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# Economic growth and environmental degradation in India: A review and trend analysis of the Environmental Kuznets Curve hypothesis

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## Abstract
This paper examines the Environmental Kuznets Curve (EKC) hypothesis the proposition that environmental degradation rises with economic growth at low levels of income and falls once a threshold income is crossed in the context of India. Drawing on secondary emissions and income data and synthesising recent Indian and cross-country empirical literature (2010–2026), the paper evaluates whether India's growth trajectory is consistent with the inverted U-shaped EKC. The evidence is mixed: several studies confirm an inverted U-shape for India, but estimated turning points vary enormously (from roughly US$1,800 to US$28,000 per-capita GDP) depending on whether environmental policy variables are included, and India's per-capita CO2 emissions were still rising as of 2023–2024. The paper argues that the EKC in India, where it exists at all, is being pulled forward chiefly by deliberate policy intervention renewable energy deployment, the PAT scheme, and electric-vehicle adoption rather than by market forces alone. Policy implications for balancing growth and sustainability are discussed.

**Keywords:** Environmental Kuznets Curve, India, CO2 emissions, economic growth, sustainable development, environmental policy

## Introduction
Economic growth and environmental quality have long been treated as competing objectives, particularly for developing economies under pressure to industrialise. The Environmental Kuznets Curve (EKC) hypothesis offers a more optimistic narrative: it proposes that environmental degradation follows an inverted U-shaped path as income rises — worsening during early industrialisation, then improving once a country becomes wealthy enough to prioritise cleaner technology, stricter regulation, and a shift toward services (Grossman & Krueger, 1995) [7]. The hypothesis takes its name from Kuznets' (1955) [8] original inverted U-curve linking income inequality to stages of economic development.

India presents a particularly important test case. It is now the world's third-largest emitter of CO2 in absolute terms, and among major emerging economies it recorded the largest relative increase in emissions in 2023, at 6.1 percent. Yet its per-capita emissions remain far below the global average — around 2.2 tonnes of CO2 versus a world average near 4.7 tonnes — reflecting both low historical industrialisation and a large population base. India is simultaneously the fastest-growing major economy and a country whose growth-environment trade-off will materially affect global climate outcomes.

This paper asks two questions. First, does the available evidence support the existence of an EKC relationship for India — that is, will continued growth eventually reduce environmental degradation on its own? Second, to the extent an EKC-like pattern is observed, is it being driven by automatic market and structural forces, or by deliberate environmental policy? The paper proceeds as follows: Section 2 reviews the theoretical foundations of the EKC; Section 3 surveys empirical evidence, with a focus on India; Section 4 presents descriptive trend analysis using secondary data; Section 5 discusses findings and policy implications; Section 6 concludes.

## Theoretical Framework
The EKC hypothesis rests on three complementary mechanisms through which rising income can eventually reduce environmental degradation (Panayotou, 1997; Dinda, 2004) [4, 11]:

**Scale effect:** as an economy grows, the sheer scale of production and consumption initially increases resource use and pollution.

**Composition effect:** as income rises, the structure of the economy shifts from agriculture to industry and eventually to less pollution-intensive services, changing the emissions profile of a unit of GDP.

**Technique effect:** higher income raises the demand for environmental quality (a normal, arguably luxury, good) and finances cleaner production technologies and stronger regulatory institutions.

The net effect on emissions over the growth path depends on which force dominates at each stage of development. In its original empirical form, Grossman and Krueger (1995) [7] found an inverted U-shaped relationship between per-capita income and several pollutants, with turning points typically in the US$8,000 per-capita range — a finding that generated a large and still-growing empirical literature applying the framework to individual countries and pollutants, including CO2, SO2, water pollutants, and ecological footprint measures.

It is important to note that the EKC is an empirical regularity observed in some contexts, not a deterministic law. Stern's (2004) [13] influential critique argues that many early EKC studies suffered from statistical problems — omitted variables, unaddressed simultaneity, and inappropriate functional forms — and that the turning points estimated in the literature are often not robust across specifications. This caution is directly relevant to interpreting the wide range of turning-point estimates found for India, discussed below.

