Testing the Validity of the Environmental Kuznets Curve in Asian and European Countries: A Panel Data Analysis and an Instrumental Variable Approach

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Abstract

This study examines the validity of the Environmental Kuznets Curve in 30 Asia-Europe meeting summit (ASEM) countries. With panel data from 1990 to 2014, a panel regression and an instrumental variable estimation are carried out to investigate the causal relationship between environmental degradation and economic growth. The findings are in line with the inverse U-shaped relationship proposed by the Environmental Kuznets hypothesis. The results are valid after testing their robustness by adding control variables. Through estimating the turning point of the curve, the paper presents an important value to the policymakers in Asian and European countries. Cooperation between country leaders and policymakers is important to take effective actions towards promoting sustainability.

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I. Introduction

1.1 Sustainable Development

"Too often, sustainability and economic development are viewed as mutually exclusive – yet one does not have to be sacrificed to achieve the other. In fact, in many situations, an investment in sustainability results in positive economic development outcomes, and vice versa."
International Economic Development Council (2017)

Starting from the late 1980s, formal discussions on sustainable economic development have started to become more apparent in economic research projects and government policies in many developing and developed countries (James, Nijkamp, and Opschoor 1989; Fitzgerald 2010; Anand and Sen 2000; Portney 2013). An organizational strategy to bring a sustainability perspective to all features of an institution's policies and activities, through promoting social progress, environmental equilibrium, and economic growth has appeared to be one of the common themes within this literature.

Promoting sustainable economic development is essential. However, for many years in the past, economic growth has been prioritized over environmental well-being. Industrial growth in developing countries causes environmental degradation in the forms of air, soil pollution, water scarcity, and droughts (El Alaoui and Nekrache 2018). Due to deteriorating climate consequences and worsening anthropogenic emissions, governments face the need for sustainability (Fulekar, Pathak, and Kale 2014; Carley and Christie 2017; Wang et al. 2020). Contributing to this literature, this paper will examine this situation in the Asia-Europe meeting summit (ASEM) countries. As ASEM member states represent the majority of the global population, economy, trade, and tourism, it becomes meaningful to examine the causal relationship between environmental quality and economic development in this region to contribute to future policy-making decisions.

1.2. Environmental Kuznets Curve

Estimating the causal relationship between environmental degradation and economic growth is not a new idea. This phenomenon is widely described as the Environmental Kuznets Curve (EKC) that was first proposed by Simon Kuznets in his paper "Economic Growth and Income Inequality" in 1955. Grossman and Krueger (1991) were the first economists to populate the EKC hypothesis. Since then, this idea of estimating the effect of economic development on environmental degradation has been investigated across many low-, lower-middle-, middle-, upper-middle-, and high-income countries (Selden and Song 1994; Stern 2004; Shafik and Bandyopadhyay 1992; Grossman and Krueger 1991).

According to the EKC theory, at early levels of development, countries promote industrial and deforestation activities for manufacturing and agricultural purposes. This effect is often called the scale effect - environmental degradation tends to increase as per capita income increases, fixing other factors constant (Dogan and Inglesi-Lotz 2020). As stricter economic policies, environmental regulations, and technological advancements are implemented to counter the effects of pollution, the economy reaches a certain pollution threshold (He and Lin 2019). After that threshold, environmental degradation decreases as per capita income continues to increase further. An inverse U-shaped relationship is apparent between environmental degradation and economic development.

The hypothesis this paper aims to test is within the framework of the Environmental Kuznets Curve. If the hypothesis holds for the sample economies - Asian and European countries - this would suggest a transition point where the economies are taking actions towards mitigating pollution levels while increasing their economic development. However, if the study is in denial of the EKC hypothesis, it will suggest that economic development does not help mitigate environmental degradation. Moreover, there exists no transition point where this could potentially happen.

The paper is structured as follows. The next section presents the literature review. The third section has data description, summary statistics, and model specification. The fourth section contains the findings and results. The sixth section contains the discussions and conclusions.

