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FEATURE

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# Environmental quality in India: Application of environmental Kuznets curve and Sustainable Human Development Index

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## Abstract

This study explores the trend of selected air pollutants, carbon dioxide ($CO_2$), nitrogen dioxide $NO_2$), sulfur dioxide ($SO_2$) and particulate matter 10 microns in diameter ($PM_{10}$) in India. Environmental Kuznets curves (EKC), which show the association of the economy and pollution, are fitted for selected Indian states to understand whether EKC in India fits well with the inverted “U” shape. We observed that $CO_2$ and $PM_{10}$ are steadily increasing in India. The states of Kerala and Punjab follow the inverted “U” shape of EKC, while Bihar, Uttar Pradesh, West Bengal, and Maharashtra may take decades to reduce pollutants. A new Sustainable Human Development Index calculated in this paper indicates a diverse picture of Indian states, especially in regard to environmental parameters. The government needs to implement stringent, state-specific laws and regulations to assist in curbing air pollutants. The time has also come to represent the rankings of states in terms of an environmentally inclusive development index.

## 1 | INTRODUCTION

Sustainable policies depend on the level, quality, and management of renewable and nonrenewable natural resources and on the condition of the environment. The global environment is changing in a unique manner in response to human activities. Greenhouse gases, such as carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), methane ($CH_4$), and ozone ($O_3$), as well as other pollutants, such as suspended particulate matter (SPM), are being released into the atmosphere along with other emissions. The natural environment is part and parcel of development. The size and structure of an economy is also fundamentally shaped by the environment. This is true from local to global economies. Economic activity, in turn, changes the environment through the use of resources and the generation of pollution and wastes.

Economic development without environmental considerations can cause serious environmental damage, impairing the quality of life of present and future generations. Sustainable development attempts to strike a balance between the demands of economic development and the need to protect the environment. The analytical paradigm of economy and environment was enriched in the late 1980s to reflect concerns about environmentally sustainable economic growth. Although, the term “sustainable development” has many interpretations, it generally refers to non-declining human well-being over time. Sustainable development was defined by the 1987 Brundtland Commission as meeting “the needs of the present without compromising the ability of future generations to meet their own needs” (Kates, Parris, & Leiserowitz, 2005, p. 8).

All economic activities either affect or are affected by natural and environmental resources. Activities such as extraction, processing, manufacturing, transporting, consumption, and disposal change the stock of natural resources, add stress to environmental systems, and introduce wastes to environmental media. The ecology of increasing incidence of diseases is exceedingly complex because of the biology and diversity of infectious organisms and how they are affected by environmental degradation (Anderson, 1992; Desai, 1998; Brock & Taylor, 2005; McMichael, 2001; Pimentel et al., 1998; Weiss & McMichael, 2004). Most countries face a variety of environmental problems with differing intensities that call for immediate action, both at the national and international levels. Although environmental problems affect all humans, the poor typically bear the brunt of environmental exposures and problems due to their lack of capabilities and resources to alleviate the effects of environmental degradation.

In the 1980s, ozone layer depletion, global warming, and biodiversity loss led to a debate on the impacts of environmental degradation on economic growth. As a result, the emphasis of the debate was moved from the source to the sink (Magnani, 2000; Andreoni & Levinson, 2001; Barbier, 1997; Stern, 2004; Van Alstine & Neumayer, 2010). The environmental Kuznets curve (EKC) hypothesis posits that in the early stages of economic development, environmental degradation will increase until a certain level of income is reached (known as the turning point), and then environmental improvement will occur

  

(Van Alstine & Neumayer, 2010). This relationship between per capita income and pollution is often shown as an inverted U-shaped curve. This curve is named after economist and statistician Simon Kuznets, who hypothesized that economic inequality increases over time, and then, after a threshold is reached, per capita income increases (Uchiyama, 2016). Grossman and Krueger (1991) estimated EKCs for sulfur dioxide ($SO_2$), particulate matter, and SPM, considering World Health Organization published data that represent varying levels of economic development and geographical conditions (Bennett, Kretzschmar, SklandHenk, & de Koning, 1985). These authors considered some related indicators, such as the population density of a city and the geographical location, such as desert, continental, or coastal areas. Bennett et al. (1985) stated that the concentration of SPM appeared to decline, even at low-income points in an economy.

As part of the background study for the 1992 World Development Report (International Bank for Reconstruction and Development, 1992), Shafik and Bandyopadhyay (1992) estimated EKCs for 10 different indicators of environmental degradation. These indicators are:

- Ambient levels of SPM,
- Ambient $SO_2$,
- Changes in forest cover,
- Annual rate of deforestation,
- Lack of clean water,
- Lack of urban sanitation,
- Dissolved oxygen in rivers,
- Fecal coliforms in rivers,
- Municipal waste per capita, and
- Carbon emission per capita.

Their study is based upon three different models: log-linear, log-quadratic, and log-cubic. Shafik and Bandyopadhyay (1992) found that the lack of clean water and poor urban sanitation indicates decline, even with increasing gross domestic product (GDP) per capita and over time. The scale and seriousness of India's environmental problems are no longer in doubt, and they are a result of the country's extremely rapid economic growth. The law of ecosystem services suggests that among Indian states, there is variation in terms of productivity. The environmental productivities have decreased more in high-income states than in low-income states. A combined effect of income on environmental productivity is negative, which answers the question of why productivity has declined faster in developed states in India than in their less developed counterparts (Managi & Jena, 2008). Developing countries such as India undoubtedly find the Kuznets verdict between economic growth and environmental development tedious. Using the Kuznets model, it has been found that, after 1990, India's $CO_2$ emission growth rate is lower than its GDP growth rate. The Indian economy witnesses inverted U shaped EKC for $CO_2$ emission, implying that India follows the EKC, as stated by Sinha and Bhatt (2016).

