Inequality in carbon emissions at sub-national level in India.

INEQUALITY IN CARBON EMISSIONS AT SUB-NATIONAL LEVEL IN INDIA

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ABSTRACT

In this study using standard measures of inequality such as Gini coefficient, Kakwani Index, coefficient of variation and Theil Index we examine inequality in carbon emissions for the years 2000-09 at the sub-national level covering 17 major states of India. At the outset, in order to estimate sub-national inequality in carbon emissions we also estimated total carbon emissions for each state for the above years using IPCC Reference Approach. Our findings showed that per capita carbon emissions were highest in the low income resource rich states and lower in the high income more developed states. The inequality in carbon emissions as demonstrated by Gini coefficients has increased over the years indicating that it is the poorer states which have to bear the burden.

Keywords: Per Capita Carbon Emissions, Sub-National, India, Inequality

INTRODUCTION

Increase in anthropogenic activities has led to the accumulation of greenhouse gases (GHG) in the earth's atmosphere with enormous climatic repercussions with further implications for economic development and people's wellbeing. Some of the major impacts include water shortages; fall in agricultural yields; risk of extinction of plants and animals by 20-30% and sharp increase in climate related disasters (IPCC 2006). While the impact of climate change will be universal, although more in the developing countries, the inequality in carbon emissions across the countries has been a subject of much debate.[1] Different levels of economic development of the countries and conflicting priorities for instance, the predicament of achieving reduction in poverty along with decrease in greenhouse gases emissions have been some of the contentious issues among the countries.

A number of studies have examined inequality in carbon emissions at the national level (Heil & Wodon, 1997; 2000; Padilla & Serrano 2006; Groot 2010; Cantore & Padilla 2010; Duro & Padilla 2006). At the sub-national level however, this remains less examined. The study of sub-national units is particularly important in large countries with considerable internal diversities. Also it provides statistical advantages due to the increase in the sample size and captures the disaggregated spatial effects of national level policies (Snyder 2001).

The only study on inequality in carbon emissions, which we are aware of, at the sub-national level, is that of Clarke-Sather, Jiansheng, Qin, Jingjing and Yan (2011). Using measures of inequality such as coefficient of variation, Gini Index, and Theil index, the study analysed provincial level carbon inequality in China for the years 1997-2007. Such a study for India is non-existent. As the role of China and India in generating carbon emssions is increasing and is expected to increase even further in the future, our study aims to fill this gap in the literature. In this study we therefore examine inequality in carbon emissions at the sub-national level in India.

The choice of India has been motivated by a number of reasons. India has been experiencing high growth rates of around 7-8% in recent years and its energy consumption has also increased as a result of increased development and per capita incomes. IEA (2011) in its World Energy Outlook noted that in the next 25 years, 90% of the global energy demand will be from the non-OECD economies within which the share of China will be 30% and the balance will be from other developing economies such as India and Indonesia. It further noted that while per capita emissions of CO_2 in India at 1.18 tonnes in 2008 was nearly one-fourth of the corresponding global average of 4.38 tonnes, the impact of climate change, nevertheless is expected to be high. The pollution levels in the country have also risen as a result of increased urbanisation and industrialisation. India has already announced to reduce the emissions intensity of its GDP by 20-25% over the 2005 levels by year 2020 (Planning Commission 2011). Also in its commitment to the reduction of carbon emissions, the government has announced a key objective in its Twelfth Five Year Plan (2012-2016) as 'low carbon inclusive growth' (Planning Commission 2011). This strategy entails low carbon policies to be differentiated across sectors with growth which includes all groups of people.

Further, the cross-country studies at the national level fail to address the inequality at the sub-national level which may be particularly high for large countries such as India. India is a large country with 28 states and seven union territories, which are at different stages of development. It would be therefore interesting to examine inequalities at the sub-national level.

