ENERGY INTENSITY AND CO_2 EMISSIONS: INDIA'S PROGRESS TOWARDS ENERGY AND CLIMATE CHANGE MITIGATION GOALS

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Overview

Improvements in energy efficiency and adoption of renewable energy sources are the key to addressing the energy and climate change challenge globally. The demand for energy and related CO_2 emissions have been growing due to the overall economic growth. The growth is being offset by a decline in energy intensity and carbon intensity of energy. India's primary commercial energy supply increased four folds in 2017 since 1990. As per the estimates by International Energy Agency (IEA), the energy-related CO_2 emissions had grown from 528 Mt in 1990 to 2161 Mt in 2017. The CO_2 emissions per unit of economic output declined steadily from 1991 to mid-2000s, remained at a higher level until 2014 and is now again declining (Fig. 2). There are multiple factors that contribute to this decline - structural changes, energy efficiency improvements and changes in the carbon content of the energy. In this paper, we study the drivers of India's energy-related CO_2 emissions during 1994-2016 and in two sub-periods 1994-2005 and 2005-2016 using index decomposition analysis (IDA)(Ang, 2005). There are few studies that have examined India's CO_2 emissions using IDA (Paul and Bhattacharya, 2004; Nag and Parikh, 2000). This paper analyses the most recent data using improved techniques for estimating the effects of underlying drivers under IDA.

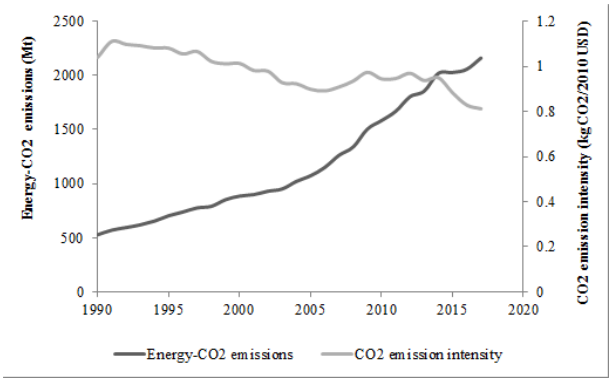

Figure 1: India's CO2 emissions and emission intensity (Source: IEA Database)

Methods

We decompose the total CO_2 emissions into four factors - population effect, income effect, energy intensity effect and carbon intensity effect (Eq. 1). We also decompose the emissions from the three value-adding sectors - agriculture, industry and services into five factors - population effect, income effect, structure effect, sectoral energy intensity effect, carbon intensity effect (Eq. 4).

Four-factor decomposition

$$CT_t = P_t \times \frac{GDP_t}{P_t} \times \frac{E_t}{GDP_t} \times \frac{CT_t}{E_t} \tag{1}$$

Where, CT_t is the total CO_2 emissions from all sectors of the economy in year t, P_t is the population in year t, E_t is the primary commercial energy supply in year t, GDP_t is the GDP in year t.

To simplify the notation we write, $\frac{GDP_t}{P_t} = G_t$ and $\frac{E_t}{GDP_t} = I_t$ and $\frac{E_t}{CT_t} = C_t$, so that,

$$CT_t = \underbrace{P_t}_{\text{population effect}} \times \underbrace{G_t}_{\text{income effect}} \times \underbrace{I_t}_{\text{energy intensity effect}} \times \underbrace{C_t}_{\text{carbon intensity effect}} \tag{2}$$

The change in the emissions from year 0 to T is calculated as

$$\Delta CT_{tot} = CT_T - CT_0 = \Delta CT_P + \Delta CT_G + \Delta CT_I + \Delta CT_C \tag{3}$$

Sectoral five-factor decomposition

$$CV_t = \sum_i CV_{it} = \sum_i P_t \times \frac{VA_t}{P_t} \times \frac{VA_{it}}{VA_t} \times \frac{EV_{it}}{VA_{it}} \times \frac{CV_{it}}{E_{it}} \tag{4}$$

Where, CV_t is the total CO_2 emissions from all value adding sectors
CV_{it} is the CO_2 emissions from value adding sector i in year t
P_t is the population in year t
VA_{it} is the value added by sector i in year t
VA_t is the total value added by all the sectors
EV_{it} is the energy consumption of value adding sector i in year t

