95.18	-0.044	0.964
DLGDP(-1)	61.925	53.61	1.155	0.249
DLGDP2	0.524	2.938	0.175	0.068
DLGDP2(-1)	-2.321	1.798	-1.29	0.198
DLTRADE	**0.312	0.174	2.116	0.035
DLTRADE(-1)	**0.392	0.201	1.944	0.052
DLPOP	-53.199	72.07	-0.736	0.461
DLPOP(-1)	37.774	62.24	0.95	0.555
C	***6.128	1.063	5.76	0.000
ECM(-1)	***-0.551	0.092	-5.957	0.000

** $p < 0.05$.

*** $p < 0.01$.

Regarding the long-term results of N_2O emissions shown in Table (7), all variables have been predicted at the 1% level. With regard to the mark of GDP and its coefficients in the long run, the environmental Kuznets hypothesis is not confirmed. However, the elasticity of the variations in N2O emissions relative to GDP variations is 0.38. Accordingly, assuming that other conditions are constant, if GDP per capita is increased by 10%, CH_4 emissions are moderately increased during the studied period. The volume will increase by 3.8%. Also, according to the results, the negative trade coefficient is about 0.31; that is, a 1% increase in trade will reduce N_2O emissions by 0.31%. According to the results of N_2O, in contrast to the other two GHGs, the variable of population is significant, meaning that this relationship is direct. In other words, with increasing population, the amount of N_2O emissions is also increased. The short-run results also show that only the variable of trade has a significant direct relationship with N_2O emission. The error correction factor is also 0.55, suggesting that after about two periods, the short-term equilibrium converges to the long-term equilibrium.

4.Conclusion

In this study, the variable of GDP and its square were investigated to study the environmental Kuznets hypothesis and the variables of open trade and population on carbon dioxide, methane, and nitrogen oxide emissions. The study period was 27 years (1990-2016) and the study focused on Asian countries, which included 20 countries including Iran. Since the panel data was used for the structure of the research data, the new Panel ARDL method was used. Based on the results, the Panel ARDL (1.1-1.1.1) model is the best model for CO_2 and CH_4 emissions and Panel ARDL (1, 2, 2, 2, 2) was selected for N_2O. According to the results obtained from the long-term estimation, the environmental Kuznets hypothesis is verified as a reverse U for CO_2 and methane, but not for nitrous oxide. The carbon dioxide conversion curve in APO member countries was achieved at US$ 86876662.64 per capita income and the maximum per capita income in these countries period was US$ 31152893.4 during the studied period and is smaller than per capita income at the EKC return point, so the countries of the organization have not yet reached the point of departure for carbon dioxide emissions. Also, the return point for methane gas in per capita income is US$ 1544174.47. According to the maximum per capita income, the curve return point for this model is within the sample, which is based on the data of the studied countries during the period. Eight countries of 20 including Vietnam, Mongolia, Laos, South Korea, Cambodia, Japan, Iran, and Indonesia were in EKC and earned more than the return point. Also, according to the elasticity obtained for CO_2, N_2O, and CH_4, which were 0.4, 0.38, and 0.04, respectively, the effect of GDP increase on CO_2 emissions is higher than N_2O emissions and CH_4 and these results represent the importance of CO_2, which is more polluting than other GHGs and will have an important impact on the environment quality. This scientifically agrees with the fact that CO_2 accounts for more than 60% of the GHG emissions. It should be noted that our results corroborate with many studies, including Drabo (2017), Alam et al. (2016), and Amiri et al. (2016). But, the common result for all three GHGs is the negative relationship between the variable of open trade and pollutant emissions. As it was stated at the beginning of the paper, open trade can have a negative or positive effect on the environment and has three effects of scale, composition, and technology on environmental quality, among which the effect of the technology has a negative impact on the quality of the environment. Therefore, the potential negative relationship between trade and the distribution of contamination resulting from this study was related to the effect of technology, since most of the APO member states are developing countries and use new technologies for production.

But unlike the long-term results, the environmental Kuznets hypothesis has not been approved in the short run, and only methane has a U-relation at a probability level of 10%, which was also reported by Alam et al. (2016). Because environmental phenomena usually occur in the long run, the short-term results are not expected to be very real and, as already stated, the importance of the short-run model is the error correction coefficient, which was 39.0, 45.0 and 55.0 for CO_2, N_2O, and CH_4, respectively, indicating a high modulation rate, meaning that the short-term model for CO_2 will reach long-term equilibrium after approximately 5.2 years, and it will converge to long-term equilibrium for N_2O and CH_4 after about 2 years. However, according to the results, which showed that GDP increase is more influential on CO_2 emissions than on N_2O and CH_4 emissions, it is suggested to use more measures for CO_2 to control its release. Also, given the negative relationship between trade and GHG emissions, it is suggested that the government reduce the tariff for imported clean goods and less energy-intensive goods and stop importing dirty goods (goods that spread pollution during production). Also, since the population has a positive and significant relationship with N_2O emission, it is suggested that policies such as reducing urban populations be implemented by preventing the migration of villagers to cities. Finally, it is suggested that other pollution indicators such as water pollution should be considered in Iran and other countries in future studies so that planners and authorities can use the results of these studies to achieve sustainable development goals and make the right decisions. Also, given that the return point of carbon dioxide emission occurs at high per capita income and given that carbon dioxide emission reduction through achieving higher per capita income and higher economic growth is time-consuming, it is necessary to establish strict rules and use modern technology and economic tools such as taxes to prevent the growing release of these GHGs and control pollution sources.

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