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EFFECTS OF ECONOMIC GROWTH AND HUMAN CAPITAL ON CO_2 EMISSIONS IN SELECTED HIGH-INCOME COUNTRIES: PANEL ECONOMETRIC ANALYSIS[1]

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ABSTRACT

This study attempts to investigate the effects of economic growth (GDP) and Human capital (HDI) on carbon dioxide emissions (CO_2) in selected eight high income countries. These countries are Australia, Japan, South Korea, Luxembourg, New Zealand, Singapore, the United Kingdom and the United States. To do the study, an annual panel economic model was used for the period 1990-2020. ADF-Fisher Chi-square, PP-Fisher Chi-square and Im, Pesaran and Shin W-stat unit root tests revealed that the variables are stationary at the first differences. The Kao and Johansen Fisher Panel Cointegration Tests confirmed the cointegration among the variables. The Pooled Fully Modified OLS (FMOLS) results showed an inverted U-shaped relationship between CO_2 emissions and economic growth which implies that there exists the Environmental Kuznets Curve (EKC) hypothesis in the model. Furthermore, this Pooled FMOLS test results also showed that human capital improves environmental quality by reducing CO_2 emissions in the long-run. The VECM Granger causality results revealed the short-run unidirectional causality from CO_2 emissions to economic growth and from economic growth to human capital, and the long-run bidirectional causality between CO_2 emissions and economic growth. The study finished by providing recommendations for future studies based on the findings obtained from this study.

Key Words: CO_2 emissions, Economic Growth, Human Capital, Panel Data Analysis, Environmental Kuznets Curve (EKC) Hypothesis, Kao Panel Cointegration Test, Johansen Fisher Panel Cointegration Test, FMOLS Long-run Estimation Test, VECM Granger Causality Test.

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SEÇİLMİŞ YÜKSEK GELİRLİ OLAN ÜLKELERDE EKONOMİK BÜYÜME VE BEŞERİ SERMAYENİN CO_2 EMİSYONU ÜZERİNE ETKİLERİ: PANEL EKONOMETRİK ANALİZ

ÖZET

Bu çalışma, sekiz seçilmiş yüksek gelirli olan ülkede ekonomik büyüme (GDP) ve Beşeri sermayenin (HDI) karbondioksit emisyonu (CO_2) üzerine etkilerini araştırmayı amaçlamaktadır. Bu ülkeler Avustralya, Japonya, Kore Cumhuriyeti, Lüksemburg, Yeni Zelanda, Singapur, Birleşik Krallık ve Amerika Birleşik Devletleri'den oluşmaktadır. Çalışmada 1990-2020 dönemi panel ekonomik modeli kullanılmıştır. Sonuçlar, ADF-Fisher Ki-kare, PP-Fisher Ki-kare ve Im, Pesaran ve Shin W-stat birim kök testleri, değişkenlerin birinci farklarda durağan olduğunu ortaya koymuştur. Kao & Johansen Fisher Panel Eşbütünleşme Testleri, değişkenler arasındaki eşbütünleşmeyi doğrulamıştır. Havuzlanmış Tamamen Değiştirilmiş OLS (FMOLS) sonuçları, CO_2 emisyonu ve ekonomik büyüme arasında ters U-şeklinde bir ilişki olduğunu göstermiştir. Bu sonuç Çevresel Kuznets Eğrisi (ÇKE) hipotezinin var olduğunu ima etmektedir. Ayrıca, bu Havuzlanmış FMOLS test sonuçları, beşeri sermayenin uzun dönemde CO_2 emisyonunu azaltarak çevre kalitesini iyileştirdiğini de göstermektedir. VECM Granger nedensellik sonuçları, CO^2 emisyonundan ekonomik büyümeye, ekonomik büyümeden beşeri sermayeye doğru kısa dönem tek yönlü nedenselliği ve CO_2 emisyonu ile ekonomik büyüme arasındaki uzun dönem çift yönlü nedenselliği ortaya koymuştur.

