Sharmiladevi, Jekka Chandrasekaran

Article

Detecting the role of agriculture and industry value added, energy, capital flow, and openness to trade upon environmental Kuznets Curve for India

International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Sharmiladevi, Jekka Chandrasekaran (2024). Detecting the role of agriculture and industry value added, energy, capital flow, and openness to trade upon environmental Kuznets Curve for India. In: International Journal of Energy Economics and Policy 14 (6), S. 55 - 62.
https://www.econjournals.com/index.php/ijeep/article/download/16950/8243/39712.
doi:10.32479/ijeep.16950.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(6), 55-62.

Detecting the Role of Agriculture and Industry Value Added, Energy, Capital Flow, and Openness to Trade upon Environmental Kuznets Curve for India

J. C. Sharmiladevi*

Symbiosis Centre for Management Studies, Symbiosis International (Deemed University), Pune, Maharashtra, India.
*Email: sharmiladevi@scmspune.ac.in

Received: 23 May 2024 **Accepted:** 02 September 2024 **DOI:** https://doi.org/10.32479/ijeep.16950

ABSTRACT

This study revisits the environmental Kuznets curve for India, considering unique variables like agriculture and industry value added, fossil fuel energy consumption, inward foreign direct investment, openness to trade, economic growth and carbon dioxide (CO_2) emission. The study results indicate the presence of EKC for India, indicating a positive long-term equilibrium relationship between agriculture and industry value added and fossil fuel energy consumption with CO_2 emission. Inward FDI and trade openness have a negative relation with CO_2 emission, supporting the fact that the environmental regulations for international investments and trade in India are becoming more assertive. At the same time, India needs stringent regulations on emissions from the agriculture and industry sectors.

Keywords: Environmental Kuznets Curve, Agriculture Value Added, Industry Value Added, Inward FDI, CO_2 Emission, Trade Openness, Economic Growth
JEL Classifications: F2, O13, O4, Q52, Q58

1. INTRODUCTION

Human activities shape the environment. With the increase in human activities, the shape of the environment is changing uniquely. The economic structure of a nation gets modified with environmental changes through the use of resources and the generation of pollution. In globalization-induced development, environmental concerns took a back sheet that resulted in severe challenges in resource utilization, leading to multifold increases in all kinds of pollutants. Environmental Kuznets Curve (EKC), developed by Grossman and Krueger (1993), indicates the inverse relationship between environment and development, which is similar to that of the inverted U-shaped relationship between income inequality and development postulated by the famous economist Simon Kuznets. Grossman and Krueger's preliminary empirical research on the relationship between environmental quality and per capita income indicated that pollution increases with GDP per capita at low-income levels but decreases with GDP growth at high-income levels (Grossman and Krueger, 1993).

In the initial stages of development, when the economy is more interested in the creation of new opportunities, focus and attention are given more towards the creation of additional income and employment, and environmental concerns are weak, as and when the economy grows and reaches to a level, environmental regulations become stronger with regulatory institutions, that results in cleaner technology with less pollution, that levels off and then falls at the pre-industrial levels. Kuznets's work on income inequality indicates that, as per capita increases, income inequality initially increases and then decreases gradually, after reaching a threshold level, which means, the distribution of income is more unequal in the beginning stage of growth, distribution becomes more equal when growth continues (Kuznets, 1955).

EKC takes the form of an inverted U-shaped curve. It indicates that as the country's economic growth increases, environmental pollution intensifies and reaches a peak, and subsequently, as and when the country attains economic prosperity, environmental pollution gradually decreases. Environmental pollution due to emissions of carbon dioxide, sulphur, nitrogen, and other particulate pollutants poses severe threats and challenges to weather events, leading to unprecedented climate changes and threats to all living species (Adebayo et al., 2021). Grossman and Kruger's EKC hypothesis was introduced, and it initiated a series of debates on understanding the relationship between environmental pollution and economic development.

The concept of EKC has been applied to a spectrum of issues, from species extinction and nitrogen fertilizer to a variety of environmental challenges across geographies, yet debates are continuing regarding the extent, effects and presence of EKC (McPherson and Nieswiadomy, 2005; Zhang et al., 2015; Frank et al., 2012; Carson, 2010; Kaika and Zervas, 2013; Chow and Li, 2014; Wagner, 2015). Many studies support this hypothesis (Pata, 2018; Jian et al., 2019; Destek and Sarkodie, 2019; Murshed et al., 2020; Akadırı et al., 2021; Balsalobre-Lorente et al., 2021), whereas few studies question the existence of EKC (Dinda, 2004). Arrow et al. (1996) indicate that EKC is the outcome of international trade from specialisation and comparative advantages. Studies also indicated that EKC needs intensive empirical examination (Johansson and Kriström, 2007), with new models and decompositions with multiple panels and time series data sets (Stern, 2004; Wagner, 2008).

Literatures indicate that EKC needs to be studied in sync with changing economic growth and international trade scenarios, as increasing trade and development results in higher levels of pollutants. With this idea, this paper examines the existence of EKC for India, considering carbon dioxide emission, agricultural value added, industry value added, economic growth, international business and openness to trade. At a time when India is pursuing the emergence of the "Vishwa Guru"-the teacher of the world- understanding the existing ground realities is vital for walking confidently towards the perceived path of Vishwa Guru (De Estrada, 2023). India comprises 1417.173 million people, has a 6.56 gross domestic product (GDP) growth rate, and is one of the fastest-growing economies (UNCTAD, 2024). 11.4% of India's GDP is spent on energy, which is half of the Asian average, with coal being the top energy source consumed at 46% of total consumption in 2022, (Enerdata, 2023) justifies taking India for this study.