A number of studies have also noted that regional disparities have increased significantly in the post-reform period in India (Ahluwalia, 1999, 2002; Bhattacharya & Sakthivel, 2004; Kurian, 2000; Nagaraj, Varoudakis, & Veganzones, 1998; Rao, Shand, & Kalirajan, 1999; Sachs, Bajpai, & Ramiah, 2002; Shand & Bhide, 2000). These studies observed widening of regional disparities in the country especially during the nineties. The widening regional disparity across the states has been a subject of much discussion even in the recent years. Thus, Kanbur (2010) argued that inter-state disparities have increased widely in the post-reform period, particularly between rural and urban areas. Gaur (2010) using standard measures of inequality such as the Gini coefficient, Theil's index, Kakwani index and Atkinson's index, confirmed an increase in inequality across the states especially since the reforms in 1991.

The only study, to our knowledge, which exists for India on carbon emissions at the sub-national level, is Ghoshal and Bhattacharya (2008). The authors therein estimated total carbon emissions in the major Indian states for the period 1980 to 2000. They found that per capita carbon emissions have increased in all the states and the relationship between states' per capita income and CO_2 is that of inverted U shape curve. We extend their study further and in addition to estimating carbon emissions for each state, estimate inequality in carbon emissions across the states. Further, our study covers more recent years 2000 to 2009 spanning a period of high growth rates witnessed in the country and, is therefore, a step ahead of Ghoshal and Bhattacharya (2008), who covered the earlier years 1980-2000.

The major questions which our study raises are: what are the levels of CO_2 emissions at sub-national level in India? Are these higher in high income states? Is the carbon emission inequality similar to the inequality in per capita state domestic product in the states? The results of the study show that per capita carbon emissions were highest in the low income resource rich states. Inequality as revealed by Gini coefficients has increased during the period of our study. The rest of the paper is organised as follows. Section 2 outlines data and methodology used in the study, section 3 reports the results and the last section concludes.

DATA AND METHODOLOGY

Our study considers 17 major Indian states covering around 95 per cent of the country's total population as per the 2011 census. The time frame is 2000 to 2009, a period when Indian growth rates averaged 7.2 per cent. Data for the consumption of fuels has been obtained from indiastat.com. Per capita income data of the states are from Ministry of Planning and Programme Implementation, Government of India and the population data are from Census, Government of India. Following Clarke-Sather, Jiansheng, Qin, Jingjing and Yan (2011), our method of estimation is in two steps: first, we calculate per capita carbon emission for each state for the above period. Subsequently, we estimate inequality in carbon emissions per capita. The consumption of following fuels have been covered in our study: coal, Liquefied Petroleum Gas (LPG); Naptha, motor gasoline, kerosene, aviation turbine fuel, light diesel oil, furnace oil, low sulphur heavy stock, hot heavy stock, high speed diesel oil, bitumen and a miscellaneous category 'others'.

Studies have noted that in India around 68 per cent of the carbon emissions emerge from coal and other solid fuels and approximately 24 per cent emanates from petroleum products (Ghoshal & Bhattacharya 2008). State level time series data for coal consumption was, however, not available to us. We therefore used production of coal in the states to estimate the emissions. Nonetheless, such emission figures may be biased, as coal may be exported and also imported from other states and overseas. Its actual consumption could, therefore, differ from the production within the state. Consumption is a more reliable indicator in this case as it takes into account both exports as well as imports and is an indicator of the final usage of the product.

We, therefore build an alternative series of carbon emissions based on the consumption of coal in the states. In the absence of yearly data on the consumption of coal at the state level, as mentioned above, we consider percentage of carbon emissions emerging from coal for each state as available in Ghoshal and Bhattacharya (2008). We believe this methodology is superior to the production approach outlined above. This may still be biased as the latest figure on the percentage of coal emission is for 2000. Nonetheless, due to data limitations we assume a constant percentage (available for year 2000 for each state separately) for the years 2001 to 2009, although the estimates so derived would tend to be on the higher side as the consumption of coal would tend to decline as income increases as people move on to superior methods of cooking and lighting. Shealy and Dorian (2010), however in the case of China, showed that as the per capita income of the country increased, the energy consumption mainly generated by coal also increased sharply. The contribution of coal in the total carbon emissions in India was 77.1 per cent in 2000 and ranged from 3.5 per cent to 92 per cent across the states. In our study, we have applied these percentages for each individual state and derived total carbon emissions.