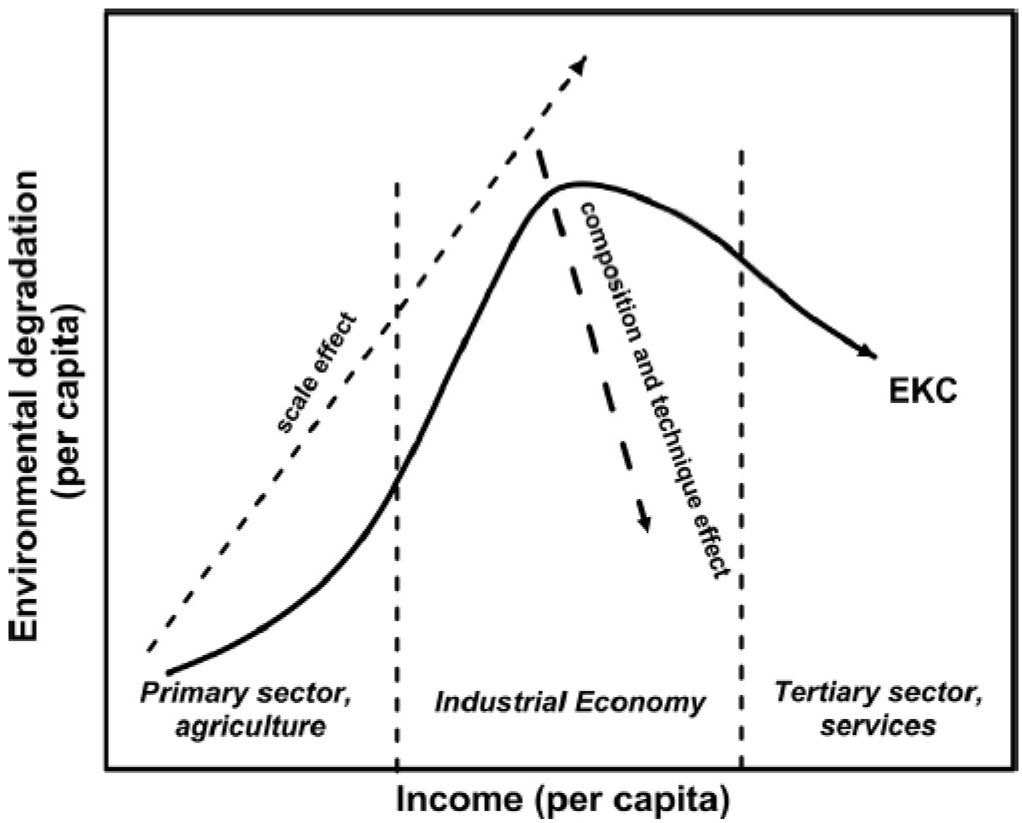
Anahtar Kelimeler: CO_2 emisyonu, Ekonomik Büyüme, Beşeri Sermaye, Panel Veri Analizi, Çevresel Kuznets Eğrisi (ÇKE) Hipotezi, Kao Panel Eşbütünleşme Testi, Johansen Fisher Panel Eşbütünleşme Testi, FMOLS Uzun Dönem Tahmin Testi, VECM Granger Nedensellik Testi.

INTRODUCTION

Economic growth is one of the most important elements that ensures the living standards of the people by increasing their per capita income. Its demand grows higher along with the increase in world population. As the world became more populated compared to the past, it became necessary to concentrate more on industrialization that enhanced the economic growth relatively higher for which the living standards of the higher populated nations can be met. As the world economy became more industrialized, economic growth became highly dependent on energy consumption. As this energy is mainly generated from fossil fuels like coal, oil and natural gas, it creates CO_2 emissions that are responsible for environmental degradation. It was found from several researches that this environmental degradation doesn't only harm the health and social structures of the nation, but also reduces the long-run economic growth. Therefore, it has become a major issue to control CO_2 emissions while keeping economic growth constant. In fact, several researches are still conducting on the topic related to controlling CO_2 emissions by ensuring sustainable economic growth.

