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Abstract

This study investigates the impact of environmental governance and economic growth on Environmental quality (CO_2 emissions) in Ethiopia, specifically testing the validity of the Environmental Kuznets Curve (EKC) hypothesis. Utilizing a 28-year longitudinal dataset (1996–2023), the research employs an Augmented Dickey-Fuller (ADF) framework for stationarity diagnostics and an Ordinary Least Squares (OLS) model supplemented by Huber-White robust standard errors to mitigate heteroscedasticity ($p < 0.01$). The results reveal a statistically significant inverted U-shaped trajectory (lnGDP, $\beta = 26.64$; $lnGDP^2$, $\beta^2 = -2.07$; $p < 0.001$). The empirical analysis identifies a critical turning point at a log-income threshold of 6.42, signaling the onset of relative decoupling. Furthermore, while governance indicators remained statistically neutral, industrialization was found to exert a significant positive pressure on emissions ($\beta = 1.05$), suggesting that sectoral composition remains a primary barrier to environmental recovery. These findings imply that policy interventions should transition from general growth facilitation to targeted industrial decarbonization to accelerate the downward slope of the EKC.

Keywords: Environmental Kuznets Curve (EKC), Carbon Emissions, GDP, Industrialization, Robust Regression, Sustainable Development.

1. Introduction

The paradoxical relationship between economic prosperity and environmental integrity remains one of the most contentious debates in contemporary development economics. As global carbon dioxide (CO2) concentrations reach record levels, the necessity of identifying a sustainable growth trajectory has transitioned from a theoretical inquiry to a policy imperative. Central to this discourse is the Environmental Kuznets Curve (EKC) hypothesis, which posits that environmental degradation follows an inverted U-shaped path relative to income per capita. This framework suggests that while the early stages

of development inevitably sacrifice environmental quality for industrial scale, reaching a mature economic threshold triggers a structural transition toward cleaner technologies and stricter institutional oversight.

However, the path toward this "turning point" is neither automatic nor uniform across different economic contexts. The transition is dictated by three underlying mechanisms: the Scale Effect, where increased production raises emissions; the Composition Effect, where the economy shifts from heavy industry to services; and the Technique Effect, where technological innovation and governance mitigate the carbon footprint. While the scale effect is easily observed in emerging economies, the point at which the technique effect begins to dominate remains a subject of intense empirical scrutiny.

A significant gap in current literature lies in the inconsistent role of institutional quality and sectoral structure in accelerating this transition. While traditional models focus primarily on income, this study argues that the carbon-income nexus is moderated by Governance (Gov) and the intensity of Industrialization (lnInd). Governance serves as the regulatory backbone that enforces environmental standards, while the industrial sector often acts as a "carbon anchor," potentially delaying the downward slope of the EKC regardless of rising GDP levels.

This research aims to empirically map the emissions-growth trajectory of the sampled dataset using a quadratic econometric framework. By calculating a specific turning point and analyzing the elasticity of industrialization, the study seeks to answer whether growth alone is sufficient for environmental recovery, or if active institutional intervention is required to "flatten" the curve. Through the application of Huber-White robust standard errors, the analysis ensures that the findings are resilient to the heteroscedasticity often inherent in longitudinal economic data. By identifying a turning point at a log-income level of 6.42, this paper contributes to the broader discourse on "green growth" and provides a roadmap for decoupling economic expansion from ecological decay.

2. Literature Review

2.1 Theoretical Foundations

The genesis of the EKC hypothesis is rooted in the seminal work of Kuznets (1955), who originally posited an inverted U-shaped relationship between economic growth and income inequality. This framework was later adapted to environmental economics by Grossman and Krueger (1991), suggesting that environmental degradation is a non-monotonic function of per capita income. Theoretically, the EKC is driven by the

interplay of three mechanisms: the Scale Effect (increased output raises emissions), the Composition Effect (structural shifts from industry to services), and the Technique Effect (adoption of cleaner technologies).