II. Literature Review

Following the pioneering studies, researchers with different strategies and methodologies have tested the validity of EKC in many countries and groups of countries. Strictly thinking, it would be impossible to compare previous empirical studies with this paper as they have different samples in terms of countries and periods. However, it would be helpful to review the methodologies as they would provide interesting generalizations and further specify the contribution of this paper to the growing literature to date.

2.1 Time Series Data

Using time-series data, the EKC hypothesis has been confirmed in China (Jalil and Mahmud 2009; Dong et al. 2018), Pakistan (Nasir and Ur Rehman 2011; Shahbaz, Lean, and Shabbir 2012), Turkey (Ozatac, Gokmenoglu, and Taspinar 2017; Pata 2018), India (Shahbaz et al. 2015), Bangladesh (Rabbi, Akbar, and Kabir 2015), Malaysia (Saboori, Sulaiman, and Mohd 2012), and Korea (Baek and Kim 2013). Even though the findings are in line with the EKC relationship, the results are diverse for these countries depending on their geography, population density, trade activities, and political stability. Carbon dioxide emissions are considered as a global pollutant - not local (Işık, Ongan, and Ozdemir 2019; Kanjilal and Ghosh 2013). Compared to other forms of degradation, carbon emissions caused by global anthropogenic activities contribute vastly to the degradation of the natural climate. As international cooperation, financial support, and foreign direct investments help mitigate deteriorating environmental consequences, this paper argues that testing EKC in a group of countries like the ASEM, as opposed to single countries, brings an important knowledge-sharing opportunity to increase international collaborative efforts.

2.2 Panel Data

With fixed effects, random effects, panel regression, and panel cointegration tests, the EKC relationship has been tested in Asian countries (Apergis and Ozturk 2015), Latin American and the Caribbean countries (Al-Mulali, Saboori, and Ozturk 2015), European countries (Ayeche, Barhoumi, and Hammas 2016), North American countries (Anastacio 2017), MENA countries (Omri 2015), and the Middle Eastern countries (Ozcan 2013). Although these studies' panel cointegration tests provide useful information about the short- and long-term relationship between the main variables, most of the panel regression estimations do not provide a realistic or optimistic turning point – a transition point that exists within the sample range. Therefore, my contribution to the literature comes from providing a turning point that exists within the range values of the sample economies.

In addition to this, the above strand of literature does not emphasize the endogeneity problem with environmental degradation and economic growth. Environmental degradation can also affect human health and lower labor productivity. Rising sea levels and changes in rainfall can impact livestock and agricultural productivity. This two-way interconnectedness associated with simultaneity and omitted variable bias has to be dealt with to provide an accurate turning point for the EKC (Begum et al. 2015; Dogan and Inglesi-Lotz 2020; Dogan and Aslan 2017). To address this problem, Paudel et al. (2014) use the total age dependency ratio - the proportion of the population under age 15 and above age 65 relative to the working-age population - and total debt service - repayment and installments as a percentage of GNI - as their instrumental variables. By providing evidence from the European Commission report, I argue that using the old-age dependency ratio will help address the endogeneity problem of the model.

Through these, I aim to expand the state of knowledge that examines the relationship between environmental quality and economic growth.

III. Data and Empirical Specification

3.1 Data

An annual panel data covering the period from 1990 to 2014 is used for this study. 30 Asian and European countries that are partners in the ASEM are used as the sample economies. There are lower-middle-income countries, such as Bangladesh, India, Philippines, Mongolia, and Pakistan; upper-middle-income countries, such as Bulgaria, China, Indonesia, Malaysia, Thailand, and the Russian Federation; and high-income countries, such as Australia, Austria, Cyprus, Denmark, Finland, France, Greece, Ireland, Italy, Japan, the Republic of Korea, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, and the United Kingdom. Even though sample countries closely represent the whole ASEM population, a future research improvement suggests including the missing data to get more robust results. Data from the World Bank Indicators (WDI) and the Global Economy website are used in this study. As an indicator of environmental degradation for dependent variable, carbon dioxide emissions per capita measured in metric tons is used. To indicate economic development, 1-year lagged GDP per capita measured in constant 2010 US dollars is used as the main independent variable. For robustness check, population density, energy consumption, foreign direct investment, forest area, political rights, and civil rights indices are used as control variables in this study.