*Using the Kuznets model, it has been found that, after 1990, India's $CO_2$ emission growth rate is lower than its GDP growth rate.*

This paper addresses the following questions:

- What amounts of environmental pollutants will be emitted in the near future, considering major pollutants such as $CO_2$, nitrogen dioxide ($NO_2$), and particulate matter 10 microns in diameter ($PM_{10}$)?
- Will deforestation be increasing in the near future?
- What is the association between various environmental parameters and economic growth in India?
- What is the shape of the EKCs in selected states of India?
- What would the development index of India be if selected environmental indicators are included within the Human Development Index (HDI), a currently established function that uses Indian Census data (Sen, 2000)?

## 2 | DATA AND METHODS

We used a variety of data sources in our research, culling data from the Indian Central Pollution Control Board; Oak Ridge National Laboratory in the United States; The International Monetary Fund; Ghoshal and Bhattacharyya's study on $CO_2$ Emissions, India 1980–2000 (Ghoshal & Bhattacharyya, 2007); Indian Census data from 1981, 1991, 2001, and 2011; (Office of Registrar General and Census Commission, 1981, 1991, 2001, & 2011) Forest Survey of India (2015); and the United States Dollar and Indian Rupee (INR) year exchange rate history (Yahoo Finance, 2014).

Projections of environmental pollutants such as $CO_2$, $SO_2$, $NO_2$, and $PM_{10}$ are made in this study. To project $SO_2$ and $NO_2$ (2004–2018) and forest cover (1995–2018), polynomial regressions are used, where the base value is considered as constant GDP in INR (2014–2018).

EKCs are constructed using three models: log-linear, log-quadratic, and log-cubic to explore the relationship between income (constant GDP and per capita GDP) and selected environmental indicators. The functions are:

log-linear function:

$$\mathrm{Ei} = a_1 + a_2 \log Y + a_3 \mathrm{time}$$

log-quadratic function:

$$\mathrm{Ei} = a_1 + a_2 \log Y + a_{32}(\log \gamma)_2 + a_4(\log \gamma)_3 \ \mathrm{time}$$

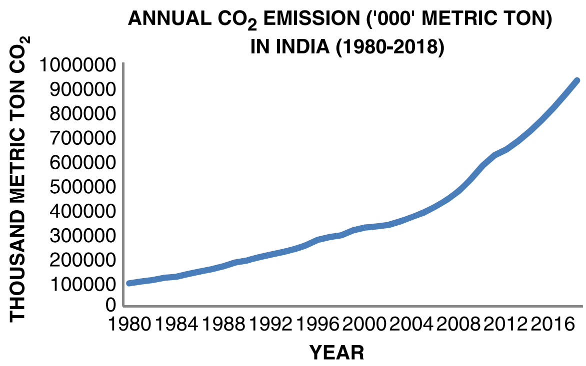


**EXHIBIT 1** Trend of $CO_2$ emissions in India [Color figure can be viewed at wileyonlinelibrary.com]

log-cubic function:

$$\text{Ei} = a_1 + a_2 \log Y + a_{32}(\log \gamma)_2 + a_{43}(\log \gamma)_2 + a_5 \text{time}$$

where Ei is environmental parameter; $a_1$ is constant value; $a_2$, $a_3$, $a_4$, and $a_5$ are determined values, and log $Y$ is log value of GDP.

We constructed EKCs for specific states of India. States are selected considering their unique contexts of development. For example, Punjab and Maharashtra have good economic indicators in terms of GDP. Kerala has shown good social development. West Bengal is one of the most diversified states compare to others, while Uttar Pradesh and Bihar are poor in regard to socioeconomic conditions.

For calculating development indices, similar methodology is applied as it is done for HDI, 2000, (Sen, 2000).

In brief, two development indices calculated for this study are as follows:

- Development index 1 or HDI = GDP + Life expectancy at birth + Education (Gross enrollment: primary, secondary, and tertiary + adult literacy).
- Development index 2 or SHDI (Sustainable Human Development Index) = GDP + Life expectancy at birth + Education (Gross enrollment: primary, secondary, and tertiary + adult literacy) + $CO_2$ Index + Household facilities (Safe drinking water + Bathroom, latrine facility, and wastewater outlet).

GDP is taken at constant GDP price. For calculating the new development index, household facilities, such as safe drinking water, availability of bathroom and latrine facilities, and wastewater outlets, are considered. $CO_2$ emissions are included in this new index, as it is one of the important pollutants of the environment (Allen & Stocker, 2014). The highest and lowest value of per capita $CO_2$ emissions of the world are considered, that is, the United States of America (19.7 $CO_2$ emission per capita, 2001) and Afghanistan (0.027 $CO_2$ emission per capita, 2001), indicate the two extreme values (World Development Bank, 2001). State-wise $CO_2$ emissions in India were projected with the help of linear regression.

$$CO_2\text{Index} = \frac{Xi - 0.027}{19.7 - 0.027}$$

where $xi$ is actual $CO_2$ emission.