2. EMPIRICAL EVIDENCE ON EKC

Empirical evidence of EKC covers wide areas of phenomena like the presence/absence of EKC and its shape and position, which are examined with diverse sets of variables across different geographies by adopting multiple econometric techniques. Research, upon identifying the existence of EKC, has considered economic growth and different kinds of emissions. Most studies on EKC fall in this category. Studies considering income and emissions usually take the shape of an inverted U and was found by Adebayo (2021) for Indonesia, Akbostanci et al. (2009) for Turkey, Asongu et al. (2016) for 24 African countries, Diao et al. (2009) for China; and He and Richard (2010) for Canada. A positive relationship is found between economic growth and environmental degradation (Ozturk and Acaravci, 2013; Apergis and Ozturk, 2015; Asongu et al., 2016; Pata, 2018; Adams and Nsiah, 2019; Jian et al., 2019; Ahmad et al., 2021; Namahoro et al., 2021).

Checking the causal relation between energy consumption and income in combination with other variables is primarily used for detecting EKC. The first study in this line was conducted by Kraft and Kraft (1978); this study identified unidirectional causality from energy consumption to economic growth. Studies by (Apergis and Payne, 2010; Lee and Chang, 2008; Lean and Smyth, 2010; Narayan and Smyth, 2008) found unidirectional causality between energy consumption and economic growth. Few studies also indicated reverse causality (Lise and Van Montfort, 2007; Zhang and Xu, 2012; Ang, 2008; Ozturk et al., 2010). Bi-directional causality is also reported in studies (Ozturk et al., 2010; Apergis and Payne, 2009; Jalil and Mahmud, 2009; Nasir and Ur Rehman, 2011; Hossain, 2011; Zhang and Cheng, 2009; Saboori and Sulaiman, 2013). Studies have also found different effects of EKC at regional, national and global levels. Namahoro et al.'s 2021 study of East African countries indicates a positive relationship at the regional level and an unstable relationship at the national level.

Agriculture and allied activities are significant for development but also result in pollution, which demands colossal investment for mitigation (Nelson and Maredia, 2001). EKC has also been studied using scale and time effects. Scale effect indicates an increase in economic activities with more energy utilization leading to an increase in output and income, as seen in developing/emerging economies. In wealthy countries, environmental damage is slow as they take more precautions since they have already crossed the development threshold. The scale effect makes environmental damage more significant, and developing countries are in a compelling situation to address and remedy this issue (Dasgupta et al., 2002).

The role of inward FDI in carbon dioxide emission has been examined recently. Yin et al. (2021) identified the causal relation among FDI, CO_2 emission, and economic growth for 101 countries; the results of this study indicate the presence of EKC. Yasmeen et al. (2022) indicate that FDI leads to pollution in Belt and Road Regions when FDI is examined with other variables like technological innovation, natural resources, population density on biomass energy consumption and ecological footprints.

The structure of an economy, level of economic freedom, and economic complexities also act as enabling factors for EKC. Economic complexity negatively affects the environment, leading to pollution; this phenomenon demands a restructuring of knowledge-intensive and complex developmental projects during the expansion phase of development (Taghvaee et al., 2022). Mixed results were seen when EKC was tested considering economic freedom and other income- and emission-related variables; while economic freedom reduces environmental degradation in developed countries, it is the opposite in emerging economies in the long term (Bektur, 2023). EKC is confirmed for European Union countries when industrialisation and economic structure were considered. EKC is not seen when the above two variables were not considered for the same countries, indicating the fact that the structure of an economy is an essential enabler for the presence/absence of EKC (Dogan and Inglesi-Lotz, 2020).

With the advent of new technology which are clean, many sectors are moving forward from traditional polluting energy resources like firewood, charcoal, and bio-waste to modern, cleaner energy resources like gas, electricity and solar. Few studies identify the effect of cleaner technology upon EKC across different sectors like manufacturing, housing construction, etc. (Htike et al., 2022)

EKC for India, is studied considering the agricultural and industry sector (Htike et al., 2022), coal consumption (Tiwari et al., 2013), economic structure (Villanthenkodath et al., 2021), renewable energy, FDI, stock market, energy intensity and private investment (Gopakumar et al., 2022) environmental-control technology (Uche et al., 2023), population growth, natural resource depletion, consumption of non-renewable energy, national income, remittances and industrial output, CO_2 emission (Itoo and Ali, 2023), CO_2, ecological footprint, GDP, natural resource rent, energy consumption, and urbanization (Hossain et al., 2023), CO_2 emission, economic growth, manufacturing output and export (De, 2023), energy consumption, agricultural value added, trade, world uncertainty index, geopolitical risk, emission of greenhouse gas (Rashid and Gopinathan, 2023), tourism development, GDP per capita, energy consumption, urbanization and CO_2 emissions (Sharma et al., 2023), environmental quality, energy consumption, population, and urbanization (Villanthenkodath, 2023), EKC in different states of India (Rudra and Chattopadhyay, 2018), environmental pollutants and GDP (Sajeev and Kaur, 2020), globalization and CO_2 emissions (Shahbaz et al., 2015), carbon emission, energy use, economic activity and trade openness (Kanjilal and Ghosh, 2013; Sanusi and Dickason-Koekemoe, 2024). Studies of EKC for India, considering agricultural and industrial value-added, with other macroeconomic and emission variables, are not there. This study becomes an addition to the existing literature on EKC for India. Table 1 provides a quick synopsis of the literatures on EKC in 2024.