The $C0_2$ emissions were obtained by using the IPCC Reference Approach[2] using the guidelines provided by IPCC (2006). The formula used by us for estimating carbon emissions is:

$$T_{CO_{2_{ij}}} = \sum_{i=1}^{n} \left\{ [A_{ij}\, e_{ij}\, c_{ij}] \times 10^{-3} - S_{ij} \right\} o_{ij} \times \frac{44}{12} \qquad (1)$$

Where n is the number of states (17), A_{ij} is the Apparent Fuel Consumption of the i^{th} fuel in the j^{th} state, e_{ij} is the Net Calorific Values (NCV) of the i^{th} fuel, $c_{ij}$is the Carbon Emission Factor (CEF) of the i^{th} fuel, o_{ij} is the i^{th} fuel's fraction of carbon oxidised (OC). S_{ij} is the stored carbon of the i^{th} fuel in the j_{th} state.

Following other studies (Ghoshal & Bhattacharya 2008; Clarke-Sather, Jiansheng, Qin, Jingjing & Yan 2011), we estimate carbon emissions based on the combustion of fossil fuels. Among fossil fuels, petroleum products and coal are the most important in India. The coefficients used in the estimation of emissions are available in the IPCC Guidelines and these are given in Table 1.

TABLE 1. COEFFICIENTS FOR FUELS ACCORDING TO IPCC

Fuel	NCV (*ei*)	CEF *(ci)*	OC(*oi)*/CSR*si*)
Liquid fossil			
Primary fuels			
Crude Oil	42.62	20	0.98
Secondary Fuels			
Gasoline	44.8	18.9	0.98
Kerosene	44.67	19.55	0.98
Diesel oil	43.33	20.2	0.98
Fuel oil	40.19	21.1	0.98
LPG	47.31	17.2	0.98
Naptha	45.01	20	0.8
Bitumen	40.19	22	1
Lubricants	40.19	20	0.5
Other Oil	40.19	20	0.98
Solid Fossil			
Primary Fuels			
Crude coal	20.52	24.74	0.90
Secondary Fuels			
Cleaned Coal	20.52	24.74	0.90
Other washed coal	20.52	24.74	0.90
Briquettes	20.52	24.74	0.90
Coke oven	28.2	29.5	0.97
Coal tar	28.0	22.0	0.75
Gaseous fossil			
Natural Gas	48	15.3	0.99

Source: Clarke-Sather, Jiansheng, Qin, Jingjing and Yan (2011)

We estimate inequality by using dispersion methods such as the coefficient of variation, Gini coefficient, Kakwani index and Theil Index. The coefficient of variation (CV) is the simplest among all the methods and is easily comprehensible. The coefficient of variation is calculated as follows:

$$CV = \frac{\sqrt{\sum_{i=1}^{N}(y_i - \bar{y})^2/N}}{\bar{y}} \quad (2)$$

Where y_i is the per capita CO_2 emissions of state *i*. *N*, as given earlier is the number of states and $\bar{y}$ is the average per capita carbon emission of states.

We further build Gini coefficients for per capita CO_2 emissions. The value of Gini lies from 0 to 1. A value of 0 implies that GHG emissions across states are perfectly equal, while 1 implies that only in one state GHG emissions exist resulting in perfect inequality. It thus measures the extent to which the distribution of emissions deviates from the equal distribution. A high value of Gini coefficient indicates more unequal distribution. Although Gini coefficient satisfies the condition of mean independence, population size independence, symmetry and also Pigou-Dalton Transfer Sensitivity, it cannot be decomposed to show the sources of inequality between regions or sectors. The formula used for calculation of Gini coefficients for per capita carbon emissions is:

$$G_{ghg} = \left[\frac{2}{N\sum_{i=1}^{N} ghg_i}\sum_{i=1}^{N} i \, . \, ghg_i\right] - 1 - \frac{1}{N} \quad (3)$$

Here *N* is the number of states and ghg_i is the per capita CO_2 emissions of the *i*th state by per capita emissions ordered by per capita CO_2 emissions.