## Literature Review: Evidence from India

Empirical work on the EKC in India has grown substantially over the past decade, employing varied time periods, pollutants, and econometric techniques — most commonly the Autoregressive Distributed Lag (ARDL) and Dynamic ARDL (DARDL) cointegration approaches, which are well suited to India's relatively short annual macroeconomic time series. Table 1 summarises key studies.

**Table 1:** Selected empirical studies on the EKC hypothesis in India

| Study | Period / Data | Method | Key Finding |
|---|---|---|---|
| Ghosh (2010) [5] | 1971–2006, India | Multivariate cointegration (VECM) | Bidirectional causality between growth and CO2; no clear EKC turning point found. |
| Sinha & Bhattacharya (2016) [12] | Indian cities, NO2 | Panel EKC estimation | Inverted U-shaped relationship for NO2 emissions across Indian cities. |
| Gopakumar, Jaiswal & Parashar (2022) [6] | 1991–2018, India | ARDL cointegration | Inverted U-shaped EKC confirmed, but emissions kept rising past the estimated turning point; income inequality matters more than income level. |
| Villanthenkodath, Gupta & Saini (2021) [14] | India, structural variables | ARDL | Economic structure (industry vs. services share) significantly shapes the EKC path in India. |
| Bandyopadhyay & Rej (2021) [3] | India, nuclear energy | ARDL | Nuclear energy use supports the EKC by lowering long-run emissions. |
| Al-Mulali, Ridwan, Aslan & Raboshuk (2025) [2] | 1980–2023, India | Dynamic ARDL (DARDL) with policy interaction terms | Inverted U-shaped EKC; targeted policy (EV adoption, PAT scheme, green hydrogen) shifts the turning point from ~US$28,000 to ~US$1,800 per capita. |
| Agarwal & Sharma (2026) | 1990–2023, India | VECM / panel fixed-random effects | Non-linear EKC with turning point around US$6,500–7,200 per-capita GDP. |

Two broad patterns emerge from this literature. First, a majority of Indian studies do find statistical support for an inverted U-shaped relationship between income and emissions (Gopakumar et al., 2022; Sinha & Bhattacharya, 2016; Al-Mulali *et al*., 2025[2, 6, 12]; Agarwal & Sharma, 2026), consistent with the general EKC literature summarised in Dinda's (2004) [4] survey. Second, and more strikingly, the estimated income level at which the curve turns down varies by more than an order of magnitude across studies — from under US$2,000 to nearly US$28,000 per-capita GDP. Al-Mulali et al. (2025) [2] show this variation is not merely a matter of statistical noise: when environmental policy variables (renewable energy adoption, the Perform-Achieve-Trade energy-efficiency scheme, electric-vehicle incentives) are explicitly modelled, the estimated turning point falls dramatically, from roughly US$28,000 without policy interaction terms to around US$1,800 with them. This is a critical finding for a country whose 2024 per-capita GDP (PPP) stood at roughly US$9,800 — below the 'no-policy' turning point but above the 'with-policy' one.

Gopakumar *et al*. (2022) [6] add a further caution: even where an inverted U-shape is statistically confirmed for India over 1991–2018, actual CO2 levels continued to rise past the estimated turnaround point, and income inequality — not income level alone — appeared to be a more decisive determinant of emissions outcomes. This is consistent with Ghosh's (2010) [5] earlier finding of bidirectional causality between growth and emissions in India without a clean EKC turning point, and with the broader observation that India's per-capita CO2 emissions rose in nearly every year on record through 2023–2024[15].

Taken together, the Indian literature does not support a simple 'grow now, clean up later' reading of the EKC. Instead, it points to a conditional EKC: the curve bends downward only where, and to the extent that, policy actively compresses it.

## Data and Trend Analysis

To complement the econometric literature, this section presents descriptive trends using publicly available secondary data (World Bank; Our World in Data, 2025 [10]; EDGAR emissions database) rather than original regression estimates, consistent with the scope of an undergraduate review paper.