3. METHODOLOGY

This research is an applied research with an empirical design. The objectives of this research are to identify the presence of EKC for India considering the variables carbon dioxide emission, agriculture forest and fishing value added, industry value added, fossil fuel energy consumption, inward foreign direct investment, economic growth, and trade openness. The data source is from the World Bank World Development Indicator, and the time period is from 1990 to 2022. Variables descriptions are given in Appendix 1. The Unit root test indicates that all the variables are stationary at I(1), as shown in Appendix 2.

3.1. Model and Model Specification

The variables are checked for stationarity, and an autoregressive distributed lag model is employed to estimate the short and long-term effect, measured using bound testing. Error correction can indicate model stability. Further, the ARDL model can successfully address endogeneity and autocorrelation through lag modifications within the model, which makes it appropriate to understand the dynamism among the variables in the long run (Pesaran et al., 2001; Sarkodie and Ozturk, 2020). The ARDL model used in this study is given below. Equation (1) indicates the functional relationship among the variables. The Error Correction Model (ECM) representation of ARDL is formulated about equation (2) in order to examine cointegration, if present, among the variables defined in equation (1)

$$CO_{2t} = f\,(AVA_t, IVA_t, IFDI_t, FF_t, DGDP_t, DTOP_t) \quad (1)$$

$$\Delta L\ CO_{2\ (t)} = \beta 0 + \delta 1LAVA_{(t-1)} + \delta 2LIVA_{(t-1)} + \delta 3LFF_{(t-1)} + \delta 4LGDP_{(t-1)} + \delta 5LIFDI_{t-1)} + \delta 6LTOP_{(t-1)} + \varepsilon_{(t)} \quad (2)$$

All variables are in log form and first differenced.

Where,
LCO_2 = Carbon dioxide emission
LAVA = Agriculture forest and fishing value added
LIVA = Industry value added
LFF = Fossil fuel energy consumption
LGDP = Gross domestic product
LIFDI = Inward foreign direct investment
LTOP = Openness to trade
t = time from 1990 to 2022
t-1 = one period lag
β = intercept
δ1, δ2, δ3, δ4 δ5 δ6 = coefficients
ε = error term.

4. ANALYSIS AND INTERPRETATION

The dependent variable is carbon dioxide emission, and the independent variables are agriculture, forest and fishing value added, industry value added, fossil fuel energy consumption, gross domestic product, inward foreign direct investment and trade openness. Since the study variables follow the first order of integration, the ARDL model is found to be suitable for understanding the effects among the variables. This model runs with one period of lag and is significant. The bounds test was checked to understand long-run effects; it indicates the presence of cointegrating relations, as the F statistics value of 13.68, which is above the lower and upper bound, as shown in Table 2, ensures long-run equilibrium cointegrating relations among the test variables. From Table 3, it is known that the long-run relationship between carbon dioxide emission, agriculture and industry value added, fossil fuel, and GDP are significant. But, inward FDI and trade openness are not significant. From Table 3 long-run estimates, we can understand that a one per cent increase in carbon dioxide emission can result in a 72.3% increase in GDP and a 54% increase in fossil fuel emission. However, at the same time, a one

Table 1: Synopsis of recent literatures on EKC in 2024

Authors	Country and study period	Period	Variables	Techniques	EKC
Hassan et al.	United States of America	1973-2021	Nuclear energy generation, population dynamics, economic progress	Dynamic autoregressive distributed lag	Validated
Wang et al.	147 countries from 1995 to 2018	1995-2018	Trade openness, economic growth, environmental degradation	Panel data regressions	Validated
Erdogan	African countries	1992-2020	Aggregated and disaggregated natural resource rents, ecological sustainability load capacity	Linear-logarithmic models of panel data	Validated
Subramaniam	European Union	2012-2020	Economic growth, green economy, population, energy consumption, emissions	GMM	Validated
Ben Youssef and Dahmani	88 Low- and middle-income countries (LMICs) and High-income countries (HICs),	2000-2021	Gross domestic product per capita, environmental tax revenue, ICT and energy capacity index	Cross-sectional ARDL	Validated
Pata and Karlilar	24 OECD countries	1995-2018	Energy security, green innovation, economic stringency, income, fossil fuel footprint	Augmented mean group and half panel jackknife causality	U and inverted N are validated
Guo and Shahbaz et al.	1991-2023,		Systematic literature review	-	EKC validated at the sectoral level
Saud et al.	1990-2019	EU	Natural resources, economic complexity, sustainable development	Pooled mean group-autoregressive distributed lag (PMG-ARDL)	EKC in the form of N-shaped is validated
Wang and Kim	--	USA	Decoupling between CO_2 emissions and income growth	Panel fixed effects, two-stage least square	Validated
Ullah et al.	2009-19	OECD (17 selected)	Digitalization, technological, financial innovation, environmental quality		N-shaped EKC
Mitić et al.	1995-2019	Serbia	CO_2 emissions, economic growth, electricity consumption, trade openness	ARDL	inverted U-shaped EKC
Liu et al.	2005-2018	China and BRI Nations	Outward FDI, renewable energy, energy intensity		validated
Dardouri and Smida	1961–2018.	Germany, France, Japan, Canada, UK, and US	Economic growth per capita and renewable energy consumption	ARDL	N-shaped and U-shaped patterns validated