According to Kuznets (1955), economic growth increases CO2 emissions at its initial level while it decreases after economic growth reaches a threshold point. The reason why economic growth increases CO_2 emissions at its initial stage is that the demand for energy consumption is relatively higher during the initial stage of the production. As a result, the energy intensity increases along with economic growth. However, the energy intensity becomes lower once the economic growth reaches the threshold point for which more production requires less energy consumption and thereby increasing economic growth with less energy consumption. Therefore, the study conducted by Kuznets (1955) revealed that the relationship between economic growth and CO_2 emissions is inverted U-shaped. It means that there exists a quadratic relationship between CO_2 emissions and economic growth. As Kuznets (1955) revealed the inverted U-shaped relationship between economic growth and CO_2 emissions, the study later on was considered as the Environmental Kuznets Curve (EKC) hypothesis (Stern, 2004). The EKC hypothesis can be interpreted in the following graph.

Graph 1: An Environmental Kuznets Curve (EKC).



Source: Kaika & Zervas (2013)

The above graph 1 showed how the EKC hypothesis works. It shows that the environmental degradation increases when the economy moves from agricultural to industrialization. As the economy is at the initial stage during this time, the demand for energy use, especially the consumption of fossil energy such as coal and oil are relatively higher.

However, since the demand for energy reduces after the economic growth reaches the threshold point, the environment degradation states decreasing after the further increase in economic growth. In this case, the environmental degradation starts decreasing if the economy moves from industrialization to service economy. At this stage, the developed technology and investment for renewable energy development for which the increase in energy efficiency and the use of renewable energy in the production process reduce environmental degradation for the further increase in economic growth. The transfer of economy from agriculture to industrial economy is known as scale effect while its shift from industrial economy to service economy is known as composition and technique effects (Kaika & Zervas, 2013; Özcan & Öztürk, 2019:1).

Several studies have been conducted in order to identify the reasons why the energy intensity is lower once the economic growth reaches a certain threshold point. Many of these studies revealed that it is possible to invest more on technological development if the economic growth is relatively higher which may lead to increased energy efficiency. As a result, fewer energy consumption increases more production and thereby lower CO_2 emissions are generated with higher economic growth. Moreover, some other research revealed that more investment can be made for renewable energy production if the economy of a country is relatively developed. This renewable energy can be used as an alternative to fossil energy consumption for the production process. As renewable energy generates lower CO_2 emissions, replacing renewable energy with fossil energy reduces CO_2 emissions without decreasing economic growth. Moreover, some recent studies also revealed that human capital reduces CO_2 emissions while keeping economic growth constant.

As human capital can play an important role in ensuring sustainable economic growth, the main objective of this study is to investigate the relationship between CO_2 emissions and economic growth under the framework of the EKC hypothesis where human capital is used as a control variable to investigate its effect on CO_2 emissions. If the empirical results confirm that there exists an inverted-U relationship between CO_2 emissions and economic growth, then the study implies that the EKC hypothesis for this study is valid. Furthermore, if the long-run estimation results show that the EKC hypothesis for the study is valid along with a negative effect of human capital on CO_2 emissions, then the study implies that human capital contributes to reducing CO_2 emissions by keeping economic growth sustainable.

As it is evident that countries having higher economic growth are more likely to control CO_2 emissions while ensuring constant economic growth, eight high income countries were randomly selected for the study. Countries that were selected for this study are Australia, Japan, South Korea, Luxembourg, New Zealand, Singapore, United Kingdom and United States.

The first part of the study provides literature review on the past study of the effects of economic growth and human capital on CO_2 emissions. The second part includes brief information on models and data that were selected for the study. The third part contains methodology and empirical analysis for the study. The last part concludes by discussing the overall findings of the study.

1. LITERATURE REVIEW

In this part, eight past studies on the effects of economic growth and human capital on CO_2 emissions in different country groups were reviewed. Here the effect of economic growth on CO_2 emissions were investigated under the framework of the EKC hypothesis in three of these studies. Therefore, a quadratic equation was used in these three literatures to analyze the effect of economic growth on CO_2 emissions where human capital is used as a control variable to observe its effect on CO_2 emissions. However, as the rest of the past literature were conducted without the framework of the EKC hypothesis, linear equations were used in these studies to observe the effects of economic growth and human capital on CO_2 emissions. Annual panel data was used in all these studies where different panel econometric models were applied. The summary for the selected literature review is overviewed in the Table 1a and Table 1b.

