REASSESSING THE ENVIRONMENTAL KUZNETS CURVE: THE SQUARED-TERM IMPACT OF GLOBALIZATION ON ENVIRONMENTAL QUALITY IN DEVELOPING ECONOMIES

Kanwal Younas [1], Dr. Noreen Safdar [2]
[1]*PhD Scholar, The Women University Multan, Punjab, Pakistan*
Corresponding Author: Kanwal Younas
Email address: kanwalyounas75@gmail.com
[2]*Assistant Professor, The Women University Multan, Punjab, Pakistan*
Email address: noreen.safdar@wum.edu.pk

ABSTRACT

This study reassesses the Environmental Kuznets Curve (EKC) by exploring the squared-term effect of globalization on environmental quality in developing economies using panel data from 2000–2024. Environmental quality is proxied by ecological footprints, while economic growth is represented by per capita income. Human development is measured using the United Nations Development Programme's Human Development Index (HDI), and globalization is captured through the KOF Globalization Index (KOFGI). To ensure robustness, foreign direct investment (FDI) and financial development are included as control variables. The analysis employs the Generalized Method of Moments (GMM) estimator to address potential endogeneity.

Findings reveal a positive and significant lagged effect of globalization on ecological footprints, indicating that globalization initially degrades environmental quality in underdeveloped nations. However, the squared-term of globalization has a negative and significant impact, confirming an inverted U-shaped EKC relationship. This implies that while globalization initially harms the environment, its effects become beneficial after surpassing a certain threshold. Moreover, improvements in human development are shown to enhance environmental awareness and contribute positively to environmental quality over time.

Keywords: Ecological Footprint, Globalization, Economic Growth, Financial Development, Foreign Direct Investment, Human Development Index, GMM

Introduction

In the 21st century, globalization is the main factor that is transforming the world (Mosoh et al., 2024). It changes how economies work, how communities are connected, and how governments handle their natural resources (Matenda et al., 2024). Many countries' economies have gotten better because of globalization, especially those in the developing world. However, there is a lot of disagreement about how it affects the environment and public health, and how the benefits should be shared. Globalization, economic growth, environmental health, and human progress all have many complex effects on each other (Rasool et al., 2024). This is especially clear in developing countries, where protecting the environment and growing the economy are at odds with each other (Y. Khan & Hassan, 2024).

In the field of development economics, the "Environmental Kuznets Curve" (EKC) and the link between economic growth and natural health are important topics. Rich countries can get better technologies, make sure that environmental rules are followed, and switch to businesses that use fewer resources (Grossman et al., 1991).

There are still disagreements about how useful EKC is for developing countries. In many low- and middle-income countries, economic growth has not greatly improved the health

of the environment (Kuziboev et al., 2024). Large changes in the environment have often happened because of fast growth and development (de Souza & Weaver, 2024). Pollution levels are rising in cities like Delhi, Mexico City, and Jakarta, mostly because of pollution from cars and factories (World Bank, 2023).

In developing countries where environmental damage is getting worse, the lack of strong environmental laws and police systems makes things worse (Arora, 2024). Countries that put economic growth ahead of environmental problems may cut down on trees and wildlife to get to natural resources quickly, which can lead to unsustainable use of land and water and the loss of biodiversity (Raihan, 2023). Many developing countries are worried about the long-term stability of growth because of the possible effects of climate change, which will mostly hurt weak communities in the Global South (Rehman et al., 2024).

The globe is being more polluted, and the climate wants needful measure-ments using financial globalization support and using green innovation, these two aspects are being used in developed countries for reduction of emission. On the other hand, human Capital, financial risk, and income also affect the environmental condition towards improve. Financial risk should be taken in green innovation for achieve the sustainability and environment improvement (J. M. Chen et al., 2024).

Due to the increase in carbon dioxide emissions, developing nations are confronted with the problem of environmental degradation. Global warming has been caused by deforestation, which has resulted in forests being depleted. The state of the environment is also being impacted by the process of industrialization.

In an ecosystem the biodiversity found there all habitant human and other living organism live. In result of Human activities, as industrialization, other technology production in modern way, will makes the environment worse. Clean Water and air are polluted badly. Somehow the economic growth increase by using the new technology on the other hand the environment also decline (Edo et al., 2024)

Literature Review

This hypothesis asserts that environmental degradation first increases with economic expansion but later declines after reaching a certain income level. This hypothesis demonstrates the relationship with globalization, as it fosters growth; yet, its environmental consequences depend on whether nations are on an ascending or descending path on the Environmental Kuznets Curve (EKC). Theory suggests that technological advancement and increased environmental awareness at higher income levels lead to enhanced environmental policies (Dinda, 2004).