For inclusion of $CO_2$ in the development index, the actual values are subtracted from 1. Household facilities, such as sanitation and access to safe drinking water, are considered for measuring development Index 2. According to census data from 2001 (Office of Registrar General and Census Commission 2001), taps, hand pumps, and tube wells are considered as producing safe drinking water. The value of safe drinking for indexing is as follows:

$$\text{Safe drinking water}(\%) = \frac{\textit{No. of households using drinking water from tap, hand pump, and tube well}}{\textit{Total no. of households}} \times 100$$

$$\text{Safe Drinking Water (SDW) Index} = \frac{SDW(\%) - 0}{100 - 0}$$

For sanitation, three types of facilities are considered, these are—bathroom, toilet, and wastewater outlet facilities.

$$\text{Bathroom facility in percent} = \frac{\textit{Total no. of households having bathroom facilities}}{\textit{Total no. of households}}$$

$$\text{Latrine facility in percent} = \frac{\textit{Total no. of households having pit latrine, water closet, and other latrine}}{\textit{Total no. of households}} \times 100$$

$$\text{Wastewater outlet in percent} = \frac{\textit{Closed drainage and open drainage having households}}{\textit{Total no. of households}} \times 100$$

$$\text{Sanitation} = (1/3 \times \text{Bathroom facility}) + (1/3 \times \text{Latrine facility}) + (1/3 \times \text{Wastewater outlet})$$

So, the household facility index is:

$$\text{Household Facility Index} = (1/2 \times \text{Sanitation}) + (1/2 \times \text{Safe drinking water})$$

## 3 | RESULTS

### 3.1 | Pollutants, forest cover, and EKC of India

The most important environmental parameter, $CO_2$ emissions, has increased 10-fold from 1980 to 2018 (**Exhibit 1**). However, $SO_2$ emissions have been decreasing over time (**Exhibit 2**), as have emissions of $NO_2$ over specific time periods (**Exhibit 3**). From 2004 to 2010,

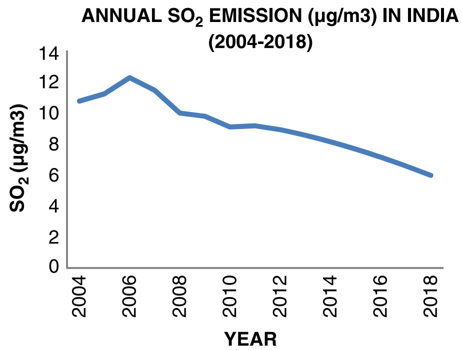


**EXHIBIT 2** Trend of $SO_2$ emissions in India
Note: $\mu g/m^3$, micrograms per cubic meter.
[Color figure can be viewed at wileyonlinelibrary.com]

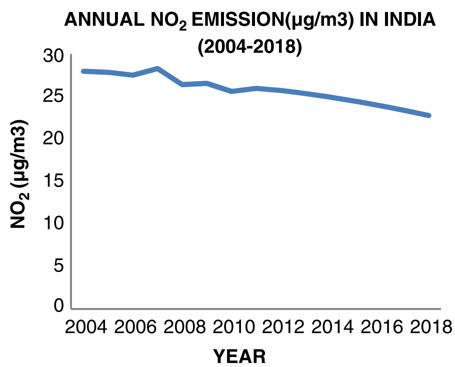


**EXHIBIT 3** Trend of $NO_2$ emissions in India
Note: $\mu g/m^3$, micrograms per cubic meter.
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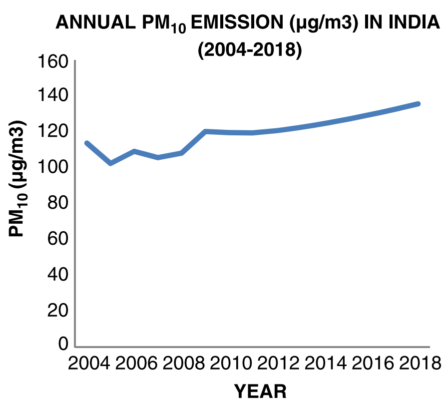


**EXHIBIT 4** Trend of $PM_{10}$ emissions in India
Note: $\mu g/m^3$, micrograms per cubic meter.
[Color figure can be viewed at wileyonlinelibrary.com]

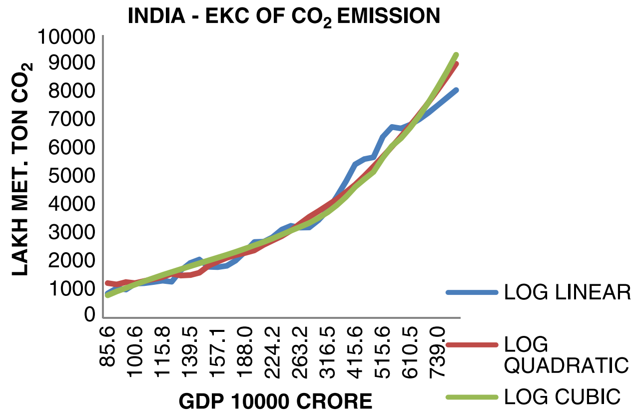


**EXHIBIT 6** Fitting of EKC with selected environmental parameters in India—$CO_2$ emissions [Color figure can be viewed at wileyonlinelibrary.com]