In Yao et. al. (2020), a panel data for 20 OECD economies with the variables including CO_2 emissions, GDP per capita, financial development trade openness and human capital between 1870 and 2014 by applying STIRPAT model concluded that tertiary schooling reduces CO_2 emissions while primary and secondary schooling were found to be insignificant to CO_2 emissions. This implies that the relationship between human capital and CO2 emissions is time-varying. In Fact the evidence showed that this relationship switched from positive to negative in the 1950s and became more strongly negative thereafter reflecting heterogeneity in the relationship between different levels of human capital and CO_2 emissions and the growth in investment in higher education in the OECD since the 1950s.

In Ahmed et. al. (2021), it was found by applying different panel econometric techniques for 15 Latin American and Caribbean countries for time span from 1995-2017 that both economic growth and human capital increase CO_2 emissions. The positive impacts of human capital on CO_2 emissions reveals that the current education and returns to education doesn't reduce the environmental degradation automatically. In this case the education syllabus needs to be reformed by including topics related to environmental awareness, capabilities and the right mindset to combat environmental degradation.

In Çakar et. al. (2021), The application of PSTR model for 21 EU countries with annual data of CO_2 emissions, GDP per capita, financial development and human capital between 1994 and 2018 showed that human capital increases CO_2 emissions if human capital increases because of economic growth. However, if human capital increases because of increasing financial development then it leads to reduced CO_2 emissions. The result therefore implies that the improved human capital leads innovation to be increased which is helpful for environmental protection and thereby occurring less environmental degradation in society.

In Haini (2021), a panel fixed effect model was applied for 10 ASEAN economies between 1996 and 2019. Although the overall study results revealed that human capital increases CO_2 emissions, the result varies in different industrial sectors. For instance, human capital decreases CO_2 emissions in manufacturing and other industries while it increases CO_2 emissions in the residential and transport industries. The positive impact of human capital on CO_2 emissions occurred because it indirectly affects economic growth.

However, human capital can enhance the absorptive capacity of an economy as well as the effectiveness of ICT technologies indicating the potential CO_2 emissions. The EKC hypothesis was found to be valid in the research area indicating the inverted U-relationship between economic growth and CO_2 emissions.

In Hao et. al. (2021), ARDL model was applied for G-7 countries between 1991-2017. The study revealed the negative relationship between human capital and CO_2 emissions. Moverover, it was also found from this study that both technological innovation, renewable energy consumption and environmental tax reduce CO_2 emissions as well. The investigation of the EKC hypothesis was found to be valid in this study. Although it was advised in this study for the G-7 economies to focus on green growth along with eco-innovation and environmental pricing through taxation in order to deal with environmental degradation, human capital was considered as a prerequisite for successful implementation of this policy. The reason is that the improvement of human capital through investment and education can create opportunities for enhancing awareness among the people for the use of eco-friendly technologies.

In Khan et. al. (2021), it was found after applying a balanced panel data set for seven OECD countries for the time span from 1990-2018 that human capital reduces CO_2 emissions both directly and indirectly when it is integrated with fiscal decentralization. Here it was advised for these seven OECD economies to implement eco-friendly strategies through the development of human capital that will ensure green economic growth for selected countries. As a result, the education system of these countries will improve the environmental quality while enhancing domestic productivity and well-being of the society.

In Rahman et. al. (2021), the DOLS, FMOLS and pooled mean group (PMG) were applied for 10 newly industrialized economies between 1979 and 2016. Although the study revealed a negative relationship between human capital and CO_2 emissions, the investigation of the EKC revealed a U-shaped relationship between economic growth and CO_2 emissions.

In Opuku et. al. (2022), Driscoll-Kraay, instrumental variable and panel quantile regressions methods were applied for OECD economies between 1996 and 2016. The study revealed human capital to improve environmental quality by reducing CO_2 emissions. In this study, human capital variables were captured by human development index, education and human capital. All these variables showed negative effects on environmental degradation.

It was found from the above literature review that the relationship between CO_2 emissions and economic growth was investigated under the framework of the EKC hypothesis in Haini (2021), Hao et. al. (2021) and Rahman et. al. (2021). Here the EKC hypothesis was found to be valid in all the studies except Rahman et. al. (2021). The validity of the EKC hypothesis in studies imply that economic growth reduces CO_2 emissions after reaching a certain point. Furthermore, human capital was found both positive and negative to CO_2 emissions in the same studies which implies that human capital can be either positive or negative to CO_2 emissions regardless of whether the EKC hypothesis was found to be valid. The negative effect of human capital on CO_2 emissions in studies where the EKC hypothesis exists imply that human capital reduces CO_2 emissions by ensuring sustainable economic growth in any countries or country groups.