We further employ Kakwani index to measure concentration of per capita income and per capita carbon emission. The Kakwani index estimates the extent to which the inequality in the distribution of carbon emissions between rich and poor states is further away from the income inequality in the states, that is, it shows how regressive or progressive the emissions are (Cantore & Padilla 2010). Thus, a negative Kakwani index indicates that greenhouse gas emissions are less concentrated than income and the reverse is true in case of positive number. The formula used for the calculation of Kakwani Index is given below:

$$K = qG_{ghg} - G_i \quad (4)$$

Where G_i is the Gini index of income and qG_{ghg} is the quasi-Gini index of CO_2 emissions. The Gini Coefficient for per capita income is calculated by using the following formula:

$$G_i = \left[\frac{2}{N\sum_{i=1}^{N} y_i}\sum_{i=1}^{N} i \cdot y_i\right] - 1 - \frac{1}{N} \quad (5)$$

The formula for quasi-Gini Index for CO_2 emissions is as follows:

$$qG_{ghg} = \left[\frac{2}{N\sum_{i=1}^{N} ghg_i}\sum_{i=1}^{N} i \, . \, ghg_i\right] - 1 - \frac{1}{N} \quad (6)$$

Here N is the number of states and ghg_i is the per capita CO_2 emissions of the *i*th state lined up by per capita GDP.

We further calculate Theil Index (weighted entropy index). The Theil index can be decomposed and enables one to analyse distribution of regional inequality. The formula for Theil index is as follows:

$$T_{ghg} = \sum_{i=1}^{N} y_i \log(y_i/x_i) \tag{7}$$

Where y_i is the proportion of CO_2 emissions of the *i*th state in the total emissions of all states, x_i is the proportion of population of the *i*th state in the total population of all the states and N is the total number of states.

RESULTS

As stated elsewhere, we build time series trends in per capita carbon emissions for each state based on coal production and coal consumption separately. Based on coal production method, the top three states in total emissions during the period 2000-01 to 2008-09 on average are Maharashtra, Jharkhand and Andhra Pradesh, all located in different regions and with varying per capita income. If the population of states is taken into account, the per capita carbon emission is highest in the states of Chattisgarh, Jharkhand and Orissa.[3] The mean emissions of .54 metric tonnes per capita prevailed during the period 2000-01 to 2008-09. The standard deviation is 0.42 and the coefficient of variation peaked at 2006-07 and has declined since then (Table 2).

The three states with high per capita carbon emissions - Chattisgarh, Jharkhand and Orissa are all low income and also resource rich states. The production of coal, a major source of energy generation in the country, is highest in the above three states and together they contribute more than 55 per cent of the total coal production in the country. Further, major steel plants which consume large quantities of coal are also located in these states. This in turn leads to disproportionately high levels of carbon emissions (Ghoshal & Bhattacharya 2008). A similar such trend was observed by Clarke-Sather, Jiansheng, Qin, Jingjing and Yan (2011) who mentioned that in China certain low income, but resource rich (large coal producers) provinces had the highest level of carbon emissions. The authors concluded that regional differences in energy resources have played a significant role in carbon inequality.

