Original Paper

Comparison of environmental Kuznet Curve testing before and during the implementation of Sustainable Development Goals

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Abstract. *This research aims to analyse comparative environmental Kuznet Curve (EKC) testing before and during the implementation of Sustainable Development Goals (SDGS). Our study uses a quantitative approach. The sampling technique used is purposive sampling, involving countries that are included in the categories of 10 high, upper middle and lower middle-income* *countries on the Asian continent during the 2011-2020 period. The data analysis method used is panel data regression analysis by combining cross section and time series data in order to analyse the variables Gross Domestic Product, Population Density, Foreign Direct Investment, Human Development Index, Agricultural Land, and Industrialization and their influence on* CO_2 *emissions in the countries studied.*

1. Introduction

Economic development is a process with a declared aim of increasing economic growth and improving community welfare. Generally, efforts that have been made so far are still too focused on the goal of economic growth and ignore social and environmental aspects. The economic development process is still largely concerned with efforts to increase productivity in order to meet public consumption. Increasing the production of goods and services cannot be separated from the utilization of existing natural resources (Chiu 2012; Dietz et al., 2012; Suki et al., 2020), which tends to be exploitative and ignores environmental sustainability (Choumert et al., 2013; Cole & McCoskey, 2013; Lau et al., 2014). Production activities that continuously exploit natural resources have a negative impact on the environment, (Sarkodie & Ozturk 2020; Murshed et al., 2021) and issues of environmental damage, global warming and climate change have reached the world's attention in recent years because they are detrimental to human life. Excessive exploitation of natural resources, without thinking about the impacts that will result in economic, social, and other crises, pose an increasing threat to people's lives in the future (Xu 2018; Ridzuan et al., 2020). During the 2011-2020 period, carbon dioxide pollution in Asia for high income countries has tended to decrease, while upper middle and lower middle-income countries has tended to experience an increase. The environmental pollution that has occurred is due to several factors.

The first factor that can increase environmental pollution is Gross Domestic Product (GDP). Efforts to increase economic growth as indicated by an increase in GDP are also one of the causes of increasing environmental pollution. High industrial activity that produces waste and combustion smoke certainly contributes to environmental pollution. In fact, several previous studies explained that GDP growth was also offset by an increase in environmental pollution (Al-Mulali et al, 2015; Jebli & Youssef, 2015; Inglesi-Lotz and Bohlman, 2014). The second factor is population. The higher the population density, the more housing will be built, and the more household waste will be produced. The increasing population can also increase the demand for goods and services which requires greater production of these goods and services. The third factor that can increase environmental pollution is foreign investment. Foreign Direct Investment (FDI). This can boost economic activity which will certainly increase the amount of waste and pollution particles which will further worsen environmental damage (Aung 2017). The fourth factor that can increase environmental pollution is the quality of human resources. The better the quality of existing human resources, the better the quality of the environment should be because the level of public awareness of the importance of environmental sustainability becomes higher. The fifth factor that can increase environmental pollution is the availability of agricultural land. Agricultural land is becoming increasingly depleted and changing its function, which can have a negative impact if the land is used for housing and industry. The decrease in agricultural land results in a decrease in plants that can absorb carbon. The sixth factor that can influence environmental pollution is industrialization. A country's effort to improve its economy through industrialization in order to provide needed goods and services and absorb labour has a negative impact on the environment, in particular through the production of waste that pollutes the environment (Katircioglu et al., 2018; Olale et al., 2018).

Efforts to improve people's welfare are not enough if only seen from an economic development perspective. Achieving economic growth and environmental sustainability are apparently conflicting goals, even though the 2000 Millennium Development Goals (MDGs) and the 2016 Sustainable Development Goals endeavour to reconcile them. The purpose of this paper is to analyse the relationship between economic growth and environmental quality by employing the Environmental Kuznets Curve (EKC) Hypothesis. The EKC Hypothesis examines the relationship between economic development and environmental damage (Farhani 2014, Lacheheb 2015, Ahmad 2017, Aziz 2020) and posits that increasing economic development activities will initially be accompanied by increased environmental damage. However, Grossman & Krueger (1995) proposed the model of an inverted U-curve where at the beginning of economic growth environmental degradation increases, but environmental degradation will decrease as economic growth increases (Altintas, 2020), because economic growth is accompanied by an increasing demand for environmental quality, thereby leading to measures that decrease environmental deterioration. Since then, this hypothesis has become an interesting subject for researchers.