Aziz et al. (2024) examined the effects of globalization on environmental quality. They employed the usual EKc to establish the relationship between globalization, economic performance, and energy consumption on environmental quality. Panel of GCC countries were taken as sample to establish the relationship among the scrutinized variables. Results of the study declared the existence of significant relationship between the variables. According to them globalization has significant effect on environment through foreign direct investment inflows. The results suggested that globalization has adverse effect on environmental quality. Contrarily, renewable energy consumption has positive significant effect in mitigating the environmental degradation. Further, the agricultural impact on economic growth was also investigated. The results suggested that agriculture did not have any significant impact on both economic growth and environmental quality in most of the

GCC countries. Despite their participation in globalization, countries like Saudi Arabia, Oman, and the United Arab Emirates had a negative relationship with economic growth, according to a cross-country analysis.

kunimitsu, (2024) examined the relationship between globalization and environment by using computer experiment. The study utilized the regional aggregation's method bias. Further the GTAP10 database with general computable equilibrium applied pre aggregation models. The direction of relation reversed in the case of developing countries and due to high imports, the strength of association intensified. A major percentage of the regional aggregation bias was artificially manufactured by grouping countries that experienced initial shocks that were different from one another, and then spreading to other countries through a framework that was based on pseudo-trade arrangements. Based on the findings of the study, it was concluded that the implementation of a disaggregated global model is necessary to improve the accuracy of climate change assessments in the face of a variety of global shocks.

Çetin et al., (2023) examined the effects of environmental contamination caused by globalization in 14 developing economies between 1991 and 2018. "How do factors like urbanization, financial development, economic growth, and the use of renewable energy affect the ecological footprint?" was the goal of the study. ng this indicator of pollution. For long-term forecasting, the study utilized FGLS, PCSE, Driscoll-Kraay, and AMG forecaster. In addition, the Dumitrescu-Hurlin panel bootstrap causality test examined potential causal links between variables. Co-integration was supported by the long-term association of the factors. The results of the study suggested that economic growth and financial development have positive significant effects on environmental degradation. Contrarily, globalization and renewable energy consumption have negative significant impact on degradation. These findings suggested that globalization and energy consumption are helping to mitigate the adverse effects on environmental quality.

Awad & Saadaoui Mallek, (2023) investigated the relationship between globalization and environmental quality. Panels forty-four sub-Saharan countries were taken to establish the relationship. Moderate effect relationships were also examined to measure the joint effect of digitalization and globalization on environmental quality. Joint effect measured that digitalization helps in to mitigate the adverse effect of globalization on environmental quality or exaggerate it. The data demonstrated that, when examined separately, both globalization and digitalization had a direct negative effect on ecological quality. Additionally, the study concluded that digitalization services have the capacity to compensate for the negative ecological effects of globalization. The overall effect of the link between digitalization and globalization remained negative, albeit somewhat, despite this modest factor.

A recent study by Rahman et al., (2024) examined the relationship between globalization and environmental performance in BRICS countries. Dynamic econometric techniques were employed to quantify the relationship. Results indicated that globalization has positive significant impact on environment through the application of renewable energy consumption. While the application of nonrenewable energy consumption exploiting the effect of globalization on environment. The study designated that political and economic globalization has a significant positive effect on economic growth of the selected economies. Contrarily, social globalization has insignificant effect on globalization.

Results suggest that improved governance, economic globalization and foreign capital inflows are important drivers of economic growth.

This hypothesis asserts that environmental degradation first increases with economic expansion but later declines after reaching a certain income level. This hypothesis demonstrates the relationship with globalization, as it fosters growth; yet, its environmental consequences depend on whether nations are on an ascending or descending path on the Environmental Kuznets Curve (EKC). Theory suggests that technological advancement and increased environmental awareness at higher income levels lead to enhanced environmental policies (Dinda, 2004).