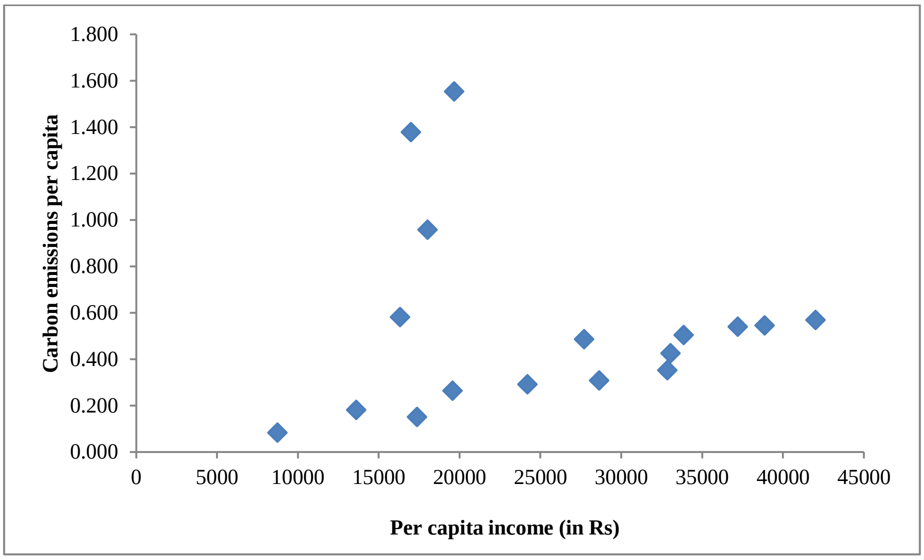
In the Indian context, we further observed that certain low income, but resource poor states had low per capita emissions. On the other hand, certain high income, relatively more developed states, had low per capita carbon emissions as well. Figure 1 displays the relationship between per capita carbon emissions and per capita income of the states. Clearly, it can be seen from the figure that states with high per capita incomes also have low carbon intensity than some low income states.

TABLE 2. PER CAPITA CO_2 EMISSION AT SUB-NATIONAL LEVEL IN INDIA (USING COAL PRODUCTION METHOD)

States	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	Average
Andhra Pradesh	0.432	0.432	0.445	0.433	0.444	0.434	0.468	0.522	0.760	0.486
Assam	0.144	0.149	0.136	0.143	0.152	0.155	0.155	0.161	0.165	0.151
Bihar	0.122	0.084	0.074	0.076	0.074	0.072	0.073	0.082	0.091	0.083
Chhattisgarh	0.527	1.286	1.340	1.417	1.587	1.712	1.837	1.971	2.303	1.553
Gujarat	0.562	0.512	0.485	0.448	0.437	0.382	0.389	0.395	0.928	0.504
Haryana	0.528	0.531	0.531	0.494	0.514	0.517	0.558	0.692	0.754	0.569
Jharkhand	0.607	1.400	1.438	1.426	1.395	1.488	1.511	1.533	1.605	1.378
Karnataka	0.257	0.274	0.276	0.278	0.284	0.276	0.302	0.328	0.503	0.309
Kerala	0.356	0.319	0.353	0.361	0.314	0.303	0.325	0.331	0.508	0.352
Madhya Pradesh	0.737	0.499	0.501	0.524	0.537	0.532	0.556	0.609	0.736	0.581
Maharashtra	0.525	0.523	0.513	0.507	0.517	0.525	0.513	0.575	0.707	0.545
Orissa	0.693	0.720	0.780	0.864	0.945	0.979	1.103	1.211	1.321	0.957
Punjab	0.529	0.554	0.543	0.517	0.536	0.495	0.533	0.559	0.593	0.540
Rajasthan	0.257	0.261	0.267	0.260	0.259	0.218	0.244	0.265	0.347	0.264
Tamil Nadu	0.406	0.390	0.398	0.380	0.384	0.374	0.400	0.430	0.664	0.425
Uttar Pradesh	0.228	0.057	0.206	0.200	0.204	0.191	0.182	0.176	0.190	0.181
West Bengal	0.291	0.307	0.285	0.281	0.294	0.290	0.295	0.291	0.295	0.292
Mean	**0.424**	**0.488**	**0.504**	**0.506**	**0.522**	**0.526**	**0.555**	**0.596**	**0.733**	**0.54**
STD	**0.19**	**0.37**	**0.38**	**0.39**	**0.42**	**0.45**	**0.48**	**0.51**	**0.57**	**0.42**
CV	**43.83**	**75.38**	**74.41**	**76.89**	**79.65**	**86.44**	**86.94**	**86.05**	**77.06**	**76.30**
Lowest	**0.122**	**0.084**	**0.074**	**0.076**	**0.074**	**0.072**	**0.073**	**0.082**	**0.091**	**0.083**
Highest	**0.737**	**1.400**	**1.438**	**1.426**	**1.587**	**1.712**	**1.837**	**1.971**	**2.303**	**1.553**