Thus far, research has provided mixed results. Some studies in diverse countries - in Pakistan (Ali et al., 2015), in Ethiopia (Endeg, 2015), and in countries with high income (Camci et al., 2018) have produced findings that the EKC hypothesis is in the long term demonstrated as an inverted U-shaped curve. However, other research actually provides contradictory findings, whereby EKC does not fully occur in the Gulf Cooperation Council (GCC) countries (Basarir and Arman, 2013), in South Africa (Inglesi-Lotz & Bohlmann, 2014), and in countries with middle and low income (Camci et al., 2018). Moreover, ECK with an N form, which suggests that the hypothesis will not hold in the long run, is found both in OECD and non-OECD countries in Latin America, Asia, and Africa (Beck & Joshi, 2015). Our aim is to conduct comparative analysis of EKC testing before and during the implementation of SDGS on the Asian continent.

2. Research methods

Our study uses a quantitative approach. We use secondary data in the form of panel data which combines time series data for the period 2011-2020 and cross-section data on 30 countries on the Asian continent consisting of high-income countries, upper middle-income countries, and lower middle-income countries. This is obtained from documents published the World Bank (2022a; 2022b; 2022c; 2022d; 2022e; 2022f) and the Asian Development Bank (2022). The sampling technique used is purposive sampling, i.e., countries that are included in the categories of 10 high, upper middle and lower middle-income countries on the Asian continent. The high-income countries include Bahrain, Brunei Darussalam, Qatar, Israel, Japan, South Korea, Oman, Saudi Arabia, Singapore, United Arab Emirates. The upper middle-income countries include Armenia, China, Fiji, Iraq, Jordan, Lebanon, Malaysia, Maldives, Thailand, and Turkmenistan. The lower-middle income countries include Bangladesh, the Philippines, India, Indonesia, Cambodia, Morocco, Mongolia, Myanmar, Sri Lanka, and Vietnam.

The data analysis method used is panel data regression analysis by combining cross section data and time series data. This data analysis is used to reduce obstacles that arise due to limited data so that the expected goals can be achieved. The cross-section data used in this research consists of 10 high income countries, 10 upper middle-income countries and 10 lower middle-income countries for a total of 30 countries. The time span for the data is from 2011-2020. Our research also compares the testing of the Environmental Kuznets Curve Hypothesis before and after the implementation of the SDGs using dummy variables. Data obtained is tabulated, processed, and interpreted using the Eviews 11 program. Several variables in this research model are converted into natural logarithm (logn) form to make the model linear so that the data can be distributed normally. To obtain an inverted-U pattern formed from the relationship between GDP and CO_2 emissions, we use a quadratic equation.

CO_2 it=α+β1 GDP it +β2 POP it +β3 FDI it +β4 HDI it+β5 TO it +β6 UB it +β7 LP it +β8 ID it +β9 D00*PDBit +β10 D00*POP it +β11 D00*FDI it +β12 D00*HDI it+β13 D00*TO it +β14 D00*UB it +β15 D00*LP it +β16 D00*ID it +εit (3.1)

The Kuznets environmental curve hypothesis created by Grossman & Krueger (1995) shows a non-linear relationship between emissions and economic growth. So, to test the validity of the Kuznets environmental curve hypothesis in this equation a variable (squared) as an explanatory variable was added. The expanded Kuznets environmental curve equation in this research is written based on country income criteria, namely high-income countries, upper middle-income countries, and lower middle-income countries. The regression equation used for each criterion is as follows:

High income countries (high income):

CO_2 it=α+β1 GDP it +β2 GDP2 it +β3 POP it +β4 FDI it +β5 HDI it+β6 LP it +β7 ID it +β8 D00*PDBit +β9 D00*POP it +β10 D00*FDI it +β11 D00*HDI it +β12 D00*LP it +β13 D00*ID it +εit (3.2)

Upper middle-income countries:

CO_2 it=α+β1 GDP it +β2 GDP2 it +β3 POP it +β4 FDI it +β5 HDI it+β6 LP it +β7 ID it +β8 D00*PDBit +β9 D00*POP it +β10 D00*FDI it +β11 D00*HDI it +β12 D00*LP it +β13 D00*ID it +εit (3.3)

Lower middle-income countries:

CO_2 it=α+β1 GDP it +β2 GDP2 it +β3 POP it +β4 FDI it +β5 HDI it+β6 LP it +β7 ID it +β8 D00*PDBit +β9 D00*POP it +β10 D00*FDI it +β11 D00*HDI it +β12 D00*LP it +β13 D00*ID it +εit (3.4)

Legend:

CO_2 it = CO_2 gas emissions for country i in year t

GDP it = GDP per capita for country i in year t

GDP2 it = GDP per squared capita for country i in year t

POP it = Density for country i in year t

FDI it = Foreign investment to country i in year t

HDI it = Human development index for country i in year t

LP it = Land agriculture for country i in year t

ID it = Industrialization for country i in year t

D00 it = SDGs program dummy for country i in year t

(0= Before SDGs, namely 2011-2015, 1=During the implementation of SDGs, namely 2016-2020)

α = constant

β1,β2,β17= coefficient

ε = residual (error term)

Our research estimates the existence of EKC as applied by Dong et al. (2018) using the model specifications in equation (3.5). The existence of EKC in a country can be determined by looking at the coefficientβ1 andβ2.

a) Ifβ2 < 0, an inverted U-shaped relationship occurs.

b) Ifβ2 > 0, there is no inverted U-shaped relationship.

After ascertaining the existence of EKC in a group of countries, the next stage is to calculate the Turning Point (TP) and Turning Year (Y) for each country using the following formula (Shuai et al., 2017):

$$TP = -\frac{\beta 1}{2\beta 2} \quad (3.5)$$

Legend:

TP = turning point, defined as the GDP per capita at which the EKC will reach its peak

β1, β2 = equation coefficients

Based on the conditions above, it can be posited that the EKC hypothesis occurs if the GDP per capita variable is significantly positive and the square of GDP per capita is negative. Furthermore, changes in the influence of economic growth, population density, FDI, HDI, trade openness, urbanization, agricultural land, and industrialization on CO_2 emissions between before and after the implementation of the SDGs program can be determined from the dummy value of each independent variable. If the dummy is significant, it means that there are changes that occurred in that variable after the SDGs came into force.

Panel data regression analysis methods can be based on three approaches.

1) Common Effect Model (CEM)

According to Baltagi (2005), a model without individual influence (common effect) is an estimate that combines all-time series and cross section data using the Ordinary Least Square (OLS) approach to estimate the parameters. This model assumes that the intercept and slope values between individuals remain constant over various periods of time, so that the estimation results do not correspond to actual reality. In general, the model equation can be written as follows:

$$Yiy = \alpha + \beta Xit + \varepsilon it \quad (3.6)$$

Legend:

Yiy = Response variable at the ith observation unit and time t

Xit = Predictor variable at the ith observation unit and time t

β = Slope coefficient or direction coefficient

α = Intercept of the regression model

εit = error

2) Fixed Effect Model (FEM)

The FEM approach or fixed effects model assumes that there are different effects according to the relationship between individuals and time, which are shown through differences in the intercept or constant for each individual. In other words, in this model the intercept or constant value between individuals is different but has a constant slope between individuals in various time periods because the characteristics of each individual are different (Basuki & Prawoto, 2016).

3) Random Effect Model (REM)

This model estimates panel data where disturbance variables may be interconnected over time and between individuals. In this model the difference between individuals and time is shown by the intercept through error. The specification effect of each individual is needed as part of the error component which is random and uncorrelated with the observed explanatory variables. Models with this approach can minimize the use of degrees of freedom but do not reduce the number as is done with fixed effects. The advantage of using this approach model is that it eliminates heteroscedasticity problems. This model is also called the Error Component Model (ECM) or Generalized Least Square (GLS) technique.

3. Results

The results of our research emerge from panel data regression analysis techniques used on secondary data related to CO_2 Emission Demand (Y), Gross Domestic Product (X1), Population Density (X2), Foreign Direct Investment (X3), Human Development Index (X4), Agricultural Land (X5), Industrialization (X6). There are three model choices in panel data regression analysis, including the common effect model, fixed effect model, and random effect model. Model selection in panel data regression analysis is carried out using specification tests. Based on the specification test, the results obtained show that the model chosen in this research is the FEM model. The panel data regression results using FEM are presented in Table 1.