3.2 Summary Statistics

As seen in Table 1, the lower-middle-income countries had average GDP per capita under 5000 US dollars and carbon dioxide emissions per capita under 6 metric tons. Not only do lower-middle-income countries have lower GDP per capita than upper-middle or high-income countries but they also have increasing rates of carbon dioxide emissions per capita.

Table 1. Summary statistics for lower-middle-income countries

	Carbon Dioxide Per Capita				**GDP Per Capita**			
Country	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Bangladesh	0.27	0.11	0.14	0.48	525	234	293	1,119
India	1.09	0.30	0.71	1.72	726	437	301	1,574
Philippines	0.86	0.09	0.68	1.04	1,448	698	716	2,960
Mongolia	5.09	3.08	3.13	15.14	1,453	1,339	340	4,366
Pakistan	0.80	0.11	0.62	0.95	707	293	372	1,251

Figure 1. CO_2 **per capita and GDP per capita for lower-middle-income countries**

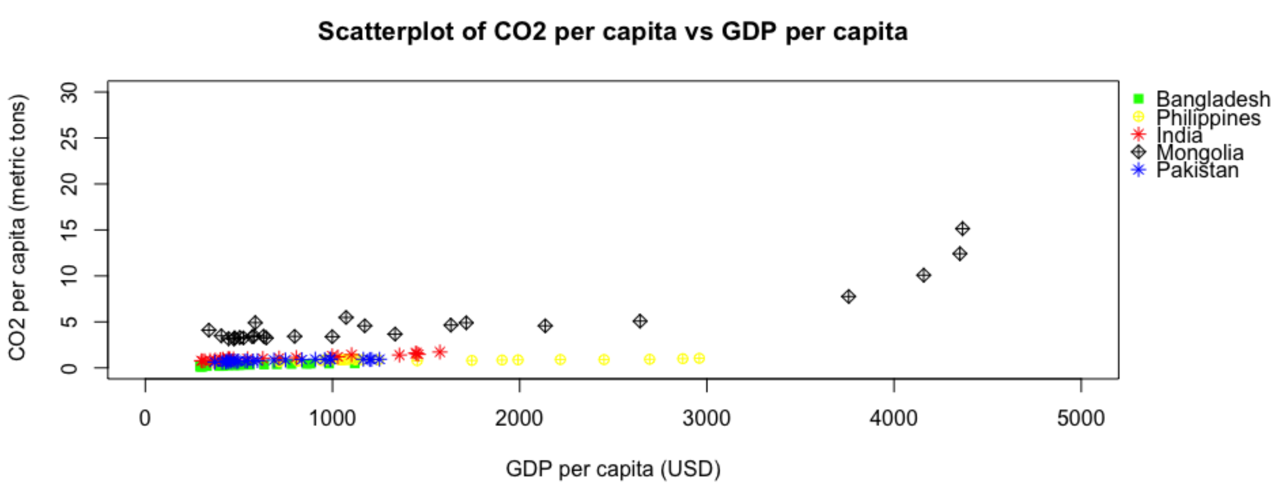


Figure 1 plots the relationship between carbon dioxide emissions per capita and GDP per capita for lower-middle-income countries. From the figure, a positive relationship is apparent. As GDP per capita increases, CO_2 per capita tends to increase.

Table 2. Summary statistics for upper-middle-income countries

	Carbon Dioxide Per Capita				GDP Per Capita			
Country	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Bulgaria	6.34	0.75	5.33	8.54	3,741	2,585	1,148	7,874
China	4.15	1.91	2.15	7.56	2,268	2,279	318	7,679
Indonesia	1.43	0.33	0.82	2.13	1,575	1,094	464	3,694
Malaysia	6.10	1.41	3.14	8.13	5,791	2,829	2,442	11,319
Thailand	3.06	0.74	1.60	4.22	3,219	1,483	1,509	6,168
Russian Federation	12.47	3.57	10.13	24.40	6,089	4,858	1,331	15,975

Table 2 shows the summary statistics of CO_2 per capita and GDP per capita in upper-middle-income countries. The average CO_2 per capita in metric tons varies from 1 to 13. The average GDP per capita in constant 2010 US dollars is from 1500 to 7000. By plotting this relationship, a similar upward trend is shown. Moomaw and Unruh (1997) state that short-term spikes in countries can be due to historic economic shocks and short-term changes in political environments.