On the other hand, studies where the relationship between CO_2 emissions and economic growth were analyzed without the EKC framework and where human capital was used as a control variable imply that the relationship between economic growth and CO_2 emissions is positive while human capital can be either positive or negative.

Table 1a: Previous Literature Review on the Effects of Economic Growth and Human Capital on CO2 Emissions

Authors	Period and study Area	Variables	Methods	Results
Yao et. al. (2020)	20 OECD economies 1870-2014	CO_2 emissions GDP per capita Primary, secondary and tertiary schooling as indicators for Human capital	STIRPAT model	$GDP \rightarrow^{(+)} CO_2$ $HC \rightarrow^{(-)} CO_2$
Ahmed et. al. (2021)	15 Latin America 1995-2017	CO_2 emissions GDP per capita Education and return on education as an indicator for Human capital	Panel econometric technique	$GDP \rightarrow^{(+)} CO_2$ $HC \rightarrow^{(+)} CO_2$
Çakar et. al. (2021)	21 EU countries 1994-2018	CO_2 emissions GDP per capita Financial development Human Development Index (HDI) as an indicator for Human capital	PSTR model	$GDP \rightarrow^{(+)} HC -$ $FD \rightarrow^{(+)} HC \rightarrow^{(}$
Haini (2021)	10 ASEAN economies 1996-2019	CO_2 emissions GDP per capita and the square of GDP Education index as an indicator for Human capital	Panel fixed effect model	$GDP \rightarrow^{(-)} CO_2$ $HC \rightarrow^{(+)} CO_2$

Table 1b: (Cont.) Previous Literature Review on the Effects of Economic Growth and Human Capital on CO_2 Emissions

Authors	Period and study Area	Variables	Methods	Results
Hao et. al. (2021)	G7 countries 1991-2017	CO_2 emissions GDP per capita and the square of GDP Education and return on education as an indicator for Human capital	ARDL model	$GDP \rightarrow^{(-)} CO_2$ $HC \rightarrow^{(-)} CO_2$
Khan et. al. (2021)	7 OECD countries 1990-2018	CO_2 emissions GDP per capita Fiscal decentralization Institutional quality Human Development Index (HDI) as an indicator for Human capital	Balanced panel dataset	$GDP \rightarrow^{(+)} CO_2$ $FSD \rightarrow^{(-)} CO_2$ $IQ \rightarrow^{(-)} CO_2$ $FSD * HC \rightarrow^{(-)} CO_2$ $FSD * IQ \rightarrow^{(-)} CO_2$ $HC \rightarrow^{(-)} CO_2$
Rahman et. al. (2021)	10 newly industrialized economies 1979-2016	CO_2 emissions GDP per capita and the square of GDP Human Development Index (HDI) as an indicator for Human capital	- Dynamic Ordinary Least Squares (DOLS), Fully Modified Ordinary Least Squares (FMOLS), and Pooled Mean Group (PMG) estimation methods	$GDP \rightarrow^{(+)} CO_2$ $HC \rightarrow^{(-)} CO_2$
Opoku et. al. (2022)	OECD economies 1996-2016	CO_2 emissions GDP per capita Human Development Index (HDI) as an indicator for Human capital	Driscoll-Kraay, instrumental variable and panel quantile regression methods methods	$GDP \rightarrow^{(+)} CO_2$ $HC \rightarrow^{(-)} CO_2$

2. MODEL AND DATA

This study intends to investigate the effects of economic growth and human capital on CO_2 emissions. As it is possible to identify whether economic growth reduces CO_2 emissions after a certain level through the EKC hypothesis, the study intends to analyze the relationship between CO_2 emissions and economic growth under the framework of the EKC hypothesis. Therefore, CO_2 emissions in this study will be regressed on both GDP and quadratic GDP. Here if the GDP is positive and the quadratic GDP is negative then it implies that the EKC hypothesis exists in this study. Human Development Index will be included in the model as a control variable. The model that will be used for this study are shown below:

$$\mathbf{LNCO2_{it} = \mathit{B_0}+\mathit{B_1}GDP_{it}+\mathit{B_2}GDP^2_{it}+\mathit{B_3}HDI_{it}+\mathit{e}_{it}} \quad (1)$$