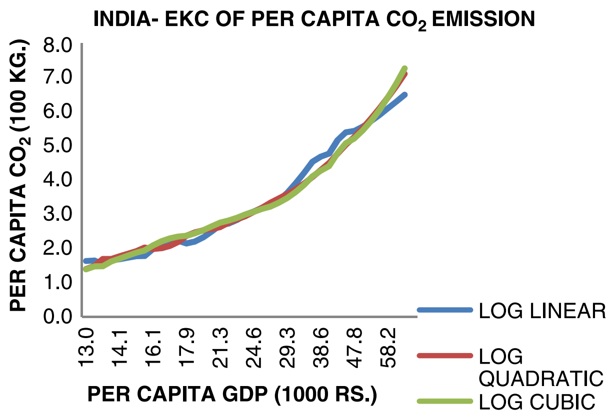


**EXHIBIT 7** Fitting of EKC with selected environmental parameters in India—per capita $CO_2$ [Color figure can be viewed at wileyonlinelibrary.com]

the annual emissions of $NO_2$ fluctuated. However, after some time, they have shown a decline. **Exhibit 4** shows that $PM_{10}$ emissions have increased over time.

**Exhibit 5** shows total forest cover in India is increasing from 1995 to 2018. According to India's National Forest Policy, the country should maintain forest cover of at least 33% (Joshi, Pant, Kumar, Giriraj, & Joshi, 2011). By 2018, India may achieve approximately 32% forest cover.

As **Exhibits 6** and **7** show, it has been observed in India that $CO_2$ emissions and GDP (total and per capita) are showing steady increases.

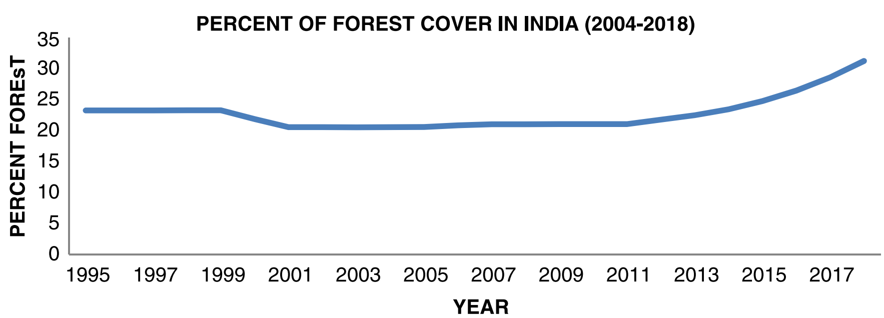


**EXHIBIT 5** Trend in forest cover in India [Color figure can be viewed at wileyonlinelibrary.com]

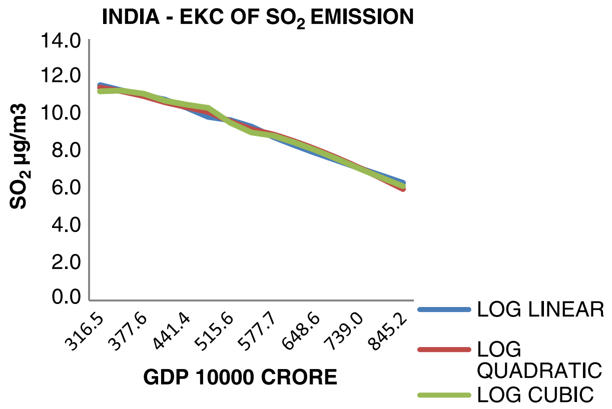


**EXHIBIT 8** Fitting of EKC with selected environmental parameters in India—$SO_2$ emissions
Note: $\mu$g /m$^3$, micrograms per cubic meter.
[Color figure can be viewed at wileyonlinelibrary.com]

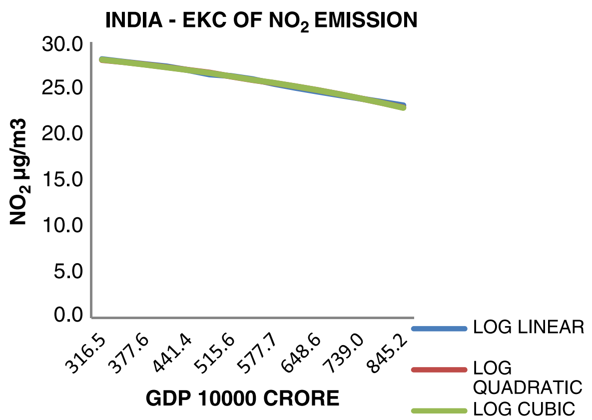


**EXHIBIT 9** Fitting of EKC with selected environmental parameters in India—$NO_2$ emissions
Note: $\mu$g /m$^3$, micrograms per cubic meter.
[Color figure can be viewed at wileyonlinelibrary.com]

India has not yet reached the level at which its EKC has stabilized and begins to move downward. In the cases of the EKCs for $SO_2$ (**Exhibit 8**) and $NO_2$ (**Exhibit 9**), however, we observed downward slopes, indicating that the EKC may not fit in a similar fashion with all environmental parameters. In the case of $PM_{10}$ (**Exhibit 10**) and forest cover (**Exhibit 11**), the slopes of EKCs are upward.

EKC variation is well observed among the states, as well. The EKC of Maharashtra (**Exhibit 12**) shows the same result as is observed for India as a whole. In the case of Punjab (**Exhibit 13**), the EKC fit is far better than in many other states of India, and its trend indicates that it will be declining in the near future.