Therefore, the following 'proximate factors' explain the EKC:

1. The scale of production denotes the augmentation of output while preserving a consistent combination of products, production inputs and technological conditions (Stern, 2004).
2. Diverse industries display varying levels of pollution intensity, and often, during economic development, the product composition changes. (Hettige et al., 2019).
3. Changes in the input mix involve substituting inputs that are less environmentally hazardous with those that are more deleterious and vice versa.
4. Technological advancements include alterations in both:
   a. Production efficiency denotes the decrease in polluting inputs per unit of output, presuming all other variables remain unchanged.
   b. Modifications particular to the process result in a decrease in pollutants emitted per unit of input.

Economists typically refer to the third and fourth components as the technique impact (Murty and Russell, 2020).

The result implies that holding either parameter constant prevents the manifestation of an Environmental Kuznets Curve (EKC), which shows an initial increase in pollution followed by a subsequent decrease. We can categorize theoretical models into two groups: those where fluctuations in the elasticity of substitution during economic expansion influence the Environmental Kuznets Curve (EKC), and those where changes in the elasticity of marginal utility primarily influence the EKC (Stern, 2017).

Assumptions made by dynamic iterations of the EKC about the impact of institutions on environmental quality vary, making it difficult to summarize the outcomes. By integrating the concept that production generates pollution, Brock and Taylor's model enhances Solow's (1956) economic development framework, suggesting that allocating a segment of final output to pollution control initiatives can alleviate this pollution. The model posits that the emission levels of nations will eventually converge; however, emissions in developing countries may initially rise due to vigorous economic growth before later decreasing (Wang and Su, 2020).

While the projections of the Green Solow model seem plausible in light of contemporary empirical evidence, as discussed below, it is not an entirely adequate framework for comprehending the dynamics of the economy and emissions. It initially assumes that the ratio of reduction in manufacturing costs remains stable, along with other implicit assumptions about the model. Secondly, there is a negligible correlation between the initial per capita income levels of countries and their rates of development, which promotes

income (Brock and Taylor, 2010). Static models seem to implausibly assume that economic activities effectively internalize pollution externalities (Dahlman, 1979).

Technological advancement and economic progress can mitigate environmental damage. Globalization promotes sustainable technologies, global environmental agreements, and resource optimization. Market-driven incentives and international environmental governance promote sustainable behavior (Choy, 2007).

Model Specification:

To derive the first model related to the environmental consequences of globalization we utilized the Stochastic impact by regression on population, affluence, and technology (STIRPAT). This model generally, used to check the socio-pecuniary effects on environmental quality (Ayad et al., 2023; Korkut Pata et al., 2022; Manocha, 2023; Usman et al., 2022; Yu et al., 2023). The model can be written as:

$$ECFP_{it} = \rho_1 ECFP_{it-1} + \rho_2 GLOZ_{it} + \rho_3 GDP_{it} + \rho_4 FDI_{it} + \rho_5 FD_{it} + \rho_6 HDI + \pi_t + \mu_{it} \quad (1)$$

The basic model presented in equation 1 establishes the relationship between environment and globalization. Where,

ECFP ➔ proxy for Environment that is ecological footprints

GLOZ ➔ proxy to measure globalization. Koff Globalization index taken to capture its effect

GDP ➔ Gross domestic product measure of economic performance and affluence

FDI ➔ represents foreign direct investment

FD ➔ financial development indicator. We measure it through domestic credit to private sector

HDI ➔ Human development index

i➔ cross sections/countries

t ➔ time from 2000 to 2024

Here all the variables are expressed in logarithmic form so that can be interpreted as elasticities. Model presented in equation one establishes the linear form relationship between GLOZ and ECFP. We are also interested in originating the shape of environmental Kuznets curve (EKC) based on GLOZ (EKC-GLOZ) by introducing the squared term of GLOZ as presented in equation 2.

$$ECFP_{it} = \rho_1 ECFP_{it-1} + \rho_2 GLOZ_{it} + \rho_3 GDP_{it} + \rho_4 FDI_{it} + \rho_5 FD_{it} + \rho_6 GLOZ^2_{it} + \rho_7 HDI + \pi_t + \mu_{it} \quad (2)$$

Where,

$GLOZ^2$➔ Squared GLOZ term introduced in equation 2 to capture the validity of EKC based on globalization.

To capture the effect of globalization on macroeconomic performance of developing countries we have the following choice of indicators like we can choose from the inflation, gross domestic product per capita, unemployment by following (Ekren et al., 2017). Among all these indicators we have selected the gross domestic product per capita to measure the economic position of the developing countries.