Table 2: ARDL bound test results

Model: $CO_2t = f$ *(AVAt, IVAt, IFDIt, FFt, GDPt, TOPt)*	Sig Level (%)	Lower bound	Upper bound	F-Stat
Null Hypothesis for Error Correction	10	2.33	3.25	13.68
	5	2.63	3.62	
	2.5	2.9	3.94	
	1	3.27	4.39	

No long-run relationship β1=β2=β3=β4, No short-run relationship Ø1=Ø2=Ø3=Ø4

per cent increase can result in a reduction in 18.4% agriculture forest and fishing value-added, a 37.7% reduction in industry value-added, and no impact of inward FDI. The error correction term, represented by the Cointegrating Equation, is negative, with an associated coefficient estimate of -0.7250. This implies that 72.50% of any movements into disequilibrium are corrected within one period. A t statistics value of −12.53 and a probability score of 0.00 indicate that the coefficient is highly significant.

Table 3: Long-run coefficient estimates

Independent variables	Coefficient (standard error)	t stat (prob)
LAVA	−1.84 (0.52)	−3.52 (0.00)
LAVA	−3.77 (1.68)	−2.24 (0.03)
LIFDI	−0.0.(0.07)	−0.46 (0.64)
LGDP	7.23 (1.47)	4.89 (0.00)
LTOP	0.88 (0.52)	1.67 (0.11)
LFF	5.40 (1.79)	3.01 (0.00)

R-Square – 0.97, Adjusted R-Square – 0.96, Durbin Watson Stat – 2.03, F Stat – 52.5, Prob (F-Stat) – 0.00, Normality [Jarque-Bera] – 1.08, Heteroskedasticity test Breusch-Pagan-Godfrey (P-value) – 0.68, Ramsey Reset test (F stat) – 0.04
Source: Authors' calculations from Eviews

Error correction mechanism integrates short-run and long-run equilibrium without losing the long-run information and takes care of spuriosity. The coefficient of error correction term shows the speed of adjustment from the short run to the long run for any disequilibrium and long-run causality relations. The error correction term is significant. The coefficient of ECM is −14.45, which means, the speed of adjustments for the previous year's errors and shocks will be corrected in the current year at a speed of adjustment of 144.5%. R square value is 90.39%, and the adjusted R square is 87.47%, indicating model fitness. Residual diagnostics with heteroskedasticity test of Breusch-Pagan-Godfrey, normality test with Jarque-Bera scores, and stability test using CUMSUM test were conducted. All the stability diagnostics tests shown in Table 3 are significant, indicating an absence of heteroscedasticity, non-normality, or serial correlation, which ensures stability.

5. DISCUSSION, CONCLUSION, POLICY IMPLICATIONS AND DIRECTION FOR FUTURE RESEARCH

The objective of this study is to check the presence of EKC by considering variables such as carbon dioxide emission, agriculture forest and fishing value added, industry value added, inward FDI, fossil fuel emission, and trade openness. Considering the above variables, this study is the first in India to study EKC, so this is a new addition to the existing literature on EKC for India. The results of this study indicate the presence of EKC in India. Results of the ARDL model indicate that there is a strong cointegrating relationship among the study variables. The long-run results are significant in the case of agriculture and industry value-added, fossil fuel emission and GDP, but insignificant for inward FDI and trade openness. This study is identical to the results of the studies of (Ozturk and Acaravci, 2013; Apergis and Ozturk, 2015; Asongu et al., 2016; Pata, 2018; Adams and Nsiah, 2019; Jian et al., 2019) (Ahmad et al., 2021; Namahoro et al., 2021) concerning emission and income growth. Currently, India stands number one in terms of utilisation of energy; agricultural production is very high, and industrial development is also multi-fold; all these happenings explain the reason for the positive relationship between CO_2 emission with agriculture industry value added, fossil fuel energy utilisation. Industries are the heart of India's economic development (Fan et al., 2003), and industry sectors are prominent emitters of carbon dioxide. Globalisation and financial development are also acting as avenues for more fossil fuel energy utilisation (Shahbaz et al., 2015).

The reasons for the long-run results not being significant in the case of inward FDI and trade openness can be the composition of economic activities and technology that create different impacts on the environment (Grossman and Kurgers, 1993), the structure of an economy essentially determines the presence/absence of EKC (Dogan and Inglesi-Lotz, 2020). The results of this study indicate that with more openness to trade and inward FDI, CO_2 emissions are decreasing, which supports the Pollution Heaven Hypothesis (PHH) of (Copeland and Taylor, 1994), indicating that polluting industries relocate to places with less stringent environmental regulations. This also leads us to understand that environmental regulations become the centre stage of discussion when firms decide to invest in the FDI route. It is observed across developing countries that liberalised FDI regulations can help get more inward FDI. However, over-hasty liberalisation may lead to long-run negative impacts if regulation in the host country cannot respond to increased economic pressures. Economic growth resulting from FDI is generated at the cost of the natural and social environment, and the impact is mixed, especially in environmentally sensitive sectors. Therefore, strong regulations are vital and act as precautions in sensitive investment areas. Wherever host country regulatory capacity is lacking, developed countries have a responsibility to help improve this before any negotiations to open up new sectors to their investors (Mabey and McNally, 1999).