In model no. 1, i and t are considered as cross-section and time-series, *e* denotes normally distributed error terms and B_1, B_2 and B_3 are the coefficient estimates of the relevant variables. If $B_1>0$ and $B_2<0$, it will be revealed that the EKC hypothesis is valid implying that there exists an inverted-U relationship between CO_2 emissions and economic growth in the model. On the other hand, since human capital was found both positive and negative to CO_2 emissions, B_3 can be either positive and negative. If it is negative then the study reveals that human capital is utilized for environmentally friendly activities in the selected study areas. Moreover, the validity of the EKC hypothesis and the negative effects of human capital on CO_2 emissions in the study will imply that human capital reduces CO_2 emissions while ensuring constant economic growth. This will reveal that the economic growth in the selected study areas is relatively sustainable.

As regards to data selection, CO_2 emissions are in metric tons per capita, GDP is the real gross domestic product (GDP) per capita in 2015 US$ and HDI is the Human Development Index (HDI). The annual panel time-series data are from 1990-2020. The data on CO_2 and GDP were collected from world development indicators (WDI) while the data on HDI was collected from the United Nation Development Program (UNDP) database. All the data that were used in this study were transformed into the natural logarithm with an intention of interpreting coefficient estimates as the elasticities of the dependent variable (CO2) with respect to the independent variables (GDP, GDP^2 and HDI).

For this study eight high income countries namely Australia, Japan, Republic of Korea, Luxembourg, New Zealand, Singapore, United Kingdom and United States were randomly selected for this study. According to the World Bank, countries having per capita Gross National Income (GNI) of more than 12,535 US$. The level of GNI per capita for the selected countries for the year 2019 are shown below. In this case, the GNI per capita for the selected countries is more than 12,535 US$ which confirms that all these countries are in high income categories. Among these countries five of the countries (Australia, Japan, Korea Republic, New Zealand and Singapore) are located in Asian region, one country that the United States is located in North America and the other two countries namely Luxembourg and the United Kingdom are located in the European region. Luxembourg is also a member of the European Union. The above table also shows that the GNI per capita for Luxembourg is higher among the eight countries. In fact, Luxembourg is the country in the European Union that has higher GNI per capita compared to other European Union countries.

3. METHODOLOGY AND EMPIRICAL FINDINGS

The study first examined the stability of the series that was investigated with first generation panel unit-root tests including ADF-Fisher Chi-square (Dickey & Fuller, 1979), PP-Fisher Chi-square (Phillips et. al., 1988) and Im, Pesaran and Shin W-stat (Im et. al., 2003). Kao panel cointegration tests developed by Kao (1999) and Johansen Fisher Panel Cointegration Tests developed by Maddala and Wu (1999) were used to investigate the existence of cointegration relationships among series.

After confirming that the variables were stationary and cointegrated for this study, the long-run coefficient estimation between dependent variable (CO2 emissions) and independent variables (GDP, GDP^2 and Human capital) was conducted by using pooled fully modified OLS (FMOLS) techniques that was previously used by Saikkonen (1991), Stock & Watson (1993), Pedroni (1996) and Pedroni (2000) in their study. Lastly, the long-run and short-run causality among the variables were examined by using VECM granger causality approach that was previously used by Pesaran et. al. (1999). The model was first presented by Eangle and Granger (1987) in order to identify the short-run and the long-run dynamic relationships among variables. EViews 9 and Stata 15 programs and codes for these programs were used.

Panel Unit Root Test

In this study the first generation panel unit root tests including ADF-Fisher Chi-square, PP-Fisher Chi-square and Im, Pesaran and Shin W-stat tests were conducted. The reason behind the selection of first generation panel unit root tests for this study is to check whether there exists any stationarity problem in the selected variables. The results from first generation unit root tests were reported in Table 2. Here the overall results indicated that all the variables are stationary at first difference because the null hypothesis (H0) was rejected in this study. Therefore it can be concluded that the variables under this investigation are I(1) instead of I(0).