Description of all variables used in all four models their definitions; sources of data collection are presented in table.

Table
Description of Variables Used

Proxy	Definition	Data Source
ECFP	Ecological footprints measure of environmental quality of a country	Global Footprint network[1]
GLOZ	Globalization and to measure it KOFF globalization index used	Swiss Economic Institute[2]
FDI	Foreign direct investment (Net inflow)	World Development Indicators (WDI)
GDP	Growth rate of GDP per capita	WDI
FD	Financial development measured using domestic credit to private sector	WDI
HDI	Human development Indicator Index	United Nation Development Program (UNDP)

Data Estimation

An empirical assessment of how globalization has affected the environment. Descriptive statistics, correlation coefficients, and variance inflation factors are among the pre-estimation diagnostics used to verify the nature of the data at the beginning of the chapter. Additionally, econometric tests such as endogeneity, autocorrelation, heteroscedasticity, and cross-sectional dependence were used. We have used the GMM estimating system to assess the relationship between globalization and environmental quality for all developing countries, based on the findings of the pre-diagnostic test suggestions from econometrics and statistics.

Statistical Estimation

Cross – Sectional Dependence (CSD)

Upon analyzing the statistical concerns of the data, it is imperative to verify the presence of any econometric issues that could lead to the estimation of false regression. Prior to estimating coefficients, it is essential to verify the feasibility of conducting first-generation and second-generation econometric tests. To address this inquiry, it is essential to first ascertain the presence of cross-sectional dependence (CSD) among the cross sections. To evaluate the Pesaran, Friedman, and Frees tests, selection is based on the chosen panels and the number of years. The outcomes of the CSD test are displayed in Table 1.1.

Table: 1.1		
Cross-Sectional Independence		
Test	**Statistics**	**Results**
Pesaran	12.61*	Cross-Sectional Dependence

Friedman	16.86*	Cross-Sectional Dependence
Frees	15.83*	Cross-Sectional Dependence
*** p<0.01, ** p<0.05, * p<0.1 Null Hypothesis: No Cross-Sectional Dependence		

The findings of Pesaran, Friedman, and Frees indicated the presence of cross-sectional dependence among the chosen panels..

Second Generation Unit Root Test

Table: 1.2				
2nd Generation Unit Root Test				
Variable	Test	At Level	At First Difference	Conclusion
ECFP	CIPS	-1.42	-2.17*	I (1)
	CADF	-1.75	-2.07*	
KOFGI	CIPS	-1.41	-3.72^*	I (1)
	CADF	-1.39	-2.87^*	
PCIG	CIPS	-2.070	-3.62^*	I (1)
	CADF	-2.01	-3.59^*	
FDI	CIPS	-1.65	-5.93^*	I (1)
	CADF	-2.61	-7.19^*	
FD	CIPS	-1.93	-6.03^*	I (1)
	CADF	-2.71	-4.53^{***}	
HDI	CIPS	-1.54	-8.28^*	I (1)
	CADF	-3.54	-7.21^*	
*** p<0.01, ** p<0.05, * p<0.1				

The outcomes of the CIPS and CADF unit root tests indicated that all variables are non-stationary at their levels, although they attain stationarity upon taking the first difference. Proposing the application of cointegration tests for further progress.

The Wald test for groupwise heteroscedasticity was employed to examine the issue of heteroscedasticity in the collected data. The test results are displayed in Table 1.3. The null hypothesis for this test posits the presence of homoscedasticity

Wald Test for Group-wise Heteroscedasticity

Table: 1.3						
Wald Test for Group-wise Heteroscedasticity						
ECFP	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
KOFGZ	3.66	1.05	3.47	0.001	15.94	5741759
PCIG	4.96	1.842	2.69	0.007	13.50	8574845
HDI	2.20	1.44	1.53	0.126	-6.18	5.03e+08
FDI	2.17	6.03	1.46	1.51	-2.75	4.90

FDv	1.12	3.13	0.58	0.242	-2.34	3.71
Cons.	6.23	9.04	0.69	0.491	-1.15	2.40

F test that all u_i=0: F(99, 2397) = 73.19   Prob > F = 0.0000

Modified Wald test for groupwise heteroskedasticity

in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (100) =   6.0e+07

Prob>chi2 =   0.0000

Wooldridge Test for Autocorrelation

The Wooldridge test was employed to ascertain the presence of autocorrelation. The outcomes of the chosen test are presented in table 1.4. The null hypothesis for the test posits the absence of autocorrelation. The results indicated the rejection of the null hypothesis, so demonstrating the presence of autocorrelation. It is essential to evaluate this conclusion prior to choosing the most appropriate econometric method for estimating regression coefficients.