Source: Author's calculations

FIGURE 1. CARBON EMISSIONS PER CAPITA AND INCOME PER CAPITA



Regionally, per capita carbon emissions were highest in the central region followed by the eastern region (Table 3). As mentioned earlier, these two regions consist of states which are rich in natural resources including coal.

TABLE 3. AVERAGE REGIONAL DISTRIBUTION OF PER CAPITA CO_2 EMISSIONS IN INDIA*

Years	North	Central	East	North-East	West	South
2000-01	0.438	0.497	0.428	0.144	0.543	0.363
2001-02	0.449	0.614	0.628	0.149	0.517	0.354
2002-03	0.447	0.682	0.644	0.136	0.499	0.368
2003-04	0.424	0.714	0.662	0.143	0.478	0.363
2004-05	0.436	0.776	0.677	0.152	0.477	0.356
2005-06	0.410	0.812	0.707	0.155	0.453	0.347
2006-07	0.445	0.858	0.745	0.155	0.451	0.374
2007-08	0.505	0.919	0.779	0.161	0.485	0.403
2008-09	0.564	1.076	0.828	0.165	0.818	0.609
Average	**0.458**	**0.772**	**0.678**	**0.151**	**0.525**	**0.393**

Source: Author's own calculations.
Notes: Using coal production method

The highest carbon emitter states within the country were not only the states with low per capita incomes, but were also poor performers in terms of human development. Infant mortality during the period 2000-09, on an average, was 65.3 deaths for every 1000 live births in Chattisgarh; 52 in Jharkhand and 78.6 in Orissa, a figure comparable to some of the countries in Sub-Saharan Africa.

Based on the methodology outlined earlier, we further estimated per capita carbon emissions based on coal consumption and is shown in Table 4.

TABLE 4. PER CAPITA CO_2 EMISSION AT SUB-NATIONAL LEVEL IN INDIA (USING COAL CONSUMPTION METHOD)