Table 2: Unit Root Tests

ADF-FisherChi-square				
Variables	Level		First Difference	
	Intercept	Intercept & trend	Intercept	Intercept & trend
LNCO2	17.3192	15.9770	64.3644***	59.3868***
LNGDP	31.7668**	9.65429	58.1788***	74.4916***
$LNGDP^2$	29.8987**	10.0067	59.2198***	73.3956***
LNHDI	47.3394***	23.9655*	50.9515***	66.3608***
PP-FisherChi-square				
Variables	Level		First Difference	
	Intercept	Intercept & trend	Intercept	Intercept & trend
LNCO2	26.8491**	23.2068	139.362***	161.537***
LNGDP	47.5918***	3.79940	87.1369***	358.784***
$LNGDP^2$	50.3730***	3.93586	87.6296***	352.931***
LNHDI	120.655***	61.3198***	90.7188***	533.609***
Im, Pesaran and Shin W-stat				
Variables	Level		First Difference	
	Intercept	Intercept & trend	Intercept	Intercept & trend

LNCO2	1.57219	0.69303	-5.70582***	-5.48362***
LNGDP	-2.58512***	2.41254	-5.08450***	-6.78982***
$LNGDP^2$	-2.39235***	2.40620	-5.17726***	-6.68990***
LNHDI	-3.67460***	-0.18602	-4.59815***	-6.24599***

*10% level of significance, **5% level of significance, ***1% level of significance.

Panel Cointegration Tests

After confirming that the variables are stationary at first difference, the study investigated whether there is cointegration among the variables. For this purpose, two cointegration tests namely Kao and Johansen Fisher panel cointegration tests were conducted in this study. The Hypothesis for the cointegration tests are as follows:

H0 = There is no cointegration relationship

H1 = There is a cointegration relationship

Table 3 shows the results obtained from two cointegration tests. In the Kao cointegration test that was showed in the table 3, the null hypothesis of no cointegration at a 5% significance level was rejected, whereas the Johansen Fisher panel cointegration test showed the null hypothesis of no cointegration at a 1% significance level was rejected. Although both test results implied that the variables are cointegrated, the more appropriate result was obtained from Johansen Fisher panel cointegration test because here the result was significant at 1% level compared to the Kao panel cointegration test where it was found to be significant at 5% level.

Table 3: Panel Cointegration Tests

Kao Cointegration Tests		
	t-statistics	Probability
ADF	-2.133466**	0.0164
Residual Variance	0.001524	
HAC Variance	0.002208	
Note: Automatic lag length selection based on SIC with a max lag of 7		
Johansen Fisher Panel Cointegration Tests		
Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Probability
None	107.0***	0.0000
At most 1	70.06***	0.0000
At most 2	52.74***	0.0000
At most 3	38.18***	0.0014
* Probabilities are computed using asymptotic Chi-square distribution.		

*10% level of significance, **5% level of significance, ***1% level of significance.

Pooled FMOLS Estimation

After confirming that the variables are cointegrated, the next step for this study is to conduct the long-run estimation between dependent variable and independent variables. As mentioned earlier, the CO_2 emissions is the dependent variable while the GDP, Square of GDP and HDI are the dependent variables for this study, the study intends to reveal the effects of GDP, Square of GDP and HDI on CO_2 emissions. In this case the pooled FMOLS model was applied for this estimation. Table 4 explained the results obtained from the estimation techniques. First of all, the results revealed that all the variables are significant at 1% level. Secondly, the result implied that GDP increases CO_2 emissions while the square of GDP and HDI decrease it. The positive effects of GDP and the negative effects of the Square of GDP on CO_2 emissions indicates that there is a quadratic relationship between economic growth and CO_2 emissions. This quadratic relationship implies that there exists an inverted-U relationship between economic growth and CO_2 emissions. Therefore, the result is consistent with the EKC hypothesis where Kuznets claimed that CO_2 emissions increase at the initial time of economic growth but it decreases when the economic growth is relatively higher. In this case the negative effects of human capital on CO2 emissions proved that human capital contributes a lot for keeping the economic growth relatively sustained by reducing CO_2 emissions while keeping economic growth constant.