Figure 2. CO_2 **per capita and GDP per capita for upper-middle-income countries**

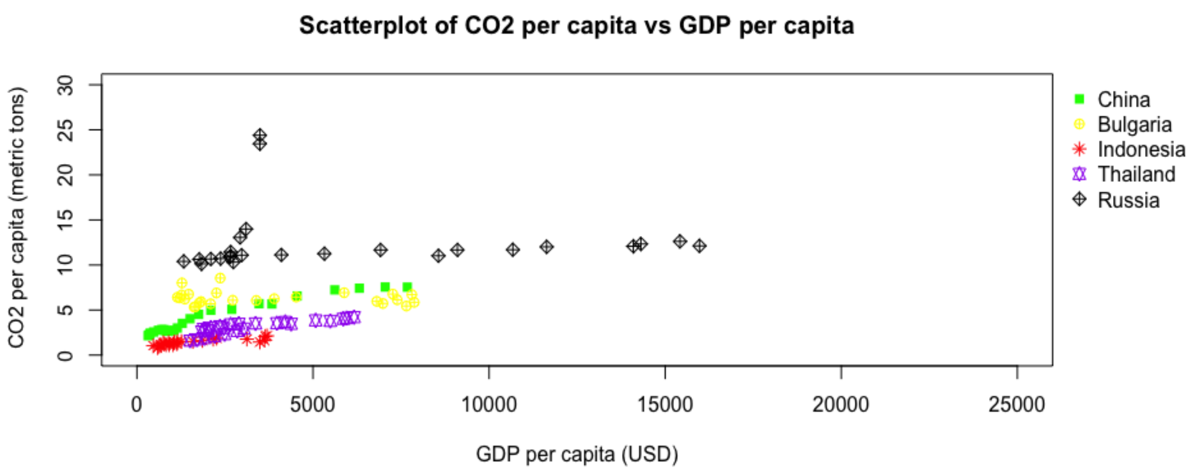
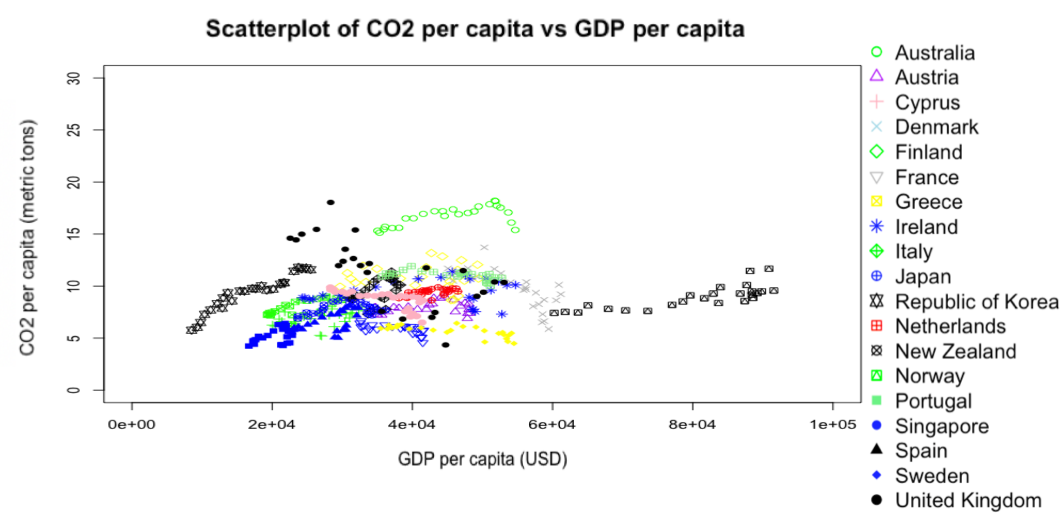