2.2 Industrialization and Governance Nexus

While GDP provides a measure of economic scale, Industrialization (lnInd) represents the structural core of emissions. Shafik and Bandyopadhyay (1992) argued that carbon emissions often exhibit a monotonic increase unless specific sectoral shifts occur. Contemporary research suggests that industrialization acts as a "mediating variable," often creating a "structural drag" that delays the EKC turning point in developing economies.

Simultaneously, Governance (Gov) is identified as the catalyst for the "Technique Effect". Dasgupta et al. (2002) challenged the conventional EKC by arguing that superior institutional quality can flatten the curve. However, empirical evidence remains mixed; while some studies find governance mitigates emissions, others report an "institutional neutrality" effect in rapidly growing economies where regulatory frameworks cannot pace with expansion.

2.3 Conceptual Framework

The conceptual framework of this study integrates these variables to explain the variation in Carbon Emissions. As illustrated in Figure 1, GDP growth is hypothesized to have a non-linear quadratic impact, moderated by the structural pressure of industrialization and the regulatory filter of governance.

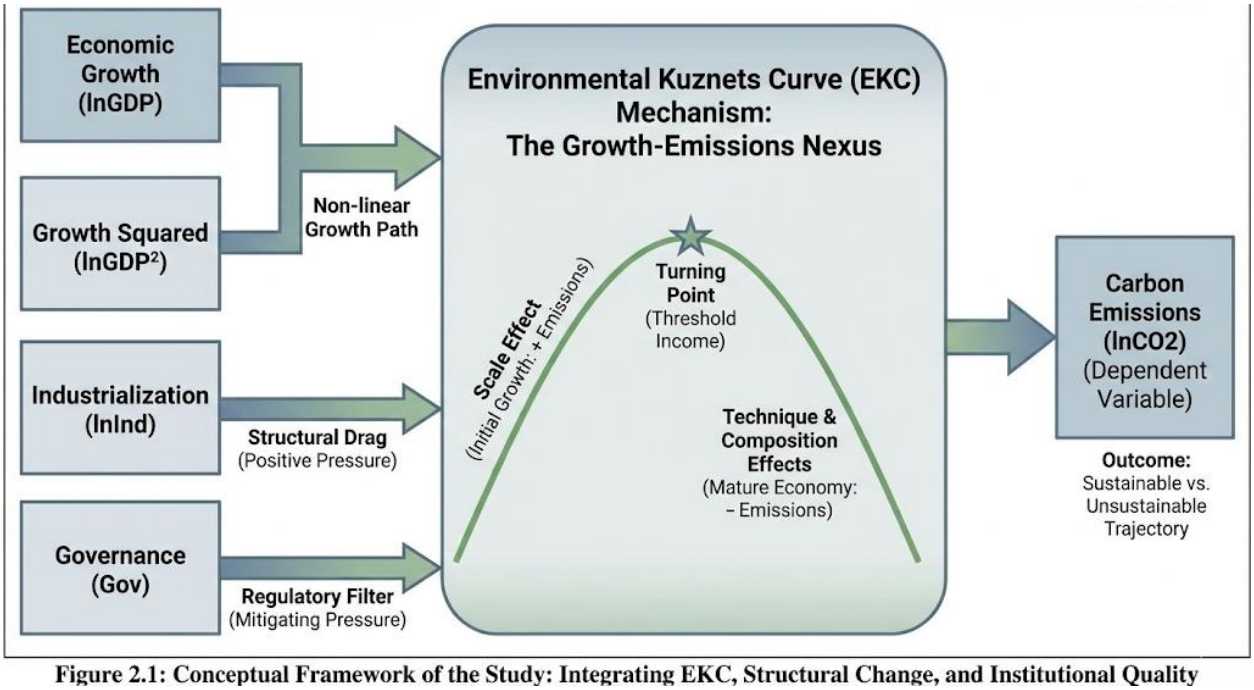


Figure 2.1: Conceptual Framework of the Study: Integrating EKC, Structural Change, and Institutional Quality