In the case of the southern states of India, Kerala (**Exhibit 14**) shows encouraging status with its EKC for $CO_2$. For example, after 2010, its GDP is increasing steadily, but $CO_2$ emissions are remaining stable. The curve is indicating a decline within the next few years. On the other hand, as **Exhibit 15** shows, the EKC of $CO_2$ for West Bengal is moving upward, while the EKCs of Uttar Pradesh and Bihar ($CO_2$ and per capita $CO_2$ with GDP) also show upward movement (**Exhibits 16** and **17**, respectively). There is no sign of decline of $CO_2$ emission with an increase of GDP, post 2018, in these two states.

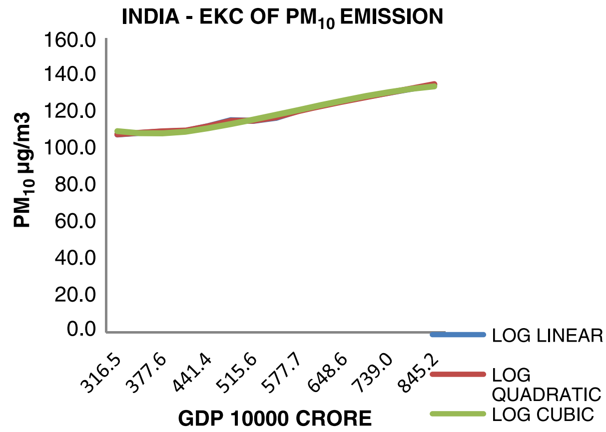


**EXHIBIT 10** Fitting of EKC with selected environmental parameters in India—$PM_{10}$ emissions
Note: $\mu$g /m$^3$, micrograms per cubic meter.
[Color figure can be viewed at wileyonlinelibrary.com]

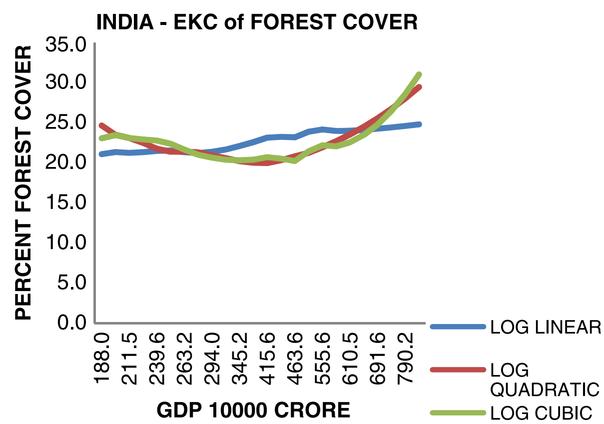


**EXHIBIT 11** Fitting of EKC with selected environmental parameters in India—percentage of forest cover [Color figure can be viewed at wileyonlinelibrary.com]

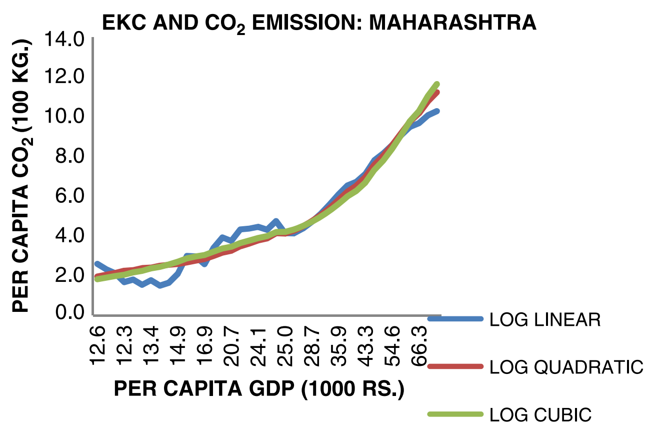


**EXHIBIT 12** State-specific EKCs of $CO_2$—Maharashtra [Color figure can be viewed at wileyonlinelibrary.com]

## 3.2 | Development indices (HDI and SHDI)

Using development index 1 (HDI), where three parameters are considered (education, GDP, and life expectancy at birth), Kerala is revealed