Future studies can focus on specific firm, industry and sector level, that can show light on the extent of pollution.

Understanding the ecological and economic complexity becomes an essential factor to understand the environmental degradation (Alvarado et al., 2021). Stimulus measures to encourage using alternative energy resources can be a long-term solution. Investing in climate-resilient agriculture (Lipper et al., 2014), energy audit, environment social and governance reports (ESG) compliances concerning profit and investments. Climate-resilient agricultural, capacity building, skill formation, elimination of disincentive policies, and industry partnering handholding with developed countries facilities are a few of the future focus areas of concern (Lipper et al., 2014; Nugroho and Lakner, 2022).

REFERENCES

Adams, S., Nsiah, C. (2019), Reducing carbon dioxide emissions; Does renewable energy matter? Science of the Total Environment, 693, 133288.

Adebayo, T.S. (2021), Testing the EKC hypothesis in Indonesia: Empirical evidence from the ARDL-based bounds and wavelet coherence approaches. Applied Economics Journal, 28(1), 78-100.

Adebayo, T.S., Awosusi, A.A., Rjoub, H., Panait, M., Popescu, C. (2021), Asymmetric impact of international trade on consumption-based carbon emissions in MINT Nations. Energies, 14(20), 6581.

Ahmad, M., Muslija, A., & Satrovic, E. (2021). Does economic prosperity lead to environmental sustainability in developing economies? Environmental Kuznets curve theory. Environmental Science and Pollution Research, 28(18), 22588-22601.

Akadiri, S.S., Adebayo, T.S. (2022), Asymmetric nexus among financial globalization, non-renewable energy, renewable energy use, economic growth, and carbon emissions: Impact on environmental sustainability targets in India. Environmental Science and Pollution Research, 29(11), 16311-16323.

Akadırı, S.S., Alola, A.A., Usman, O. (2021), Energy mix outlook and the EKC hypothesis in BRICS countries: A perspective of economic freedom vs. Economic growth. Environmental Science and Pollution Research, 28(7), 8922-8926.

Akbostanci, E., Türüt-Aşık, S., Tunç, G.İ. (2009), The relationship between income and environment in Turkey: Is there an environmental Kuznets curve? Energy Policy, 37(3), 861-867.

Alvarado, R., Tillaguango, B., Dagar, V., Ahmad, M., Işık, C., Méndez, P., & Toledo, E. (2021). Ecological footprint, economic complexity and natural resources rents in Latin America: empirical evidence using quantile regressions. Journal of Cleaner Production, 318, 128585.

Ang, J. B. (2008). Economic development, pollutant emissions and energy consumption in Malaysia. Journal of Policy Modeling, 30(2), 271-278.

Apergis, N., Ozturk, I. (2015), Testing environmental Kuznets curve hypothesis in Asian countries. Ecological Indicators, 52, 16-22.

Apergis, N., & Payne, J. E. (2009). Energy consumption and economic growth: evidence from the Commonwealth of Independent States. Energy Economics, 31(5), 641-647.

Apergis, N., & Payne, J. E. (2010). The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states. Energy policy, 38(1), 650-655.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C., Perrings, C. (1996), Economic growth, carrying capacity, and the environment. Environment and Development Economics, 1(1), 104-110.

Asongu, S., El Montasser, G., Toumi, H. (2016), Testing the relationships between energy consumption, CO_2 emissions, and economic growth in 24 African countries: A panel ARDL approach. Environmental Science and Pollution Research, 23, 6563-6573.

Balsalobre-Lorente, D., Ibáez-Luzón, L., Usman, M., Shahbaz, M. (2022), The Environmental Kuznets Curve, based on the economic complexity, and the pollution haven hypothesis in PIIGS countries. Renewable Energy, 185, 1441-1455.

Bektur, Ç. (2023), The role of economic freedom in achieving the environmental sustainability for the highest economic freedom countries: Testing the environmental Kuznets curve hypothesis. Environmental Science and Pollution Research.

Ben Youssef, A., Dahmani, M. (2024), Assessing the impact of digitalization, tax revenues, and energy resource capacity on environmental quality: Fresh evidence from CS-ARDL in the EKC framework. Sustainability, 16(2), 474.

Carson, R.T. (2010), The environmental Kuznets curve: Seeking empirical regularity and theoretical structure. Review of Environmental Economics and Policy, 4, 3-23.

Chow, G.C., Li, J. (2014), Environmental Kuznets curve: Conclusive econometric evidence for CO_2. Pacific Economic Review, 19(1), 1-7.

Copeland, B.R., & Taylor, M.S. (1994). North-South Trade and the Environment. Quarterly Journal of Economics, 109, 755-87.

Dardouri, N., Smida, M. (2024), Harnessing the power of EKC and RKC: A sustainable development perspective. Journal of Law and Sustainable Development, 12(1), e3097-e3097.