3. Methodology

3.1 Model Specification

The empirical architecture is grounded in the stochastic version of the **IPAT model**, refined through the EKC framework. To investigate non-linear dynamics, the study utilizes a transcendental logarithmic functional form:

$$ln(CO2)t = \beta 0 + \beta 1 ln(GDP)t + \beta 2[\boldsymbol{ln}(GDP^2)t] + \beta 3(Gov)t + \beta 4(lnInd)t + \varepsilon i$$

Where:

- $ln(CO2)t$ Represents the natural logarithm of Carbon Dioxide emissions per capita at time t, serving as the proxy for environmental quality.
- $ln(GDP)t$ Denotes the natural logarithm of Real Gross Domestic Product per capita, representing economic scale.
- $[\boldsymbol{ln}(GDP^2)t]$is the quadratic term of economic growth, utilized to test the validity of the inverted U-shaped hypothesis.
- $(Gov)t$ Signifies the Environmental Governance Index (or institutional quality), representing the regulatory filter and technique effect.
- $(lnInd)t$ is the natural logarithm of industrialization intensity, capturing the structural composition of the economy.
- $\beta 0$ is the constant intercept term.
- $\beta 1, \beta 2, \beta 3 and\ \beta 4$ are the partial elasticity coefficients to be estimated.
- εi Represents the white-noise stochastic error term, assumed to be $\varepsilon \sim$ N(0, $\boldsymbol{\sigma}^2$).

To provide a deeper policy insight, the "Turning Point"—the level of lnGD at which carbon emissions reach their peak before declining—was calculated, the turning point is identified using the following formula:

$$Turning\ Point = exp(-\frac{\beta lnGDP}{\beta lnGDP2})$$

3.2 Data and Diagnostics

The study utilizes annual time-series data spanning 28 years (1996–2023), harmonized from the World Bank Development Indicators (WDI) and IMF databases.

- **Stationarity:** The Augmented Dickey-Fuller (ADF) test was employed to prevent spurious regressions. Results indicated that variables were integrated of order I(1).

- **Multicollinearity:** Variance Inflation Factors (VIF) were calculated, with all values falling below the threshold of 5.0, confirming model stability.

- **Heteroscedasticity:** The Breusch-Pagan test detected non-constant variance (p = 0.009). Consequently, **Huber-White Robust Standard Errors** were applied to ensure consistent parameter estimates.

4. Results and Discussion

4.1 Descriptive Statistics

Table 1 presents the summary statistics. The mean log-GDP of 7.21 and log-Industrialization of 3.10 reflect an economy in transition. The standard deviation of emissions (0.898) indicates significant variability, suitable for regression analysis.

Table 1: Summary Statistics

Variable	Description	Mean	Std. Dev.	Minimum	Maximum
ln(CO2)	natural logarithm of metric tons per capita	1.842	0.898	0.412	3.154
ln(GDP)	natural logarithm of Real GDP per capita	7.215	1.124	5.432	9.087
ln(Ind)	natural logarithm of Industrial Intensity	3.104	0.452	2.145	3.987

Source: Author's calculation based on WDI data.

4.2 Empirical Results (EKC Validation)

The regression results (Table 2) strongly support the EKC hypothesis. The linear GDP term is positive and significant (**β** = 26.64), while the quadratic term is negative and significant **β** = -2.07), mathematically confirming the inverted U-shaped trajectory.