Table: 1.4

Wooldridge Test for Autocorrelation

D. **ECFP**	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
KOFGZD1.	-979237.3	1200178	-0.82	0.417	-3360652	1402177
PCIGD1.	268432.3	499925.1	0.54	0.593	-723527.6	1260392
HDID1.	6156615	1.18e+07	0.52	0.603	-1.72e+07	2.96e+07
FDvD1.	-650685	420864.6	-1.55	0.125	-1485772	184401.6
FDID1.	2327406	2823228	0.82	0.412	-3274491	7929303

Wooldridge test for autocorrelation in panel data

H0: no first-order autocorrelation

   F(1, 99) =   751.014

 Prob > F =   0.0000

Westerlund ECM panel cointegration

In addition, before moving forward, it is essential to determine whether the variables that have been suggested are included in the cointegration analysis. In table 1.5, the results of the test are displayed. The null hypothesis that there was no cointegration was rejected by three out of the four tests examined. indicating that there is a cointegration occurring between the variables that were chosen.

Table: 1.5

Westerlund ECM panel cointegration

Statistic	Value	Z-value	P-value
Gt	-1.640	8.945	0.003
Ga	-4.622	10.867	0.010
Pt	-8.224	14.749	0.000
Pa	-0.572	13.635	1.000

| Average AIC selected lag length: 3 |
| H0: no cointegration |

Tests of endogeneity

The endogeneity problem, which occurs when the exogenous factors become correlated with the error term, is the most significant problem that needs to be addressed when working with a large panel. In other words, the rejection of the premise of exogeneity is made by classical linear regression. Durbin Chie Square and Wu Hausman F-Statistics are the two tests that have been devised to check for the problem. The assumption that the variables are exogenous acts as the test null hypothesis. The results of the endogeneity test are provided in table 1.6. Both tests confirmed that the null hypothesis should not be accepted and raised the possibility that endogenous factors are present. This indicates that we are required to use the instrumental variables approach to measure the relationship between the variables that have been specified for the model.

Table: 1.6

Tests of endogeneity		
Test	**Statistics**	Probability
Durbin (score) chi2(1)	52.1312	0.0000
Wu-Hausman F (1,2495)	53.1349	0.0000
Ho: Variables are exogenous		

GMM Estimation

Generalized Method of Moment (GMM), are some of the options that are available to us when dealing with non-stationary variables. Based on these findings, the PMG, Fixed/Random effect, and cointegration tests were rejected in order of the coefficients while we were dealing with the problem of heteroscedasticity. Considering the endogeneity problem, every conceivable alternative of econometric methodologies was unsuccessful, except for the instrumental variable method (GMM). Generalized Method of Moment (GMM) is used to estimate the relationship among selected variables. The results of the GMM estimation are given in table 1.7.

Table: 1.7

GMM Estimation					
ECFP	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**Sig**
ECFP_lag1	0.97	0.00	1.40	0.000	***
KOFGI	0.03	0.02	1.50	0.000	***
FD	0.10	0.03	3.01	0.000	**
PCIG	0.05	0.002	35.72	0.000	**
FDI	0.15	0.10	1.46	0.000	***
HDI	-0.35	0.01	-31.44	0.000	**
Constant	2.36	0.07	29.74	0.000	**
Arellano-Bond test for AR (1) in first differences: z = -2.22 Pr > z = 0.026					
Arellano-Bond test for AR (2) in first differences: z = -0.63 Pr > z = 0.529					
Sargan test of overid. restrictions: chi2(183) = 580.47 Prob > chi2 = 0.897					

Hansen test of overid. restrictions: chi2(183) = 98.81 Prob > chi2 = 1.000
Hansen test excluding group: chi2(91) = 98.59 Prob > chi2 = 0.275
Difference (null H = exogenous): chi2(92) = 0.22 Prob > chi2 = 1.000

Results in table 1.7 indicate that lag value of dependent variable coefficient has positive significant relationship with its current value. As the one percent change in preceding value of ecological footprints brings 0.97 percent change in current value of ecological footprint. These results indicated and supported the inertia effect that suggested that current value of any variable is dependent on its preceding value. The same results are observed in this case. The existence of inertia effects is justified based on previous research (M. A. Khan et al., 2024; Nuta et al., 2025; Shams et al., 2024; Ze et al., 2023).