Dasgupta, S., Laplante, B., Wang, H., Wheeler, D. (2002), Confronting the environmental Kuznets curve. Journal of Economic Perspectives, 16, 147-168.

De Estrada, K.S. (2023), What is a Vishwaguru? Indian civilizational pedagogy as a transformative global imperative. International Affairs, 99(2), 433-455.

De, U.K. (2023), Validity of EKC for CO_2 in India during 1960 to 2020: An ARDL-cointegration approach. SN Business and Economics, 3(11), 204.

Destek, M.A., Sarkodie, S.A. (2019), Investigation of Environmental Kuznets Curve for ecological footprint: The role of energy and financial development. Science of the Total Environment, 650, 2483-2489.

Diao, X.D., Zeng, S.X., Tam, C.M., Tam, V.W. (2009), EKC analysis for studying economic growth and environmental quality: A case study in China. Journal of Cleaner Production, 17(5), 541-548.

Dinda, S. (2004), Environmental Kuznets curve hypothesis: A survey. Ecological Economics, 49(4), 431-455.

Dogan, E., Inglesi-Lotz, R. (2020), The impact of economic structure to the environmental Kuznets curve (EKC) hypothesis: Evidence from European countries. Environmental Science and Pollution Research, 27, 12717-12724.

Enerdata. (2023). Country Energy Report. Enerdata.

Erdogan, S. (2024), On the impact of natural resources on environmental sustainability in African countries: A comparative approach based on the EKC and LCC hypotheses. Resources Policy, 88, 104492.

Fan, S., Chan-Kang, C., Qian, K., & Krishnaiah, K. (2003). National and international agricultural research and rural poverty: the case of rice research in India and China.

Frank, R.H., Jennings, S., Bernanke, B.S. (2012), Principles of Microeconomics. North Ryde NSW: Mcgraw-Hill Australia.

Gopakumar, G., Jaiswal, R., Parashar, M. (2022), Analysis of the existence of environmental Kuznets curve: Evidence from India. International Journal of Energy Economics and Policy, 12(1), 177-187.

Grossman, G., Krueger, A. (1993), Environmental impacts of the North American free trade agreement. In: Garber, P., editor. The U.S.-Mexico Free Trade Agreement. Cambridge: MIT Press. p13-56.

Guo, X., Shahbaz, M. (2024), The existence of Environmental Kuznets Curve: Critical look and future implications for environmental management. Journal of Environmental Management, 351, 119648.

Hassan, A., Haseeb, M., Bekun, F.V., Yazdi, A.H., Ullah, E., Hossain, M.E. (2024), Does nuclear energy mitigate CO_2 emissions in the USA? Testing IPAT and EKC hypotheses using dynamic ARDL simulations approach. Progress in Nuclear Energy, 169, 105059.

He, J., Richard, P. (2010), Environmental Kuznets curve for CO_2 in Canada. Ecological Economics, 69(5), 1083-1093.

Hossain, M.R., Rej, S., Awan, A., Bandyopadhyay, A., Islam, M.S., Das, N., Hossain, M.E. (2023), Natural resource dependency and environmental sustainability under N-shaped EKC: The curious case of India. Resources Policy, 80, 103150.

Hossain, M. S. (2011). Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy policy, 39(11), 6991-6999.

Htike, M.M., Shrestha, A., Kakinaka, M. (2022), Investigating whether the environmental Kuznets curve hypothesis holds for sectoral CO_2 emissions: Evidence from developed and developing countries. Environment, Development and Sustainability, 24, 12712-12739.

Itoo, H.H., Ali, N. (2023), Analyzing the causal nexus between CO_2 emissions and its determinants in India: Evidences from ARDL and EKC approach. Management of Environmental Quality: An International Journal, 34(1), 192-213.

Jalil, A., & Mahmud, S. F. (2009). Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. Energy policy, 37(12), 5167-5172.

Jian, J., Fan, X., He, P., Xiong, H., Shen, H. (2019), The effects of energy consumption, economic growth and financial development on CO_2 emissions in China: A VECM approach. Sustainability, 11(18), 4850.

Johansson, P.O., Kriström, B. (2007), On a clear day you might see an environmental Kuznets curve. Environmental and Resource Economics, 37, 77-90.

Kaika, D., Zervas, E. (2013), The environmental Kuznets curve (EKC) theory. Part B: Critical issues. Energy Policy, 62, 1403-1411.

Kanjilal, K., Ghosh, S. (2013), Environmental Kuznet's curve for India: Evidence from tests for cointegration with unknown structural breaks. Energy Policy, 56, 509-515.

Kraft, J., Kraft, A. (1978), On the relationship between energy and GNP. The Journal of Energy and Development, 3, 401-403.

Kuznets, S. (1955), American economic association. The American Economic Review, 45(1), 1-28.

Lean, H. H., & Smyth, R. (2010). CO2 emissions, electricity consumption and output in ASEAN. Applied energy, 87(6), 1858-1864.

Lee, C. C., & Chang, C. P. (2008). Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. Resource and energy Economics, 30(1), 50-65.

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., ... & Torquebiau, E. F. (2014). Climate-smart agriculture for food security. Nature climate change, 4(12), 1068-1072.

Lise, W., & Van Montfort, K. (2007). Energy consumption and GDP in Turkey: Is there a co-integration relationship?. Energy economics, 29(6), 1166-1178.