Sample	Dependent Variable	Independent Variable	Coefficient	Prob. T-statistics	Prob. F-statistics	Adj-R2
High income countries	CO_2	D00*GDP	-1,206	0,000***	0,000	0.872
		D00*POP	0.842	0,000***		
		D00*FDI	3,516	0,000***		
		D00*HDI	1,034	0,000***		
		D00*LP	0.563	0,000***		
		D00*ID	6,781	0,000***		
		GDP	2,476	0,000***		
		GDP2	-1,036	0,000***		
		POP	0.568	0.325		
		FDI	4,798	0.015***		
		HDI	2,367	0,000***		
		L.P	1,876	0.124		
		ID	8,345	0.009***		
Upper middle-income countries	CO_2	D00*GDP	4,714	0,000***	0,000	0.798
		D00*POP	1,453	0,000***		
		D00*FDI	6,873	0.014***		
		D00*HDI	1,357	0.005***		
		D00*LP	1,985	0,000***		
		D00*ID	4,834	0,000***		
		GDP	23,897	0,000***		
		GDP2	-1,004	0.003***		
		POP	2,673	0.013***		
		FDI	7,352	0,000***		
		HDI	2,146	0.186		
		L.P	4,645	0.231		
		ID	6,354	0,000***		
Lower middle-income countries	CO_2	D00*GDP	3,785	0,000***	0,000	0.697
		D00*POP	2,053	0,000***		
		D00*FDI	7,342	0.007***		
		D00*HDI	1,093	0.012***		
		D00*LP	1,257	0.006***		
		D00*ID	5,893	0,000***		
		GDP	11,456	0.003***		
		GDP2	1,102	0.002***		
		POP	4,653	0.041***		
		FDI	9,065	0.217		
		HDI	1,763	0.162		
		L.P	2,356	0,000***		
		ID	8,365	0.001***		

Table 1. Summary of Hypothesis Test Results and Determination Coefficient Analysis

a. Panel Data Regression Analysis in High Income Countries

Based on the results of the regression analysis above, the result is that the GDP variable has a probability of <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The population density variable has a probability >αnamely 0.325 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The foreign investment variable has a probability <αnamely 0.015 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The human development index variable has a probability <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The agricultural land availability index variable has a probability of >αnamely 0.124 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The industrialization variable has a probability <αnamely 0.009 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. Based on the regression results, the Prob F-statistic value is 0.000, which means <0.05 so that Ha is accepted, and it can be concluded that the variables Gross Domestic Product (X1), Population Density (X2), Foreign Direct Investment (X3), Human Development Index (X4), Agricultural Land (X5), Industrialization (X6) together influence CO_2 emissions in high-income countries.

b. Panel Data Regression Analysis in Upper Middle-Income Countries

Based on the results of the regression analysis above, the results show that the GDP variable has a probability of <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The population density variable has a probability <αnamely 0.013 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The foreign investment variable has a probability <αnamely 0.015 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The human development index variable has a probability of >αnamely 0.186 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The agricultural land availability index variable has a probability of >αnamely 0.231 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The industrialization variable has a probability <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. Based on the regression results, the Prob F-statistic value is 0.000, which means <0.05 so that Ha is accepted, and it can be concluded that the variables Gross Domestic Product (X1), Population Density (X2), Foreign Direct Investment (X3), Human Development Index (X4), Agricultural Land (X5), Industrialization (X6) together influence CO_2 emissions in upper middle-income countries.

c. Panel Data Regression Analysis in Lower Middle-Income Countries

Based on the results of the regression analysis above, the results show that the GDP variable has a probability of <αnamely 0.003 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The population density variable has a probability <αnamely 0.041 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The foreign investment variable has a probability of >αnamely 0.217 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The human development index variable has a probability of >αnamely 0.162 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The agricultural land availability index variable has a probability <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The industrialization variable has a probability <αnamely 0.001 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. Based on the regression results, the Prob F-statistic value is 0.000, which means <0.05 so that Ha is accepted, and it can be concluded that the variables Gross Domestic Product (X1), Population Density (X2), Foreign Direct Investment (X3), Human Development Index (X4), Agricultural Land (X5), Industrialization (X6) together influence CO_2 emissions in lower middle-income countries.

Country Category	**Variable**	**Independent Variable Coefficient**	**Variable**	**Independent Variable Coefficient** (with dummy)
High income countries	*GDP*	6,703	*D00*GDP*	-2,013
	POP	4,378	*D00*POP*	1,561
	FDI	19,763	*D00*FDI*	9,672
	HDI	6,723	*D00*HDI*	2,987
	LP	4,098	*D00*LP*	0.968
	ID	23,567	*D00*ID*	11,675
Upper middle-income Countries	*GDP*	3,067	*D00*GDP*	1,097
	POP	2,984	*D00*POP*	1,007
	FDI	10,013	*D00*FDI*	5,467
	HDI	7,876	*D00*HDI*	6,978
	LP	2,876	*D00*LP*	1,076
	ID	16,457	*D00*ID*	9,054
Lower middle-income countries	*GDP*	5,908	*D00*GDP*	2,876
	POP	8,765	*D00*POP*	2,986
	FDI	18,092	*D00*FDI*	10,761
	HDI	7,356	*D00*HDI*	3,254
	LP	6,987	*D00*LP*	2,096
	ID	24,765	*D00*ID*	12.54

Table 2. Results of EKC Hypothesis testing before and during SDGs implementation.