India's per-capita CO2 emissions rose from roughly 0.4 tonnes in 1970 to approximately 2.1–2.2 tonnes in 2023–2024 — a more than fivefold increase over five decades, tracking closely with GDP per capita, which rose from a low base to roughly US$2,400 (nominal) and US$9,800 (PPP-adjusted) by 2024. Over the same period, coal-based CO2 emissions alone rose nearly sixfold since 1990, reflecting continued heavy reliance on coal for power generation even as renewable capacity expanded rapidly. At the global level, a 2024 cross-country study using segmented-sample regressions across 164 countries found that while the GDP–CO2 relationship is weakening over time, it remains positive for most of the world, and only a minority of high-income countries — mostly in Europe — have achieved genuine decoupling of growth from emissions; most Asian, American, and African economies, India included, have not yet done so.

This pattern is consistent with India still being on the rising, left-hand segment of the EKC in aggregate terms, even as several sub-indicators (renewable energy share, emissions intensity of GDP) are improving. Emissions intensity — CO2 per unit of GDP — has fallen over the past two decades even as absolute and per-capita emissions have risen, because GDP has grown faster than emissions. This is an important distinction: it indicates decoupling of emissions from output growth (relative decoupling) without yet achieving an absolute decline in emissions (absolute decoupling), the latter being what the EKC's downward-sloping segment actually requires.

## Discussion and Policy Implications

The evidence reviewed here suggests that whether India experiences the favourable, emissions-reducing segment of the EKC is not predetermined by income growth alone; it is substantially a policy choice. Three implications follow.

First, policy can pull the EKC turning point forward rather than waiting for organic income growth to reach it. Al-Mulali *et al*.'s (2025) [2] finding that policy interaction terms move the estimated turning point from ~US$28,000 to

~US$1,800 per capita is the clearest evidence for this in the Indian literature, and it implies far larger welfare gains from targeted intervention than from growth alone.

Second, the composition of growth matters as much as its rate. Villanthenkodath *et al*. (2021) [14] show that India's sectoral structure — the relative weight of industry versus services — materially shapes the emissions path, suggesting that industrial policy and services-sector promotion are, in effect, environmental policy tools.

Third, distributional factors deserve more attention than the standard EKC framework gives them. Gopakumar *et al*.'s (2022) [6] finding that income inequality, not income level, better predicts emissions outcomes in India implies that policies improving equity may have environmental co-benefits that a narrow focus on aggregate GDP growth would miss.

These findings support continued and expanded investment in the specific levers already shown to matter for India: renewable energy capacity addition, energy-efficiency programmes such as PAT, electric-vehicle adoption, and the emerging green hydrogen mission, alongside sectoral and equity-focused policies that shape the composition — not just the pace — of growth.

## Limitations

This paper is a literature synthesis and descriptive trend analysis rather than an original econometric study; it does not estimate a new EKC model for India and instead relies on published estimates, which vary in sample period, pollutant measured, and econometric specification. As Stern (2004) [13] cautions, EKC turning-point estimates in the wider literature are often sensitive to model specification, and the wide range of Indian estimates surveyed here (US$1,800–US$28,000) should be read as reflecting this sensitivity as much as genuine differences in underlying policy effects. Future work using a consistent, updated dataset and a single econometric specification across pollutants ($CO_2$, $SO_2$, PM2.5) would help narrow this range for India specifically.

## Conclusion

India's growth-environment relationship does not yet show a settled inverted-U pattern of the kind the classic EKC hypothesis predicts; per-capita emissions were still rising as of the most recent data (2023–2024) [15], and estimated turning points across the literature range too widely to offer confident guidance on when, left alone, growth would start reducing emissions. What the evidence does show consistently is that environmental policy — not income growth by itself — is the variable most capable of bending India's emissions path downward sooner rather than later. For a country still below most estimated 'natural' EKC turning points, this reframes the emissions-growth trade-off: continued economic growth need not be paused to protect the environment, but achieving the EKC's favourable segment earlier requires sustained policy effort rather than passive reliance on rising incomes.

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