Liu, P., Ur Rahman, Z., Jóźwik, B., Doğan, M. (2024), Determining the environmental effect of Chinese FDI on the Belt and Road countries CO_2 emissions: An EKC-based assessment in the context of pollution haven and halo hypotheses. Environmental Sciences Europe, 36(1), 1-12.

Mabey, N., McNally, R. (1999), Foreign Direct Investment and the Environment: From Pollution Havens to Sustainable Development: A WWF-UK Report. WWF-UK.

McPherson, M.A., Nieswiadomy, M.L. (2005), Environmental Kuznets Curve: Threatened species and spatial effects. Ecological Economics, 55(3), 395-407.

Mitić, P., Kojić, M., Minović, J., Stevanović, S., Radulescu, M. (2024), An EKC-based modelling of CO_2 emissions, economic growth, electricity consumption and trade openness in Serbia. Environmental Science and Pollution Research, 31(4), 5807-5825.

Murshed, M., Nurmakhanova, M., Elheddad, M., Ahmed, R. (2020), Value addition in the services sector and its heterogeneous impacts on CO_2 emissions: Revisiting the EKC hypothesis for the OPEC using panel spatial estimation techniques. Environmental Science and Pollution Research, 27(31), 38951-38973.

Namahoro, J.P., Wu, Q., Xiao, H., Zhou, N. (2021), The impact of renewable energy, economic and population growth on CO_2 emissions in the East African region: Evidence from common correlated effect means group and asymmetric analysis. Energies, 14(2), 312.

Narayan, P. K., & Smyth, R. (2008). Energy consumption and real GDP in G7 countries: new evidence from panel cointegration with structural breaks. Energy economics, 30(5), 2331-2341.

Nasir, M., & Rehman, F. U. (2011). Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. Energy policy, 39(3), 1857-1864.

Nelson, M., & Maredia, M. K. (2001). Environmental impacts of the CGIAR: an assessment.

Nugroho, A. D., & Lakner, Z. (2022). Effect of globalization on coffee exports in producing countries: A dynamic panel data analysis. The Journal of Asian Finance, Economics and Business, 9(4), 419-429.

Ozturk, I., Acaravci, A. (2013), The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Economics, 36, 262-267.

Ozturk, I., Aslan, A., & Kalyoncu, H. (2010). Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. Energy policy, 38(8), 4422-4428.

Pata, U. K. (2018). Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: testing EKC hypothesis with structural breaks. Journal of cleaner production, 187, 770-779.

Pata, U.K., Karlilar, S. (2024), The integrated influence of energy security risk and green innovation on the material footprint: An EKC analysis based on fossil material flows. Journal of Cleaner Production, 435, 140469.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics, 16(3), 289-326.

Rashid, A., Gopinathan, R. (2023), Revisiting the nexus between economic growth and disaggregated greenhouse gases in India: Evidence from necessary and sufficient conditions. Journal of Cleaner Production, 430, 139514.

Rudra, A., Chattopadhyay, A. (2018), Environmental quality in India: Application of environmental Kuznets curve and sustainable human development index. Environmental Quality Management, 27(4), 29-38.

Saboori, B., & Sulaiman, J. (2013). CO2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: A cointegration approach. Energy, 55, 813-822.

Sajeev, A., Kaur, S. (2020), Environmental sustainability, trade and economic growth in India: Implications for public policy. International Trade, Politics and Development, 4(2), 141-160.

Sanusi, K.A., Dickason-Koekemoer, Z. (2024), Trade openness, financial development and economic growth in Lesotho: BVAR and time-varying VAR analysis. International Journal of Economics and Financial Issues, 14(3), 66-75.

Sarkodie, S. A., & Ozturk, I. (2020). Investigating the environmental Kuznets curve hypothesis in Kenya: a multivariate analysis. Renewable and Sustainable Energy Reviews, 117, 109481.

Saud, S., Haseeb, A., Zaidi, S.A.H., Khan, I., Li, H. (2024), Moving towards green growth? Harnessing natural resources and economic complexity for sustainable development through the lens of the N-shaped EKC framework for the European Union. Resources Policy, 91, 104804.

Shahbaz, M., Mallick, H., Mahalik, M.K., Loganathan, N. (2015), Does globalization impede environmental quality in India? Ecological Indicators, 52, 379-393.

Sharma, M., Mohapatra, G., Giri, A.K., Wijeweera, A., Wilson, C. (2023), Examining the tourism-induced environmental Kuznets curve hypothesis for India. Environment, Development and Sustainability, 1-20.

Stern, D.I. (2004), The rise and fall of the environmental Kuznets curve. World Development, 32(8), 1419-1439.

Subramaniam, Y. (2024), Investigating the impact of a green economy on the EKC hypothesis: Evidence from European countries. Environment, Development and Sustainability, 26, 1-20.

Taghvaee, V. M., Nodehi, M., & Saboori, B. (2022). Economic complexity and CO2 emissions in OECD countries: sector-wise Environmental Kuznets Curve hypothesis. Environmental Science and Pollution Research, 29(53), 80860-80870.

Tiwari, A.K., Shahbaz, M., Hye, Q.M.A. (2013), The environmental Kuznets curve and the role of coal consumption in India: Cointegration and causality analysis in an open economy. Renewable and Sustainable Energy Reviews, 18, 519-527.

