

# 1. Full-Series Trend (1970–2024): High-Level Insights

## Overall behaviour:

The series shows a **long-run exponential-like growth** in emissions from ~700 units (1970) to ~4,300+ units (2024).

## Key quantitative features visible in the curve:

- **1970–1990:** Slow but persistent upward movement (~700 → ~1,350).
- **1990–2010:** Noticeable acceleration (~1,350 → ~2,800).
- **2010–2024:** Sharp growth (~2,800 → ~4,300), along with small volatility near 2020.

**Inference:** The growth rate steepens over time. This already suggests **multiple slope changes**, which is confirmed by the break detection.

# 2. Breakpoint Detection (2003, 2015, 2020): Interpretation Based on Plot

The BIC-based break finder identified **three breakpoints** at **2003**, **2015**, and **2020**. These correspond to significant structural shifts visible in the second plot.

## Regime 1: 1970–2003

- Longest and smoothest period.
- Slope is positive but moderate.
- Emissions increase from ~720 → ~1,900.
- The segment fit closely overlays the actual trend.

**Inference:** This era reflects foundational industrial expansion, electricity sector growth, and rising energy consumption but without rapid jumps.

## Regime 2: 2004–2015

- Distinct increase in slope relative to regime 1.
- Emissions rise faster: ~1,900 → ~3,200.
- The fitted piecewise line is significantly steeper.

## Inference:

This segment indicates a **major escalation in industrial output, coal use, transportation demand**, and overall economic expansion.

The breakpoint at **2003** captures the beginning of this accelerated trajectory.

## Regime 3: 2016–2020

- Another upward shift in slope, although the segment is short.
- Emissions:  $\sim 3,300 \rightarrow \sim 3,600$  before the COVID dip.
- Structural break at **2015** marks the beginning of this faster climb.

### Inference:

This reflects **pre-COVID peak industrialization** and consumption-linked emissions growth. The short regime still shows a strong slope, indicating high momentum.

## Regime 4: 2021–2024

- Sharp recovery from the 2020 dip.
- Emissions jump from  $\sim 3,450 \rightarrow \sim 4,300$ .
- Slope is higher than previous regimes.

### Inference:

Post-COVID rebound is not just recovery to pre-COVID trend; the slope suggests **a new, steeper post-pandemic emissions trajectory**.

The 2020 breakpoint is statistically validated in the Chow test, meaning the COVID shock introduced a genuine structural deviation.

## 3. Piecewise Regression – Data-Backed Slope Behavior

Although exact coefficients aren't shown here, the fitted lines (green) visually indicate:

### Slope ordering (from least to greatest):

Regime 1 < Regime 2 < Regime 3 < Regime 4

Meaning:

- Emissions are **accelerating across time**.
- Each new regime grows **faster per year** than the previous one.
- The model identifies genuine **trend steepening**, not noise.

### Fit Quality

- The piecewise model tracks the actual series very closely in every segment.
- Suggests **no significant overfitting** and correctly captures structural breaks.
- Confirms that the trend is **not linear across the full 1970–2024 period**, but rather piecewise-linear with statistically significant turning points.

## 4. Regime-Wise View and ARIMA Forecasting

The final plot shows the **10-year forecast (2025–2034)** based on the last regime's ARIMA model.

### Observed behavior:

- Forecast begins around ~4,500 in 2025.
- By 2034, forecast reaches ~6,000.
- Confidence band widens substantially, indicating increasing uncertainty the further out we go.

### Model implications:

- Using ARIMA(0,2,0) for the last regime implies:
  - The series is modeled as a **second-difference random walk**.
  - This typically reflects **strong and compounding upward drift**.

### Data-backed insights:

- The slope of the last regime (2021–2024) drives a strong upward future projection.
- The ARIMA forecast continues the **post-COVID high-growth path**.
- The forecast curve aligns closely with the last observed slope—indicating no expected flattening.

## 5. Integrated Interpretation: What the Data Tells Us

Based on the structural breaks, slopes, and the forecast:

### 1. Emissions growth is not steady; it occurs in distinct phases.

Each phase has a different growth rate, and the growth rate consistently increases.

### 2. Major accelerations correspond to plausible macroeconomic chapters:

- **~2003**: Industrial boom, economic liberalization effects.
- **~2015**: Infrastructure expansion, sustained high GDP growth.
- **~2020**: COVID collapse followed by aggressive rebound momentum.

### 3. The break at 2020 is real and impactful.

COVID caused a temporary deviation but did not change the long-term growth direction. The recovery in 2021–2024 is stronger than the pre-COVID trend.

#### **4. Post-2021 regime shows the steepest growth rate.**

This suggests:

- Industrial recovery + increased energy demand.
- Weak short-term impact of emission control efforts.
- A structural push to a new, higher-emission trajectory.

#### **5. Forecast indicates continued rise ( $\approx$ 40–45% increase by 2034).**

- Future emissions likely exceed 6,000 if current trend continues.
- Confidence intervals widen but do not contradict the upward trend.

### **6. Core Data-Backed Conclusions**

- **India's emissions display clear structural breaks at 2003, 2015, and 2020**, each representing a statistically different growth trend.
- **Growth accelerates in every successive regime**, indicating increasing reliance on energy-intensive development.
- **COVID produced a real but temporary break**, with emissions rebounding onto an even steeper path.
- **The most recent regime (2021–2024) drives a strong upward forecast**, projecting emissions to reach  $\sim$ 6,000 over the next decade.
- **Policy efforts, if any, have not yet produced a measurable structural slowdown in trend**, based on the data up to 2024.