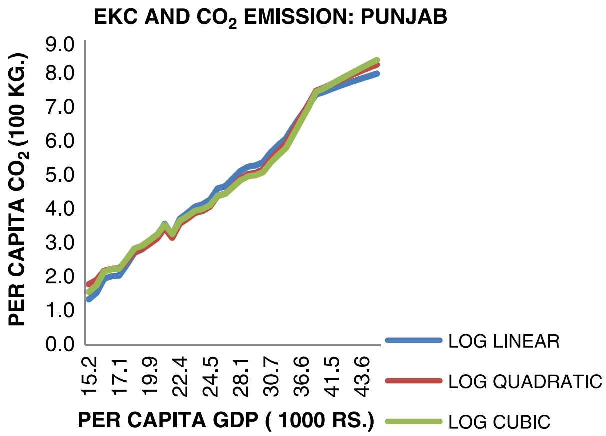


**EXHIBIT 13** State-specific EKCs of $CO_2$—Punjab [Color figure can be viewed at wileyonlinelibrary.com]

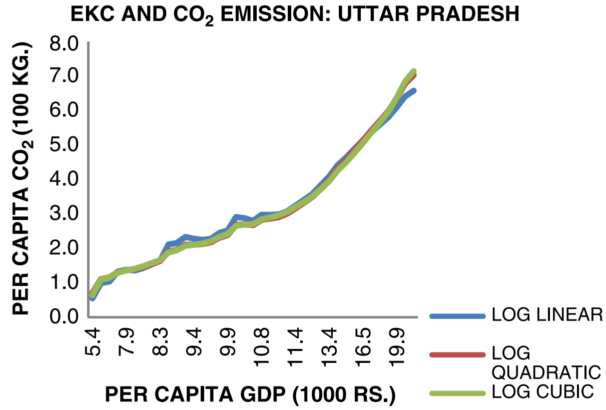


**EXHIBIT 16** State-specific EKCs of $CO_2$—Uttar Pradesh [Color figure can be viewed at wileyonlinelibrary.com]

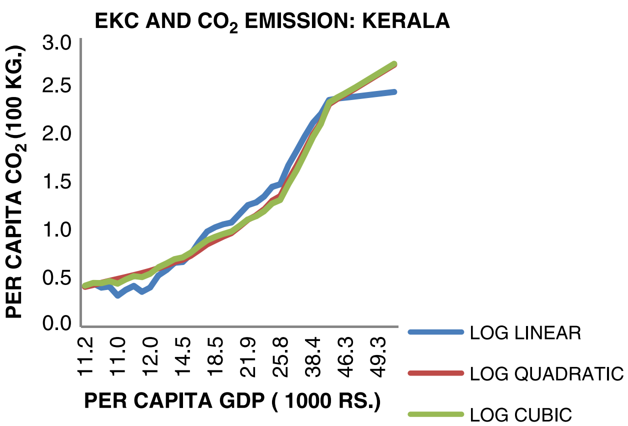


**EXHIBIT 14** State-specific EKCs of $CO_2$—Kerala [Color figure can be viewed at wileyonlinelibrary.com]

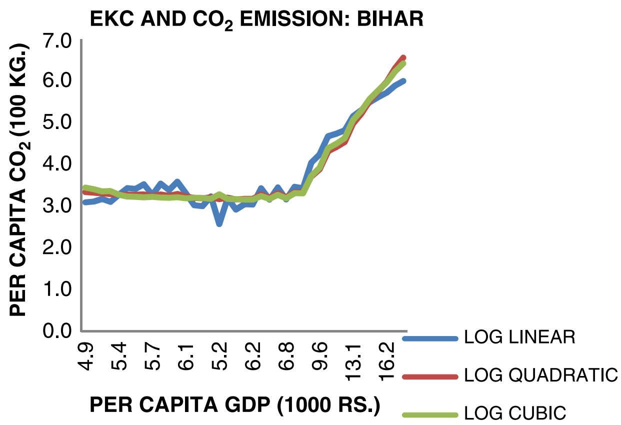


**EXHIBIT 17** State-specific EKCs of $CO_2$—Bihar [Color figure can be viewed at wileyonlinelibrary.com]

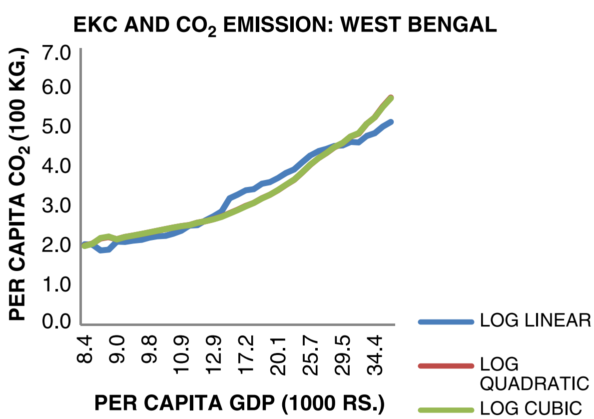


**EXHIBIT 15** State-specific EKCs of $CO_2$—West Bengal [Color figure can be viewed at wileyonlinelibrary.com]

as the most highly developed state in the country. As expected, Kerala has maintained the most favorable condition for development. Out of all of the states, a large proportion—14 states—have HDI values of less than 0.5. Bihar has the lowest HDI value of all of the states, with an index value of 0.365. Uttar Pradesh, Arunachal Pradesh, Jharkhand, Madhya Pradesh, Chhattisgarh, Orissa, Assam, Rajasthan, Andhra Pradesh, Jammu Kashmir, Uttaranchal, West Bengal, and Karnataka also have low development index values, meaning values of less than 0.5. States such as Chandigarh, Goa, Pondicherry, and Mizoram, which have index values of more than 0.55, are more developed compared to other Indian states (**Exhibit 18**).

After the addition of household facilities (bathroom facility, latrine facility, wastewater outlet, and safe drinking water) and per capita $CO_2$ emissions as environmental parameters in the new development index 2 (SHDI), some states reveal distinct changes in their development rankings in comparison with their rankings under development index 1. States such as Haryana, Karnataka, Punjab, and Uttaranchal improved their development rank in index 2 compared to index 1. However, five Northeastern states—Manipur, Mizoram, Meghalaya, Tripura, and Sikkim—saw their development rankings decline. The development rankings of the remaining states showed little change in their rankings regardless of which index was used (**Exhibit 19**). The table in **Exhibit 20** shows the HDI and SHDI for Indian states in tabular form.