Uche, E., Das, N., Bera, P. (2023), Re-examining the environmental Kuznets curve (EKC) for India via the multiple threshold NARDL procedure. Environmental Science and Pollution Research, 30(5), 11913-11925.

Ullah, A., Dogan, M., Pervaiz, A., Bukhari, A.A.A., Akkus, H.T., Dogan, H. (2024), The impact of digitalization, technological and financial innovation on environmental quality in OECD countries: Investigation of N-shaped EKC hypothesis. Technology in Society, 77, 102484.

UNCTAD. (2024). Available from: https://unctadstat.unctad.org/countryprofile/generalprofile/en-gb/356/index.html

Villanthenkodath, M.A. (2023), Revisiting the environmental Kuznets curve (EKC): An analysis using the sectoral output and ecological footprint in India. In: Economic Growth and Environmental Quality in a Post-Pandemic World. London: Routledge. p233-250.

Villanthenkodath, M.A., Gupta, M., Saini, S., Sahoo, M. (2021), Impact of economic structure on the environmental Kuznets curve (EKC) hypothesis in India. Journal of Economic Structures, 10(1), 28.

Wagner, M. (2008), The carbon Kuznets curve: A cloudy picture emitted by bad econometrics? Resource and Energy Economics, 30(3), 388-408.

Wagner, M. (2015), The environmental Kuznets curve, Cointegration and nonlinearity. Journal of Applied Econometrics, 30(6), 948-967.

Wang, Q., Wang, X., Li, R., Jiang, X. (2024), Reinvestigating the environmental Kuznets Curve (EKC) of carbon emissions and ecological footprint in 147 countries: A matter of trade protectionism. Humanities and Social Sciences Communications, 11(1), 1-17.

Wang, Z., Kim, M.K. (2024), Decoupling of CO_2 emissions and income in the US: A new look from EKC. Climatic Change, 177(3), 52.

Yasmeen, R., Zhaohui, C., Shah, W.U.H., Kamal, M.A., Khan, A. (2022), Exploring the role of biomass energy consumption, ecological footprint through FDI and technological innovation in B&R economies: A simultaneous equation approach. Energy, 244, 122703.

Yin, Y., Xiong, X., Hussain, J. (2021), The role of physical and human capital in FDI pollution- growth nexus in countries with different income groups: A simultaneity modelling analysis. Environmental Impact Assessment Review, 91, 106664.

Zhang, C., & Xu, J. (2012). Retesting the causality between energy consumption and GDP in China: Evidence from sectoral and regional analyses using dynamic panel data. Energy Economics, 34(6), 1782-1789.

Zhang, X. P., & Cheng, X. M. (2009). Energy consumption, carbon emissions, and economic growth in China. Ecological economics, 68(10), 2706-2712.

Zhang, X., Davidson, E.A., Mauzerall, D.L., Searchinger, T.D., Dumas, P., Shen, Y. (2015), Managing nitrogen for sustainable development. Nature, 528(7580), 51-59.

APPENDIX

Appendix 1: Variable Description

Variables	Variable Representation	Variable Description
Carbon di Oxide emission	CO_2	CO_2 emissions (metric tons per capita)
Agricultural forest and fishing value added	AVA	Agriculture, forestry, and fishing, value added (% of GDP)
Industry value added	IVA	Industry (including construction), value added (% of GDP)
Fossil fuel	FF	Fossil fuel energy consumption (% of total)
Gross domestic product	GDP	GDP per capita (constant 2015 US$)
Trade openness	TOP	Exports added to imports and divided by GDP
Inward Foreign direct investment	IFDI	Foreign direct investment, net inflows (% of GDP)

Appendix 2: Unit Root Test

Variables	At level I (0)	At first difference I (1)
LCO_2		
Constant	−2.03 (0.27)	−4.54 (0.00)
Constant and Linear	−2.26 (0.43)	−4.92 (0.00)
None	−1.39 (0.14)	−4.62 (0.00)
LAVA		
Constant	−1.64 (0.44)	−6.25 (0.00)
Constant and Linear	−0.93 (0.93)	−6.80 (0.00)
None	−2.22 (0.02)	−5.46 (0.00)
LIVA		
Constant	−2.32 (0.17)	−5.52 (0.00)
Constant and Linear	−1.05 (0.92)	−5.80 (0.00)
None	−0.42 (0.52)	−2.70 (0.00)
LGDP		
Constant	0.55 (0.98)	−5.54 (0.00)
Constant and Linear	−3.19 (0.10)	−5.44 (0.00)
None	8.52 (1.00)	−1.74 (0.03)
LFF		
Constant	−3.64 (0.01)	−4.51 (0.00)
Constant and Linear	−0.87 (0.94)	−5.87 (0.00)
None	−4.40 (1.00)	−3.38 (0.00)
LIFDI		
Constant	−2.39 (0.15)	−6.39 (0.00)
Constant and Linear	−2.02 (0.56)	−7.57 (0.00)
None	−2.53 (0.01)	−5.98 (0.00)
LTOP		
Constant	−0.66 (0.84)	−5.06 (0.00)
Constant and Linear	−1.54 (0.79)	−5.24 (0.00)
None	0.35 (0.78)	−5.09 (0.00)