Next questioned variable globalization coefficient is reported positive and significant. The result indicates that one percent change in globalization brings 0.03 percent increase in ecological footprint. These results suggest that in developing countries globalization has deteriorating environmental effects. Results are supported by the previous studies (Andrew et al., 2024; Awad & Saadaoui Mallek, 2023; Latif, Rafeeq, Safdar, Liaquat, et al., 2023; Law et al., 2018; Chunhong Zhang et al., 2022).

The financial development coefficient has shown positive significant relationship with the ecological footprints. As results show, one percent change in financial development brings 0.10 percent change in ecological footprints. Financial development can affect the environment through three indicators. These results are justified based on previously presented studies (Ding et al., 2022; Khan et al., 2022.; Law et al., 2018; Xue & Zhang, 2022; Zhang, 2011; Zhou et al., 2022). These results are opposed by the studies that suggested that financial development can improve the environmental quality of the country through the use of green technology and environmental friendly techniques (Chen et al., 2024).

Economic growth indicators showing the positive significant relationship with environmental quality showing that one percent change in economic growth brings 0.05 percent change in ecological footprints. (Aneja et al., 2024; Aydin & Degirmenci, 2024; Balsalobre-Lorente et al., 2023; Latif, Rafeeq, Safdar, Younas, et al., 2023; Shahbaz & Patel, 2025; Wang et al., 2024). Foreign direct investment coefficient is positive significant relationship with ecological footprints (Adebayo et al., 2024; Jahanger et al., 2022; Murshed et al., 2022; Opeyemi et al., 2024; Wang et al., 2024)..Human development indicators show that the negative significant effect on ecological footprints suggesting that one percent change in HDI brings 0.35 decrease in ecological footprints. (Fakher, 2019; Onwe et al., 2024; Suchi et al., 2024).

Impact of Globalization on Environment: Validation of EKC

The purpose of this section is to provide an empirical assessment to check the validity of usual Environmental Kuznets Curve based on globalization. In this section we are enthusiastic to check how globalization has affected the environment by introducing squared term in the previously estimated model. We have used the GMM estimating system to assess the relationship between globalization and environmental quality for all developing countries, based on the findings of the pre-diagnostic test suggestions from econometrics and statistics.

Cross-Sectional Dependence

After statistical estimation the first step of econometric estimation is to check for the cross-sectional dependence. All three tests suggested the rejection of null hypothesis of cross-sectional independence.

Table: 2.1		
Cross Sectional dependence		
Test	**Statistics**	**Results**
Pesaran	4.31*	Cross-Sectional Dependence
Friedman	83.73*	Cross-Sectional Dependence
Frees	17.85*	Cross-Sectional Dependence
*** p<0.01, ** p<0.05, * p<0.1 Null Hypothesis: Cross-Sectional Independence		

Second Generation Unit Root Test

The first important step is to check the stationarity of the variables. 2nd generation CIPS & CADF tests are applied on all the selected variables in the model to check the validation of EKC based on globalization. The squared globalization is integrated of order one I (1). All other included variables are also having the stationarity property after taking their first difference suggesting that we can proceed further towards the cointegration analysis.

Table: 2.2				
2nd Generation Unit Root Test				
Variable	Test	At Level	At First Difference	Conclusion
ECFP	CIPS	-1.42	-2.17*	I (1)
	CADF	-1.75	-2.07*	
KOFGI	CIPS	-1.41	-3.72^{**}	I (1)
	CADF	-1.39	-2.87^{*}	
PCIG	CIPS	-2.070	-3.62^{*}	I (1)
	CADF	-2.01	-3.59^{***}	
FDI	CIPS	-1.65	-5.93^{*}	I (1)
	CADF	-2.61	-7.19^{*}	
FD	CIPS	-1.93	-6.03^{*}	I (1)
	CADF	-2.71	-4.53^{***}	
HDI	CIPS	-1.54	-8.28^{*}	I (1)
	CADF	-3.54	-7.21^{**}	
$KOFGI^2$	CIPS	-1.39	-6.19^{*}	I (1)
	CADF	-1.39	-4.61^{*}	
*** p<0.01, ** p<0.05, * p<0.1				

Wald Test for Group-wise Heteroscedasticity

But before moving further and choosing the best econometric technique it's also important to check for heteroscedasticity and autocorrelation. Wald test for groupwise heteroscedasticity and Wooldridge test for panel autocorrelation applied. Results of Wald

test are reported in table 2.3 and Wooldridge test are presented in table 2.4. Results suggested that the existence of both heteroscedasticity couple with the autocorrelation.