Based on Table 2, it can be argued that before the implementation of SDGS, almost all variables in high, upper middle and lower middle-income countries had a positive influence on CO_2 emissions. However, after the implementation of the SDGs, in high income countries, the increase in GDP has a negative effect on CO_2 emissions. This shows that a number of developed countries have carried out development with low emission principles. For upper and lower middle-income countries, however, after implementing the SDGs all variables have a positive impact in increasing CO_2 emissions, while the coefficient values are lower.

Sample	Coefficient Value		Turning Point	Occurrence of EKC
	GDP	GDP2		
High income countries	2,476	-1,036	USD 11.94 thousand	Will happen in the future
Upper middle-income countries	23,897	-2,008	USD 47.98 thousand	Will happen in the future
Lower middle-income countries	11,456	1,102	USD 93.98 thousand	Will not occur

Table 3. Turning Point Test

Table 3 is a summary of the test results, which shows that there are differences in the results of testing the EKC hypothesis in Asia, both in high income countries, upper middle-income countries or in lower middle-income countries. The EKC hypothesis is declared valid if the GDP per capita variable has a positive coefficient value and the squared GDP2 per capita variable has a negative coefficient value. Based on the results of testing the EKC hypothesis, in high income and upper middle-income countries this will happen in the future because they have negative GDP2 coefficient values. The hypothesis that EKC will occur is at a GDP value of USD 11.94 thousand and USD 47.98 thousand. Meanwhile, in lower middle-income countries there is no EKC because the GDP2 value is positive.

4. Discussion and conclusions

The results of our analysis show the extent to which the six variables studied have a positive and significant or insignificant influence on CO_2 emissions. As regards the effect of per capita income on CO_2 emissions, the results of our analysis in high income countries show that the coefficient value of the GDP variable is 2,476, in upper middle-income countries, the coefficient value of the

GDP variable is 23,897, and in lower middle-income countries, the coefficient value of the GDP variable is 11,456. These values indicate that in all cases GDP has a *positive* and *significant* influence on CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the population density variable is 0.568, indicating that population density has a *positive* and *insignificant* effect on CO_2 emissions. On the other hand, in upper middle-income countries, the coefficient value of the population density variable is 2.673, and in lower income countries, the coefficient value of the population density variable is 4,653, indicating that in both cases population density has a *positive* and *significant* influence on CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the foreign investment variable is 4,798, and in upper middle-income countries the coefficient value of the foreign investment variable is 7.352, indicating that in both cases foreign investment has a *positive* and *significant* influence on carbon dioxide CO_2 emissions. In lower middle-income countries, the coefficient value of the foreign investment variable is 9.065, indicating that foreign investment has a *positive* and *insignificant* effect on carbon dioxide CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the human development index variable is 2.367, indicating that the human development index has a *positive* and *significant* influence on CO_2 emissions. In upper middle-income countries the coefficient value of the human development index variable is 2.146, and in lower middle-income countries, the coefficient value of the human development index variable is 1.763, indicating that in both cases the human development index has a *positive* and *insignificant* influence on CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the agricultural land availability variable is 1.876, and in upper middle-income countries, the coefficient value of the agricultural land availability variable is 4,645, indicating that the availability of agricultural land has a *positive* and *insignificant* influence on CO_2 emissions. On the other hand, in lower middle-income countries, the coefficient value of the agricultural land availability variable is 2.356, indicating that the availability of agricultural land has a *positive* and *significant* influence on CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the industrialization variable is 8.345, in upper middle-income countries the coefficient value of the industrialization variable is 6.354, and in lower middle-income countries, the coefficient value of the industrialization variable is 8.365, indicating that in all cases industrialization has a *positive* and *significant* influence on CO_2 emissions.

The results of dummy variable analysis show that before the implementation of SDGS, almost all variables in high-income, upper-middle, and lower-middle-income countries had a positive influence on CO_2 emissions. However, after the implementation of the SDGs, in high-income countries the increase in GDP has a negative effect on CO_2 emissions. This shows that in developed countries, many have implemented development policies with low emission principles. For upper and lower middle-income countries, although after implementing the SDGs all variables have a positive impact in increasing CO_2 emissions, the coefficient values are lower. This suggests that implementation of SDG policies can contribute to results in line with the EKC hypothesis.

In terms of overall EKC hypothesis testing our research has limitations in the form of a research model that only focuses on the dependent variable CO_2 emissions. A further limitation is that it does not include countries in the lower income category. The research methodology uses only panel data analysis techniques. Future further research should complete the model by adding environmental quality index variables to the model and using more comprehensive analysis techniques. Moreover, while our research uses a uniquely quantitative approach, future research should add a qualitative dimension.

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