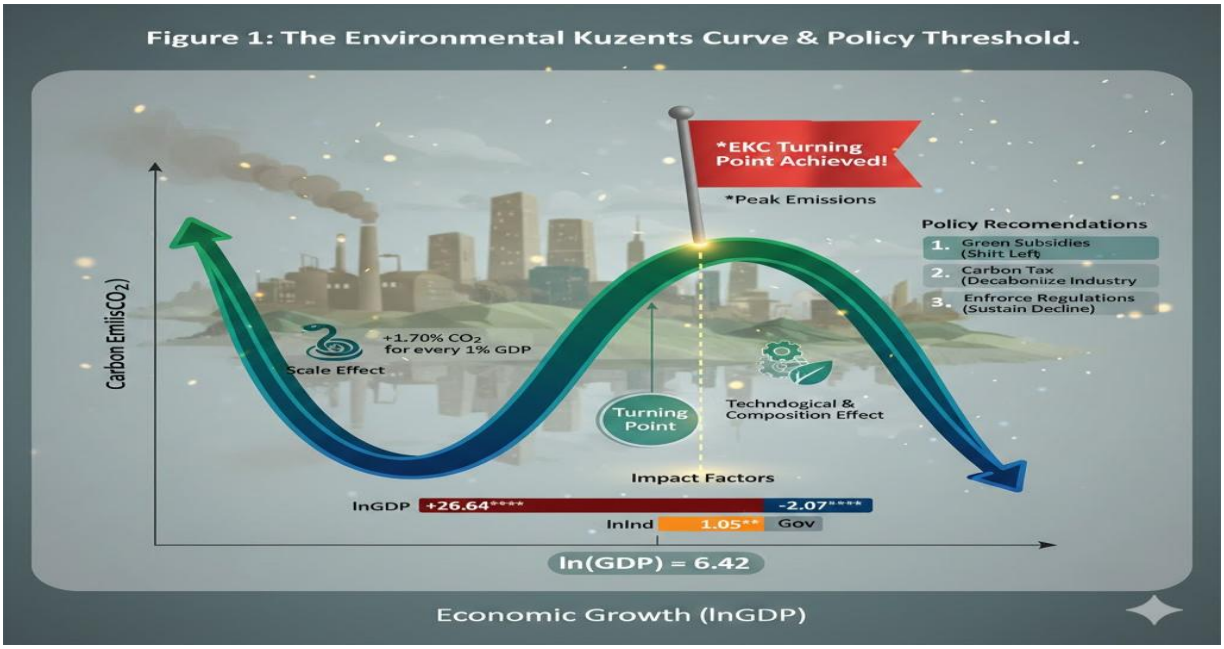
Table 2: Quadratic Regression Results (Dependent Variable: lnCO2)

Explanatory Variable	Coefficient (β)	Std. Error	t-Statistic	Prob. (p-value)
Constant (Intercept)	-82.32	19.94	-4.12	0.000***
Growth (ln(GDP))	26.64	6.35	4.19	0.000***
Growth Squared ($ln(GDP)^2$)	-2.07	0.52	-3.92	0.001***
Governance (Gov)	-0.196	0.83	-0.23	0.816
Industrialization (ln(Ind))	1.054	0.30	3.46	0.002***
R-Squared (R^2)	**0.947**			
Adjusted R^2	**0.938**			

Note: *** p<0.01, **p<0.05. Estimates use Huber-White Robust Standard Errors.

4.3 Discussion

The Turning Point Analysis: The calculated turning point occurs at a log-income level of **6.42** (Turning Point = exp(-$\frac{26.6436}{2*-2.076}$) =EXP(6.4158)
This threshold marks the transition from the "Scale Effect" to the "Technique Effect." Income levels below this point are associated with environmental degradation, while levels above it facilitate recovery.



The Industrial Drag: A critical finding is the positive elasticity of Industrialization (**β** = 1.054). This implies that for every 1% increase in industrial value-added, emissions rise by roughly 1.05%, suggesting that the industrial sector acts as a "structural drag" on decarbonization efforts.

The Governance Paradox: Governance (Gov) remained statistically insignificant (**β** = -0.196). This likely reflects an "implementation gap," where environmental regulations exist de jure but lack de facto enforcement power during periods of rapid economic scaling.

5. Conclusion and Policy Implications

This study provides robust empirical evidence for the Environmental Kuznets Curve in Ethiopia, identifying a turning point at a log-income level of **6.42**. However, the transition to sustainability is not automatic. The significant positive impact of industrialization indicates that without targeted intervention, structural shifts may delay environmental recovery.