Table: 2.3

Wald Test for Group-wise Heteroscedasticity							
ECFP	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
KOFGI	-5.92	5.23	-11.33	0	-6.95	-49036377	***
PCIG	5.16	1.81	2.84	.005	1.60	8727090.3	***
FDI	-0.01	0.04	-3.16	.002	-0.02	-.005	***
FD	-3.73	6.84	-0.61	.54	-1.56	820024.59	
HDI	2.68	1.40	1.91	.057	-7.50	5.437e+08	*
KOFGI^2	5.87	4.84	12.24	0	4.98	688216.87	***
Constant	1.56	1.479	10.61	0	1.279	1.859e+09	***
*** p<.01, ** p<.05, * p<.1 Modified Wald test for groupwise heteroskedasticity in fixed effect regression model H0: sigma(i)^2 = sigma^2 for all i chi2 (100) = 6.3e+06 Prob>chi2 = 0.0000							

Wooldridge Test for Autocorrelation

Table: 2.4						
Wooldridge Test for Autocorrelation						
D. **ECFP**	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
KOFGID1.	-2.82	1.78	-1.59	0.11	-6.35	7.07
PCIGD1.	3.50	4.98	0.70	0.48	-6.38	13.78
HDID1.	2.49	1.33	0.72	0.476	-1.68	3.58
FDvD1.	-5.83	3.79	-1.53	0.128	-13.36	1.70
FDID1.	-0.01	0.15	-0.60	0.54	-.3.90	0.02
KOFGI²D1.	2.82	1.84	1.53	0.13	8.48	-6.49
Wooldridge test for autocorrelation in panel data H0: no first-order autocorrelation F(1,99) = 901.021 Prob > F = 0.0000						

Westerlund ECM panel cointegration

The Westerlund cointegration test results presented in table 2.5. This is the 2nd generation test designed to check for the existence of cointegration among the suggested variables. This test comprises of four tests Gt, Ga, Pt, & Pa. Three out of four tests suggested the existence of cointegration among the selected variables.

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Table: 2.5

Westerlund ECM panel cointegration

Statistic	Value	Z-value	P-value
Gt	-1.58	9.57	0.001
Ga	-4.54	10.97	0.003
Pt	-7.47	15.61	1.000
Pa	-0.55	13.66	0.000

Results for H0: no cointegration
With 100 series and 1 covariate
Average AIC selected lag length: 3
Average AIC selected lead length: 3

Tests of endogeneity

Both tests suggested that the absence of exogeneity means that endogeneity. This issue must be kept in mind while selecting the best econometric technique to estimate the coefficients.

Table: 2.6

Tests of endogeneity

Test	Statistics	Probability
Durbin (score) chi2(1)	62.01	0.0000
Wu-Hausman F(1,2495)	63.44	0.0000
Ho: variables are exogenous		

GMM Estimation

The estimation results for the validation of EKC based on globalization are presented in table 2.7.

Table: 2.7

GMM Estimation

ECFP	Coef.	St.Err.	t-value	p-value	Sig
ECFP_LAG1	0.973	0	8843.79	0	***
HDI	-0.33	2.85	-11.87	0	***
KOFGI	0.07	5.6	12.51	0	**
PCIG	0.32	3.49	92.46	0	**
FD	0.41	7.08	58.57	0	***
FDI	0.09	0.76	-150.43	0	**
$KOFGI^2$	-0.09	5.42	-17.38	0	**
Turning Point	**0.39**				
Marginal Effects	Minimum			-2.63	
	Mean			-9.16	
	Maximum			16.31	
Arellano-Bond test for AR(1) in first differences: z = -2.23 Pr > z = 0.026					

Arellano-Bond test for AR(2) in first differences: z = -0.90 Pr > z = 0.368
Hansen test excluding group: chi2(89) = 96.70 Prob > chi2 = 0.271
Difference (null H = exogenous): chi2(92) = 260.49 Prob > chi2 = 0.000
Hansen test excluding group: chi2(177) = 127.04 Prob > chi2 = 0.998
Difference (null H = exogenous): chi2(4) = 230.15 Prob > chi2 = 0.000
*** p<.01, ** p<.05, * p<.1