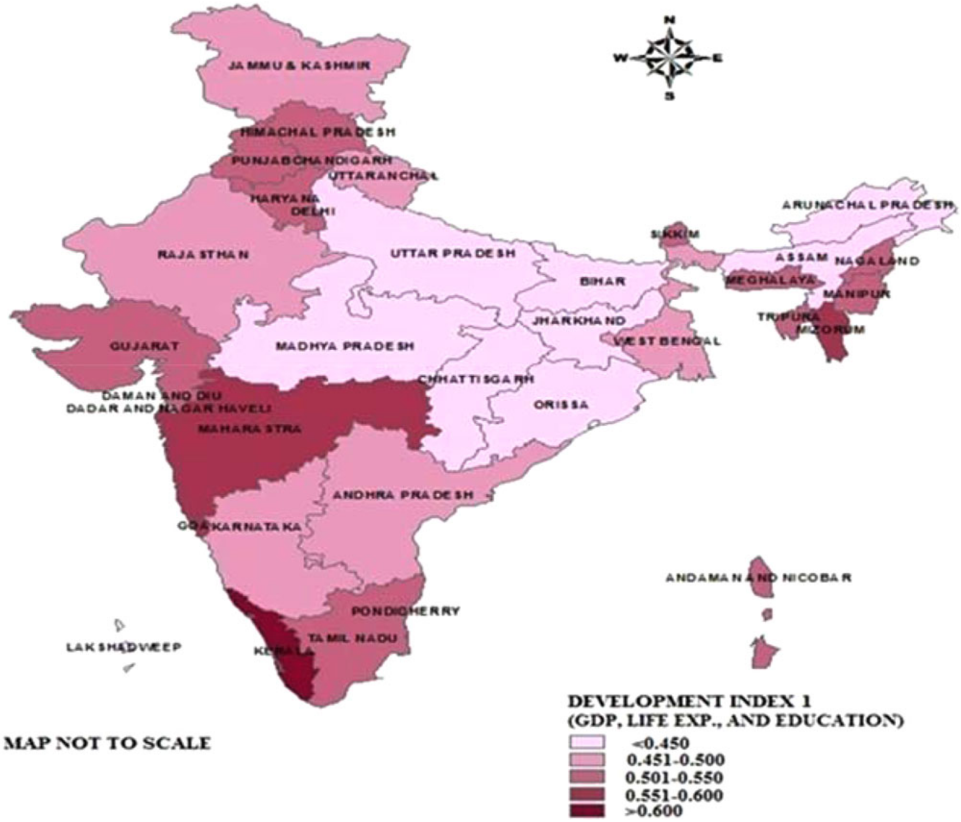


**EXHIBIT 18** Human Development Index (HDI) map of India (2001) [Color figure can be viewed at wileyonlinelibrary.com]

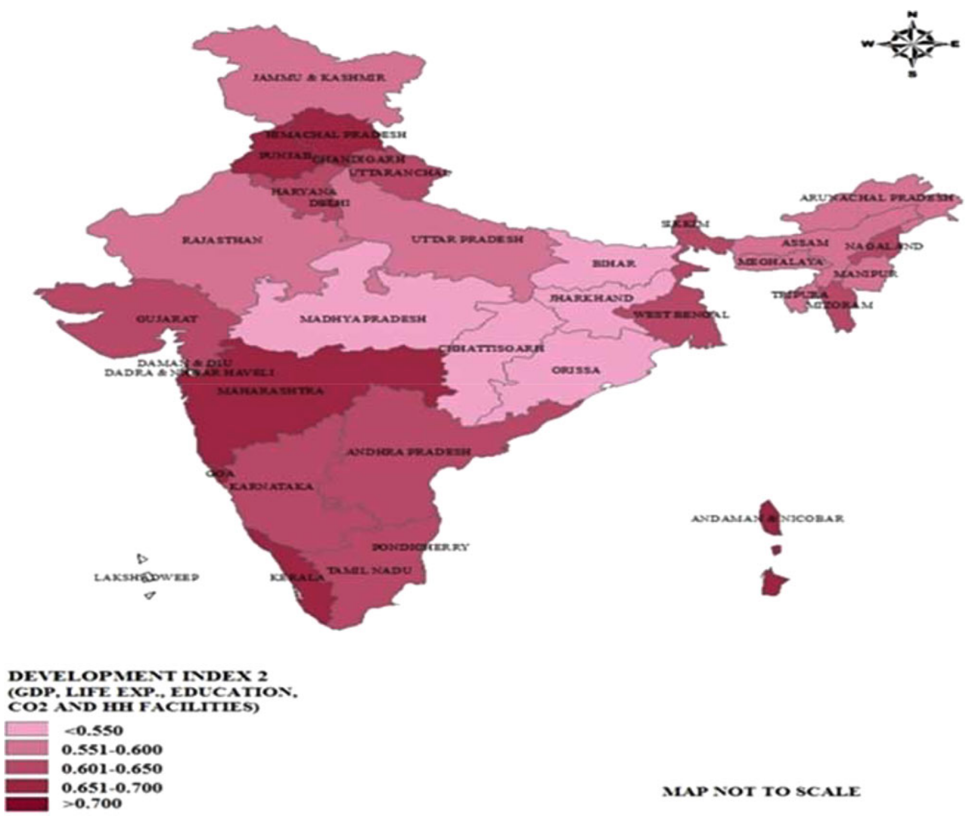


**EXHIBIT 19** Sustainable Human Development Index of India (2001) [Color figure can be viewed at wileyonlinelibrary.com]