Table 3 shows the summary statistics for high-income countries. The average GDP per capita varies from 10’000 to 80’000 US dollars. The average CO_2 emissions vary from 5 to 20 metric tons. Figure 3 shows an interesting relationship between CO_2 emissions and GDP per capita. An inverse U-shaped relationship is apparent in most countries. In Japan, the Republic of Korea, Sweden, and the Netherlands, the turning point of the EKC curve is seen to be around 10'000 to 30' 000 US dollars.

Table 3. Summary statistics for high-income countries

	Carbon Dioxide Per Capita				GDP Per Capita			
Country	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Australia	16.72	0.95	15.13	18.20	45,230	6,683	35,035	54,679
Austria	7.90	0.56	6.90	8.97	42,067	5,052	33,889	48,172
Cyprus	6.88	0.70	5.20	7.93	26,688	4,022	20,065	32,726
Denmark	9.63	1.85	5.87	13.72	54,428	5,393	44,569	61,175
Finland	10.82	1.20	8.65	13.17	40,352	6,712	29,684	49,441
France	5.84	0.49	4.57	6.67	37,821	3,387	32,524	41,583
Greece	7.88	0.81	6.20	8.98	23,774	3,591	19,304	30,055
Ireland	9.49	1.16	7.30	11.39	41,810	10,577	24,315	54,708
Italy	7.37	0.76	5.27	8.21	34,903	2,331	30,871	38,272
Japan	9.40	0.33	8.63	9.88	42,584	2,444	38,074	46,484
Netherlands	11.01	0.43	10.01	11.92	45,372	5,797	35,703	52,728
New Zealand	7.82	0.54	6.89	8.88	30,367	4,025	23,660	36,185
Norway	8.92	1.13	7.43	11.68	80,282	10,036	60,227	91,566
Portugal	5.24	0.72	4.24	6.41	20,511	2,030	16,668	22,859
Singapore	11.27	3.34	4.34	18.04	36,686	9,269	22,572	53,068
The Republic of Korea	9.33	1.74	5.76	11.80	17,007	5,348	8,496	25,486
Spain	6.52	0.96	5.03	8.10	27,790	3,344	22,513	32,302
Sweden	5.67	0.54	4.49	6.43	45,791	6,860	35,495	54,493
United Kingdom	8.71	0.93	6.50	9.87	35,895	4,738	28,291	41,466

Figure 3. CO_2 **per capita and GDP per capita for high-income countries**



3.3 Model Specification

The standard EKC model is specified as the following:

$$ln(CO_2)_{it} = \alpha_i + \gamma_t + \beta_1 ln(GDP)_{it} + \beta_2 \left(ln(GDP)\right)^2{}_{it} + u_{it} \tag{1}$$

where CO_2 is the carbon dioxide emissions per capita measured in metric tons, α is the parameter that varies across i countries, holding time constant. γ is a parameter that varies across the years. β_1 and β_2 are the coefficients that I aim to estimate. GDP is the lagged GDP per capita measured in constant 2010 US dollars. u is the error term. i lies from $i = 1, \ldots, N$. t lies from $t = 1, \ldots, T$. According to the hypothesis, EKC will hold if $\beta_1 > 0$ and $\beta_2 < 0$. The turning point can be found using the following formula: $\tau = exp\left(\frac{-\beta_1}{\beta_2}\right)$.

To test whether fixed-effects or random-effects models are appropriate, the Hausman test is used. If the Hausman test is rejected at the 5% significance level, a fixed-effects model is preferred to the random-effects (Stock and Watson 2011). The p-value is 0.02295. Therefore, a fixed-effects model is used in this study.