Table 4: Pooled FMOLS Tests

Regressors	Dependent variable: LNCO2	
	Coefficient	p-value
LNGDP	8.770836***	0.0000
$LNGDP^2$	-0.378728***	0.0000
LNHDI	-4.132625***	0.0000
Adjusted R^2	0.943757	

*10% level of significance, **5% level of significance, ***1% level of significance.

VECM Granger Causality Test

After confirming that all the variables for the study are cointegrated, it was decided to examine the causal relationship among the variables by using VECM granger causality test technique. This test revealed This test shows the Short-run causal relationship based on the F-test and long-run causal relationship based on the lagged error correction term ect(1). Table 5 reviewed the granger causality test results. It showed that there is a short-run unidirectional causality from CO_2 emissions to GDP and from GDP to HDI. The results also showed the long-run bidirectional causality between CO_2 emissions and GDP.

Table 5: VECM Granger Causality test

Dependent Variables	Short-run causality				Long-run causality
	LNCO2	**LNGDP**	**LNGDP^2**	**LNHDI**	**ECT(-1)**
LNCO2	-	8.721052	8.582960	4.062411	5.24155***
LNGDP	36.59409***	-	7.506899	2.569893	1.94713*
LNGDP^2	36.79583***	8.417507	-	2.306522	1.73109*
LNHDI	5.697379	17.85968***	17.57974***	-	-0.60470

*10% level of significance, **5% level of significance, ***1% level of significance.

CONCLUSION AND EVALUATION

Kuznets is the one who invented that there exists an inverted U-shaped relationship between CO2 emissions and economic growth that later on was known as the Environmental Kuznets Curve (EKC) hypothesis. He argued that economic growth increases CO_2 emissions at the initial stage and it reduces after reaching a certain threshold point. The reason is that energy intensity is higher at the initial stage of economic growth and it becomes lower after a certain level. Extending the EKC hypothesis, several researches showed that higher economic growth increased the opportunity of investment for technological development and thereby increased energy efficiency. Furthermore, higher economic growth creates the opportunity of renewable energy production that can be used as an alternative to fossil energy consumption. Here increasing efficiency reduces energy intensity on the one hand, and renewable energy replaces fossil energy that generates more CO_2 emissions. These cause the economic growth to remain constant with generating lower CO_2 emissions. Moreover, some recent studies revealed that human capital can reduce CO_2 emissions and thereby improve environmental quality. Here it was argued that higher economic growth can increase investment for human capital which later on reduces CO_2 emissions by remaining economic growth to be constant. Therefore, human capital can play an important role in ensuring sustainable economic growth by improving the environmental quality.

Although it is obvious that the EKC hypothesis is valid in countries or country groups that are in high income categories, some research revealed that this hypothesis might not be valid in countries or country groups that are in high income categories. The reason is that these countries or country groups are still dependent on fossil energy consumption in the production process despite the economic growth crossing the threshold point. Therefore, it is necessary to reduce the dependence on fossil energy consumption in order ensure sustainable economic growth where lower CO_2 emissions are generated along with constant economic growth. Furthermore, it is also obvious that human capital increases CO_2 emissions in countries that are in high income categories. This also occurs because of the dependency on activities that are not environmentally friendly.

In this study, effects of economic growth and human capital on CO_2 emissions in the 1990-2020 period for eight high income countries were investigated. In this study, the Panel Unit Root test was conducted first to stabilize the series. Panel Cointegration, Panel Long-run Estimation, Panel Cointegration and Panel Causality were then applied. The overall long-run estimation results determined that there exists an inverted U-shaped relationship between CO_2 emissions and economic growth in the selected high income countries that confirmed the validity of the EKC hypothesis for the study. Therefore, the results as a whole implies that all these high income countries are less dependent on fossil energy consumption during the production process which ensures that there exists sustainable economic growth in these countries. Furthermore, the negative effects of human capital on CO_2 emissions implies that human capital in the selected research ensures sustainable economic growth by reducing CO_2 emissions while economic growth remains constant. Lastly, short-run unidirectional causality from economic growth to human capital increased the possibility of investing more in human capital development that can ensure sustainable economic growth in the long-run. It was recommended to do cross-sectional data analysis in the future so that the effects of economic growth and human capital on CO_2 emissions can be investigated in country specific data. This will help to identify the estimation results in each country.

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