To simplify the notation we write, $\frac{VA_t}{P_t} = GV_t$; $\frac{VA_{it}}{VA_t} = S_{it}$; $\frac{EV_{it}}{VA_{it}} = EI_{it}$ $\frac{CV_{it}}{EV_{it}} = C_{it}$
so that,

$$CV_t = \sum_i CV_{it} = \sum_i \underbrace{P_t}_{\text{population effect}} \times \underbrace{GV_t}_{\text{income effect}} \times \underbrace{S_{it}}_{\text{structure effect}} \times \underbrace{EI_{it}}_{\text{sector energy intensity effect}} \times \underbrace{C_{it}}_{\text{carbon intensity effect}} \tag{5}$$

The contribution of each factor in the total change is calculated using Eq 6.

$$\Delta CV_{tot} = CV_t - CV_0 = \Delta CV_P + \Delta CV_{GV} + \Delta CV_S + \Delta CV_{EI} + \Delta CV_C \tag{6}$$

The effect of the contributing factors are calculated using log-mean divisia index technique (LMDI).

Results

The results of the decomposition analysis show that the decline in energy intensity of the economy has partially offset the increase in emissions in the entire study period (Fig 2 (a)). The offset was higher during 1994-2005 as compared to 2005-2016 (Fig 2(b)). At the sectoral level, during 1994-2005, the increase in emissions in industry and services due to income effect was completely offset by energy intensity effect (Fig 2(c)). However, during 2005-2016, the income effect was far greater than the energy intensity effect (Fig 2(d)). The effect of the carbon intensity of energy is negative during 1994-2005 and positive during 2005-2016.

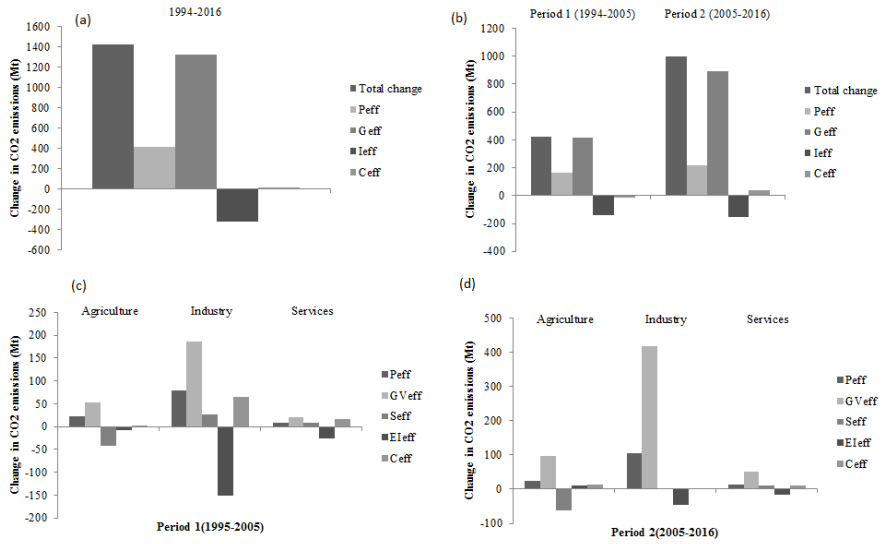

Figure 2: Results of the decomposition analysis: Four-factor decomposition (a)over entire study period, (b) over two sub-period, Sectoral five-factor decomposition over (c)sub-period 1, (d)sub-period 2

Conclusions

India's energy-related CO_2 emissions are rising due to the increase in energy demand. The increase in energy demand is driven by an increase in population and per capita income. Meeting the conflicting objectives of energy security and climate-change mitigation requires that the increase in emissions is offset by a decrease in energy and emission intensity effect. The decomposition analysis presented in this paper show that energy intensity and

emission intensity effect were promising during 1994-2005, but were unable to match the income effect in the last decade. India's has put forth several policies to promote energy efficiency and renewable energy in the last decade. It should be a matter of time that the impact of these policies are seen more clearly on the trends of energy and emission intensity and hence contributing to the country's energy and climate goals.

References

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