The extended model is then specified as the following:

$$\begin{aligned} ln(CO_2)_{it} = {} & \alpha_i + \gamma_t + \beta_1 ln(GDP)_{it} + \beta_2 \left(ln(GDP)\right)^2{}_{it} + \beta_3 ln(Pop)_{it} \\ & + \beta_4 Energy_{it} + \beta_5 PR_{it} + \beta_6 CR_{it} + \beta_7 ln(FA)_{it} + \beta_8 FD_{it} + u_{it} \end{aligned} \tag{2}$$

Compared to equation 1, the following control variables are added in equation 2:

- Population Density (Pop)

Population density is measured in the number of people per km squared of land area. Areas with high population density are predicted to be more concerned about pollution and have environmentally sustainable policies in place that could lead to reduced carbon dioxide emissions (Apergis and Ozturk 2015).

- Energy Use ($Energy$)

Energy use is measured in kg of oil equivalent per capita. According to the World Bank data description, energy use has been growing rapidly in developing and developed countries. Governments are increasingly paying attention to the sustainable use of these resources.

- Political Rights & Civil Rights (PR, CR)

Political and civil rights indices are measured from 1 (strongest) to 7 (weakest). Lomborg and Pope (2003) and Daspugta and Maler (1995) suggest that variables such as these explain an important part of countries' actions towards environmental protection.

- Forest Area (FA)

According to the World Bank dataset description, forests regulate carbon cycles and mitigate negative climate consequences. Increasing forest cover has become one of the main goals of the United Nations 2017 – 2020 strategic plan.

- Foreign Direct Investment (FD)

Foreign Direct Investment (FDI) measured in percentage of GDP is a source of capital that impacts export activities. According to Pazienza (2015), FDI can lead to environmental degradation in host countries, but more FDI can also promote environmentally sustainable technology that positively affects environmental quality.

4. Findings and Results

The first OLS regression model in Table 4 states the marginal effect of GDP per capita on carbon dioxide emissions per capita. Since the relationship between the main variables is non-linear, marginal effects can be calculated by taking the first-order derivative of the quadratic GDP model. The results are statistically significant at the 1% significance level. The EKC hypothesis states that if $\beta 1 > 0$ and $\beta 2 < 0$, an inverse U-shaped relationship exists. This is valid in regression model 1.

In regression 2 in Table 4, control variables - population density, energy consumption, political rights index, civil rights index, forest area, and foreign direct investment - are added for robustness checks. The statistical significance of the results in regression model 2 and the signs of the coefficients on GDP tell that the EKC hypothesis remains valid.

However, the OLS regression models 1 and 2 assume homogeneity in countries and periods. Therefore, to account for heterogeneity, time fixed effects – unobserved factors that vary within time, holding countries constant, and country fixed effects – unobserved heterogeneity in countries – are added to the regression model 3 in Table 4. Results in regression models 3 and 4 are tested for heteroscedasticity and autocorrelation using Breush-Pagan and Breush-Godfrey/Wooldridge tests in panel models. The null hypothesis of the Breush-Pagan test supports the absence of heteroscedasticity in the data. The null hypothesis in the Breush-Godfrey/Wooldridge test says no autocorrelation. Both hypotheses are rejected at the 5% significance level. Thus, the results in regression models 3 and 4 have been controlled for heteroscedasticity and autocorrelation using robust covariance matrix estimation. In regression model 3, $\beta 1 > 0$ and $\beta 2 < 0$ hold, and results are statistically significant at the 1% significance level.

One of the innovative approaches of this paper is the use of an instrument. Instruments are used to correct simultaneity bias and omitted variable bias. In regression 4 of Table 4, I use the old-age dependency ratio and old-age dependency ratio squared as instrumental variables. The instruments suffice the relevance property of instruments in the first stage least squares regression. I reject the null hypothesis that the instruments are irrelevant at the 5% significance level. The results of the report written by the European Commission support that there is no significant feedback from environmental quality to the aging of the population. Their statistical analysis has proven that elderly generations are generally less mobile. The aging of the population leads to lower consumption in areas such as transport, bringing less pressure on the environment. In addition to this, older people take up new consumption habits slower than other age groups, implying that their effect on environmental quality is not direct, but can only be through GDP. Regression 4 of Table 4 shows statistically significant results at the 1%. $\beta 1 > 0$ and $\beta 2 < 0$ hold, which proves that the EKC hypothesis is valid.