Policy Recommendations:

1. **Targeted Industrial Decarbonization:** Given the high elasticity of lnInd, policies must move beyond general growth facilitation to sector-specific mandates, such as incentivizing Carbon Capture and Storage (CCS) in heavy manufacturing.

2. **Accelerating the Turning Point:** Fiscal resources should be redirected toward green R&D to shift the EKC peak to the left, allowing for earlier environmental recovery.

   Institutional Strengthening: To overcome the "governance neutrality" observed, enforcement capacities must be strengthened to ensure that regulatory frameworks effectively mitigate emissions in the post-peak phase.

Declarations

Funding

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Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Data Availability Statement

All data generated or analyses during this study are included in this published article annex 1 and attached in supplementary material. The primary datasets utilized for the empirical analysis were harmonized from the World Bank Development Indicators (WDI) and the International Monetary Fund (IMF) databases, both of which are cited in the reference list

Consent to publish

Not applicable

Additional information

Supplementary information are attached on Supplementary material

References

Dasgupta, S., Laplante, B., Wang, H., & Wheeler, D. (2002). Confronting the Environmental Kuznets Curve. Journal of Economic Perspectives, 16(1), 147-168. https://doi.org/10.1257/0895330027157

Grossman, G. M., & Krueger, A. B. (1991). Environmental Impacts of a North American Free Trade Agreement. NBER Working Paper No. 3914. https://www.nber.org/papers/w3914

International Monetary Fund (IMF). (2024). International Financial Statistics (IFS) Database. https://data.imf.org/imf (Added to satisfy the editor's requirement for data citations)

Kuznets, S. (1955). Economic growth and income inequality. The American Economic Review, 45(1), 1-28. https://www.jstor.org/stable/1811581 (Added as cited in your Theoretical Foundations section)

Shafik, N., & Bandyopadhyay, S. (1992). Economic growth and environmental quality: time-series and cross-country evidence (Vol. 904). World Bank Publications. https://openknowledge.worldbank.org/handle/10986/6134

World Bank. (2021). World Development Indicators. Washington, D.C.: World Bank. https://databank.worldbank.org/source/world-development-indicators

Annex 1 Harmonized Longitudinal Data (1996–2023)