As this model is the extension of the previous estimated model having all the indicators included and estimated in the previous model except the squared term of globalization indicator. This model is designed to check the validation of environmental Kuznets curve based on globalization by introducing the squared term of globalization. The squared term of globalization has the negative significant effect of ecological footprints suggesting the validation of inverted u shape environmental Kuznets curve. This coefficient suggested that in its linear form it has the adverse effect of environment and in its squared form it has improving effect on environment. As the one percent change in squared globalization brings 0.09 percent decrease in ecological footprints. These results verified that after a certain level of increase in globalization its negative effect on environment turns out to be positive effect. To check that turning point we have partially differentiated this equation with respect to globalization and by considering the mean, maximum and minimum values of globalization index we have calculated the marginal effect. We have calculated the turning point in this model, that is0.39,9 meaning that as globalization achieves the level of 0.39 percent its negative effect on environment turns out to be positive. Suggested that developing countries should increase globalization up to the 0.39 level so that globalization will reduce the environmental degradation. Results are supported by the studies previously check the validation of usual environmental Kuznets curve based on different economic indicators (Balsalobre-Lorente et al., 2023; Islam et al., 2023; Latif, Rafeeq, Safdar, Younas, et al., 2023; Shahbaz & Patel, 2025). Remaining results are similar as discussed previously in detail.

Results & Discussion

Measurement of objective requires checking the effect of globalization and HDI on environmental quality. For this purpose, linear and nonlinear forms of globalization indicators are utilized to capture the comprehensive effect of globalization on environment. This yields the same results. Inertia effects are supported by prior research (M. A. Khan et al., 2024; Nuta, 2025; Shams,2024;Ze,2023). Globalization coefficient is positive and substantial. Globalization may cause environmental degradation by increasing production to export excess goods to countries that need more energy-intensive goods. Previous studies support results (Andrew et al., 2024; Awad & Saadaoui Mallek, 2023; Latif, Rafeeq, Safdar, Liaquat, et al., 2023; Law, 2018; Chunhong Zhang, 2022). Law and order and stringent laws that require investors to use green technologies can also benefit the environment. In this case, Globalization may benefit the local ecology. Based on the aforesaid logic, past research have contradictory outcomes (Jun et al., 2021; Shabir & Shabir Mohsin, 2022; Wen,2021). Financial development coefficients positively correlate with ecological footprints. Studies (Ding et al., 2022; Khan, 2022; Law, 2018; Xue & Zhang, 2022; Zhang, 2011; Zhou, 2022) support these findings. Ecological footprints positively correlate with foreign direct

investment coefficient. (Ahmad et al., 2021; Benzerrouk et al., 2021; Leitão et al., 2023; Opeyemi et al)

Human investment in education, health, and life expectancy may benefit the environment. Investing in responsible people who know how to save their environment would benefit the environment. Studies show that later human development increases environmental awareness. Human development benefits the environment this way. Previous investigations support results (Fakher, 2019; Onwe et al., 2024; Suchi, 2024).

The extension of the objective is based on the introduction of squared term of globalization to check the validity of EKC based on globalization. This model introduces the squared Globalization term to validate environmental Kuznets curves. The squared term of Globalization negatively impacts ecological footprints, supporting the inverted u-shape environmental Kuznets curve. Previous research has validated the standard environmental Kuznets curve using several economic indices (Balsalobre-Lorente et al., 2023; Islam, 2023; Latif, Rafeeq, Safdar, Younas, et al., 2023; Shahbaz & Patel, 2025).

Policy Recommendations

Based on the study findings, the study recommends some policy recommendations for developing countries.

- As globalization is found to increase the environmental degradation, then government should design policies to channel globalization towards environmentally friendly outcomes. This can be done through environmental clauses in trade and foreign direct investment agreements by restricting multinational corporations to adopt environmentally friendly technology and sustainable development procedures.

Dimension for Future Research

Future research could expand as follows:

- The effect of globalization on economic growth and environmental quality can be revisited by using the threshold effect model.
- Disaggregate analysis can be used to detect which indicator worsens the environmental quality.

Disclosure Statement:

This article has been extracted from Kanwal Younas PHD Thesis.

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