The turning point can be found using the following formula: $\tau = exp\left(\frac{-\beta_1}{\beta_2}\right)$. Using regression 4 results, the turning point for the Asian and European countries that partner in ASEM turns out to be around 11’000 USD which is within the range of values described in tables 1 to 3.

6. Discussions and Conclusions

This study uses the widely investigated Environmental Kuznets framework in Asian and European countries. Additionally, the paper addresses the endogeneity problem and uses robustness checks to verify the inverse U-shaped relationship between environmental degradation and economic growth. The results imply that countries reduce their carbon dioxide emissions when they reach higher levels of development. It could potentially happen because of newly adopted environmental regulations, enhanced demand for a better environment, sustainable change in the services sector, and cleaner use and production of technologies. This paper provides a turning point that falls within the GDP range of the sample economies

The results suggest that once countries move to the high-income range, they can promote their economic growth without exerting pressure on environmental quality, controlling for other factors. Countries that fall below this turning point could be dealing with poverty. Reducing greenhouse gas emissions is costly. However, most high-income countries seem to be growing economically with decreasing rates of greenhouse gas emissions. Thus, collaborative efforts, resources sharing, and technology adoption could support developing countries to mitigate environmental degradation. After adding control variables, the inverse U-shaped relationship was still apparent. Using the old-age dependency ratio and old-age dependency ratio squared as instruments, consistent coefficients were produced.

The study presents several limitations that need careful consideration. First of all, the results of the study depend on the accuracy of the World Bank and the Global Economy data. The estimation considers GDP per capita as the key independent variable of the regression. However, as GDP is correlated with other factors, determining the main driving effect on carbon dioxide emissions becomes difficult. Control variables and an instrumental variable approach are introduced to counter this problem.

Apart from these limitations, this study presents an important value to policymakers in Asian and European countries. Environmental impact is global and greenhouse gas emissions are seen to be increasing year by year. To take effective actions towards promoting sustainability, cooperation between country leaders and policymakers comes into major play. More developed countries have a crucial role in this cooperation since they are predicted to have more resources and knowledge than other developing countries. Thus, this study invites future research to investigate the contribution of developed and developing countries in reducing global emissions.

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Appendix

Table 4. Regression Results

	Dependent Variable: $ln(Carbon\ Dioxide\ Emissions)$			
	OLS (1)	OLS (2)	FE (3)	IV (4)
$ln(GDP\ per\ capita)$	3.042^{***}	3.044^{***}	2.959^{***}	3.503^{***}
	(0.151)	(0.123)	(0.481)	(0.540)
$(ln(GDP\ per\ capita))^2$	-0.147^{***}	-0.163^{***}	-0.153^{***}	-0.188^{***}
	(0.009)	(0.007)	(0.026)	(0.033)
$ln(Population\ Density)$		0.313^{***}	0.469^{**}	0.422^{**}
		(0.078)	(0.189)	(0.212)
$Energy\ Use$		0.0003^{***}	0.0002^{***}	0.0003^{***}
		(0.00002)	(0.0001)	(0.0001)
$Political\ Rights\ Index$		-0.034^{***}	-0.033^{*}	-0.036^{*}
		(0.007)	(0.019)	(0.019)
$Civil\ Rights\ Index$		0.047^{***}	0.048	0.057
		(0.013)	(0.035)	(0.038)
$ln(Forest\ Area)$		0.049	0.070	0.148
		(0.098)	(0.153)	(0.221)
$Foreign\ Direct\ Investment$		-0.00002	-0.00003	-0.00003
		(0.0001)	(0.0001)	(0.0001)
Country Fixed Effects	no	no	yes	yes
Time Fixed Effects	no	no	yes	yes
Robust SE	no	no	yes	yes
Observations	720	720	720	720
R^2	0.515	0.686	0.667	na
Adjusted R^2	0.493	0.668	0.636	na

Note:

* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level