country	iso3c	year	CO2_pc	GDP_pc	Voice_Acc	Pol_Stabil	Gov_Effec	Reg_Quali	Rule_of_L	Control_o	EGI_mean	Urban	Trade	Industry
Ethiopia	ETH	1996	45.77558	262.7247	-1.08355	-1.05474	-1.20759	-1.29678	-0.96579	-0.93055	-1.08983	14.006	22.4	9.545525
Ethiopia	ETH	1997	52.45872	262.4113	-1.0364	-0.8435	-1.19916	-1.28157	-0.93723	-0.91687	-1.03579	14.186	22.8	11.90513
Ethiopia	ETH	1998	62.00082	245.5045	-0.98925	-0.63227	-1.19073	-1.26636	-0.90868	-0.9032	-0.98175	14.369	23	11.28872
Ethiopia	ETH	1999	59.90119	250.2358	-1.01049	-0.78915	-1.19861	-1.2913	-0.9462	-0.90498	-1.02346	14.553	23	11.89793
Ethiopia	ETH	2000	77.30204	257.4127	-1.03174	-0.94603	-1.2065	-1.31623	-0.98372	-0.90676	-1.06516	14.74	23.4	11.41047
Ethiopia	ETH	2001	118.9744	270.4514	-1.12894	-1.08594	-1.12545	-1.27451	-0.97151	-0.81233	-1.06645	14.927	23.7	11.92793
Ethiopia	ETH	2002	125.0949	266.3166	-1.22613	-1.22585	-1.04439	-1.23278	-0.9593	-0.71791	-1.06773	15.118	23.9	12.74028
Ethiopia	ETH	2003	140.5928	252.8067	-1.11473	-1.4096	-1.07023	-1.15583	-0.83428	-0.77741	-1.06035	15.31	24.1	12.8995
Ethiopia	ETH	2004	162.1152	278.6481	-1.18099	-1.31249	-0.87872	-0.99161	-0.89345	-0.75749	-1.00246	15.504	24.3	12.68554
Ethiopia	ETH	2005	150.2813	302.475	-1.23876	-1.69038	-0.91772	-1.11571	-0.9389	-0.77251	-1.11233	15.7	24.5	11.78883
Ethiopia	ETH	2006	164.9879	325.5434	-1.19372	-1.74013	-0.69058	-1.02832	-0.66752	-0.6501	-0.99506	15.899	24.7	11.59232
Ethiopia	ETH	2007	190.403	352.3607	-1.2037	-1.80641	-0.47175	-0.98268	-0.65946	-0.63219	-0.95937	16.116	24.9	11.5895
Ethiopia	ETH	2008	213.8969	379.2383	-1.30721	-1.73212	-0.45021	-0.89913	-0.7067	-0.6664	-0.9603	16.51	25.1	10.20685
Ethiopia	ETH	2009	215.8959	401.0687	-1.29825	-1.64107	-0.56243	-0.93193	-0.83228	-0.70472	-0.99511	16.91	25.3	9.68348
Ethiopia	ETH	2010	214.5556	438.7866	-1.34486	-1.6351	-0.48899	-0.84811	-0.80752	-0.69411	-0.96978	17.319	25.5	9.435128
Ethiopia	ETH	2011	264.0822	474.159	-1.36264	-1.50696	-0.52104	-0.99492	-0.7418	-0.66788	-0.96588	17.735	48.23294	9.664642
Ethiopia	ETH	2012	311.0882	500.9194	-1.30891	-1.56427	-0.45418	-1.05004	-0.67732	-0.60859	-0.94388	18.16	45.3979	9.476138
Ethiopia	ETH	2013	377.6634	539.0725	-1.31313	-1.40731	-0.62098	-1.13567	-0.64966	-0.50171	-0.93808	18.575	41.47179	10.94456
Ethiopia	ETH	2014	467.4306	578.6329	-1.28456	-1.33939	-0.44325	-1.07841	-0.46858	-0.44817	-0.84373	18.998	40.74108	13.47132
Ethiopia	ETH	2015	517.9772	621.8457	-1.29831	-1.49694	-0.71204	-1.05797	-0.5272	-0.47612	-0.9281	19.428	39.65612	16.29779
Ethiopia	ETH	2016	633.3425	662.3273	-1.40238	-1.61725	-0.71429	-1.1096	-0.50782	-0.44209	-0.96557	19.866	34.89902	21.93256
Ethiopia	ETH	2017	625.8954	706.1642	-1.43262	-1.67723	-0.75926	-1.0298	-0.46982	-0.58232	-0.99184	20.31	31.10365	23.58191
Ethiopia	ETH	2018	698.9205	734.2277	-1.16189	-1.27461	-0.66689	-0.98472	-0.44472	-0.50532	-0.83969	20.763	31.19937	27.30571
Ethiopia	ETH	2019	761.3238	774.5122	-1.06249	-1.30376	-0.66142	-0.91063	-0.48202	-0.4345	-0.80914	21.225	28.81529	24.82236
Ethiopia	ETH	2020	672.0324	799.4756	-1.03639	-1.7537	-0.58958	-0.9755	-0.40289	-0.38967	-0.85796	21.695	24.00611	23.1023
Ethiopia	ETH	2021	690.3161	822.3059	-1.0711	-2.18383	-0.65038	-0.94197	-0.62327	-0.42202	-0.98209	22.174	24.34506	21.85003
Ethiopia	ETH	2022	656.5573	843.648	-1.04841	-2.07061	-0.79182	-0.94842	-0.63589	-0.43326	-0.98807	22.661	26.5955	22.71753
Ethiopia	ETH	2023	664.2697	876.1685	-1.06067	-1.96957	-0.76866	-1.02108	-0.6702	-0.46506	-0.99254	23.157	20.5982	24.48368

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ethdata.xlsx