**EXHIBIT 20** Human Development Index and Sustainable Human Development Index of Indian states

| States | (HDI) index 1 | Rank for index 1 | (Sustainable HDI) index 2 | Rank for index 2 |
|---|---|---|---|---|
| Andhra Pradesh | 0.4654 | 23 | 0.6138 | 18 |
| Andaman | 0.5287 | 10 | 0.6634 | 7 |
| Arunachal Pradesh | 0.4206 | 30 | 0.5982 | 21 |
| Assam | 0.4461 | 25 | 0.5912 | 23 |
| Bihar | 0.3651 | 32 | 0.5256 | 31 |
| Chandigarh | 0.6252 | 1 | 0.7534 | 1 |
| Chhattisgarh | 0.4302 | 27 | 0.5440 | 29 |
| Delhi | 0.5477 | 7 | 0.6782 | 6 |
| Goa | 0.5920 | 3 | 0.6820 | 5 |
| Gujarat | 0.5092 | 15 | 0.6326 | 13 |
| Haryana | 0.5094 | 14 | 0.6464 | 10 |
| Himachal Pradesh | 0.5462 | 8 | 0.6588 | 9 |
| Jharkhand | 0.4224 | 29 | 0.5158 | 32 |
| Jammu & Kashmir | 0.4680 | 22 | 0.5974 | 22 |
| Karnataka | 0.4975 | 19 | 0.6328 | 12 |
| Kerala | 0.6097 | 2 | 0.6846 | 3 |
| Maharashtra | 0.5507 | 6 | 0.6604 | 8 |
| Manipur | 0.5036 | 18 | 0.5804 | 24 |
| Meghalaya | 0.5081 | 16 | 0.5784 | 25 |
| Mizoram | 0.5634 | 5 | 0.6302 | 15 |
| Madhya Pradesh | 0.4280 | 28 | 0.5468 | 28 |
| Nagaland | 0.5047 | 17 | 0.6074 | 19 |
| Orissa | 0.4312 | 26 | 0.5342 | 30 |
| Pondicherry | 0.5833 | 4 | 0.6849 | 2 |
| Punjab | 0.5291 | 9 | 0.6836 | 4 |
| Rajasthan | 0.4581 | 24 | 0.5746 | 26 |
| Sikkim | 0.5227 | 11 | 0.6256 | 16 |
| Tamil Nadu | 0.5224 | 12 | 0.6378 | 11 |
| Tripura | 0.5192 | 13 | 0.6006 | 20 |
| Uttar Pradesh | 0.3883 | 31 | 0.5596 | 27 |
| Uttaranchal | 0.4861 | 21 | 0.6310 | 14 |
| West Bengal | 0.4960 | 20 | 0.6170 | 17 |

## 4 | CONCLUSION

This paper sought linkages between environmental conditions and economic conditions in India. It portrays the past, present, and future scenarios of emissions of some important pollutants, such as $CO_2$, $SO_2$, $NO_2$, and $PM_{10}$. $CO_2$ and $PM_{10}$ are continuing to increase over time and require both policy attention and stringent regulation. India is emitting huge amounts of $CO_2$, and these emissions are not declining over time. $CO_2$ emissions are a matter of concern today and tomorrow, as well as for future generations. India's energy supply largely depends on coal, because of the accessibility of its ample coal reserves. Various national and international agencies have projected coal to be dominant supplier of India's energy. Compared to coal found in other parts of the world, the burning of Indian coal generates especially high $CO_2$ emissions. As a result, the Indian economy faces the challenge of balancing economic growth and environmental protection like other developing economies in the world (Kanjilal & Ghosh, 2013).

In regard to forest cover, forests have the potential to reduce pollution levels. According to this study, India will be covered by approximately 32% forest cover by 2018—a good sign of an enhancement of an important pollution sink. After 1998, forest cover increased because of various policy measures and awareness about forest.

Anthropogenic $SO_2$ emissions come from many sources, primarily from the combustion of sulfur-containing fossil fuels, such as coal and oil. However, the decreasing trend in $SO_2$ and $NO_2$ emissions levels may be due to various measures taken to reduce vehicular emissions through greater pollution controls and emissions norms, as vehicle emissions are also a source of $SO_2$, especially. Furthermore, the high ash content of Indian coal may lead to high PM emissions. Although all coal plants in India have electrostatic precipitators, the high ash content of coal and its chemical composition reduce their removal efficiency (Pandey, Singh, Singh, Singh, & Yunus, 2011; Pappu, Saxena, & Asolekar, 2007). There is also the problem of fly ash disposal. Other sources of PM are vehicles, natural dust, facilities such as coal-fired power plants, and industries involving sugar processing, cement manufacturing, and the like.

The EKCs of the various environmental indicators discussed in this article vary at different levels of GDP. This means that EKCs may not necessarily be the same for all components over the same time and in a given space. In addition, different states within the country reveal varying environmental conditions at varying levels of State Gross Domestic Product. Hence, there could be considerable variability among EKCs in the states within a country depending on their levels of development. Together, all such EKCs form the national EKCs that may or may not conform with state scenarios.

The new development index, SHDI, or development index 2, which was calculated in this paper, indicates some clear pictures of the conditions of different states in India, especially in regard to environmental parameters. Almost all of the small states in the northeast part of India are lagging behind in basic facilities, such as drinking water and sanitation, and their state rankings are lower under development index 2 than under the HDI or development index 1. Some of the larger states are losing their higher rankings using this new index, mainly due to their high per capita $CO_2$ emissions.

The key environmental challenges that India faces are related to the nexus of environmental degradation with poverty in its many dimensions as well as economic growth. These challenges are intrinsically connected to the state of environmental resources, such as land, water, air, and accompanying flora and fauna. The Indian economy is a brown economy that creates environmental damage. Therefore, it is the time to adopt a green economy. Public participation is an essential ingredient of environment management along with other components, such as regulation and the use of economic instruments.

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