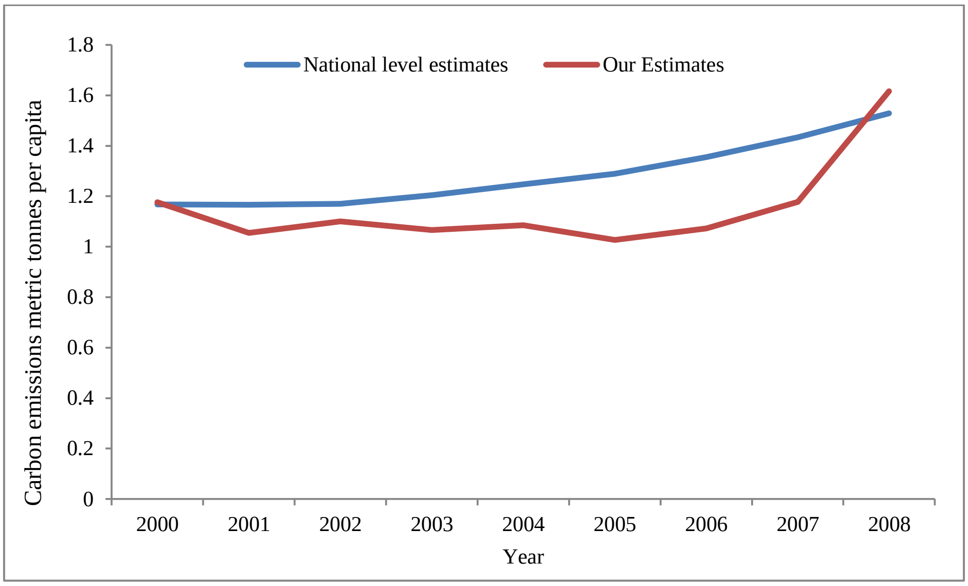
States	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	Average
Andhra Pradesh	1.526	1.520	1.527	1.445	1.470	1.397	1.560	1.804	3.134	1.709
Assam	0.185	0.192	0.175	0.182	0.197	0.194	0.192	0.200	0.208	0.192
Bihar	1.079	0.742	0.652	0.669	0.655	0.638	0.644	0.723	0.800	0.734
Gujarat	1.382	1.259	1.193	1.103	1.074	0.939	0.958	0.972	2.284	1.240
Haryana	1.052	1.058	1.058	0.984	1.024	1.030	1.112	1.378	1.502	1.133
Karnataka	0.656	0.699	0.703	0.708	0.723	0.703	0.770	0.835	1.282	0.786
Kerala	0.368	0.331	0.366	0.374	0.325	0.314	0.336	0.343	0.526	0.365
Madhya Pradesh	2.539	2.089	2.058	2.053	2.059	1.824	1.857	1.930	3.288	2.189
Maharashtra	1.488	1.450	1.411	1.370	1.391	1.402	1.366	1.608	2.082	1.507
Orissa	1.711	1.665	1.833	1.784	1.934	1.883	1.980	2.254	2.470	1.946
Punjab	1.722	1.804	1.768	1.681	1.743	1.609	1.734	1.818	1.928	1.756
Rajasthan	0.603	0.611	0.627	0.610	0.607	0.512	0.571	0.622	0.813	0.619
Tamil Nadu	1.121	1.077	1.100	1.048	1.061	1.031	1.105	1.187	1.832	1.174
Uttar Pradesh	1.022	0.068	0.893	0.890	0.904	0.851	0.810	0.835	0.905	0.798
West Bengal	1.186	1.259	1.151	1.094	1.119	1.069	1.092	1.158	1.182	1.146
Mean	**1.18**	**1.05**	**1.10**	**1.07**	**1.09**	**1.03**	**1.07**	**1.18**	**1.62**	**1.15**
Std	**0.60**	**0.60**	**0.55**	**0.53**	**0.55**	**0.52**	**0.54**	**0.61**	**0.92**	**0.58**
CV	**50.76**	**57.34**	**49.82**	**49.48**	**51.00**	**50.42**	**50.63**	**51.73**	**57.15**	**50.65**
Lowest	**0.185**	**0.068**	**0.175**	**0.182**	**0.197**	**0.194**	**0.192**	**0.200**	**0.208**	**0.192**
Highest	**2.539**	**2.089**	**2.058**	**2.053**	**2.059**	**1.883**	**1.980**	**2.254**	**3.288**	**2.189**

Source: Author's calculations

Again, as in the case of our estimates based on coal production, estimates based on coal consumption also showed high per capita carbon emissions in low income states of Madhya Pradesh and Orissa. High per capita carbon emissions in Madhya Pradesh come as no surprise as the state of Chattisgarh was created from Madhya Pradesh in 2001 and our figure for estimating level of carbon emissions derived from Ghoshal and Bhattacharya (2008) (percentage of coal emission) relates to 2000, that is a year before the new state came into existence. Most of the carbon emissions for Madhya Pradesh, therefore, relates to the region now known as Chattisgarh. Surprisingly Punjab, a high income agricultural state, also showed high average emissions per capita during the period 2000-2009. Increased use of advanced farm technological inputs such as farm machinery, fertilisers, irrigation systems and pesticides has led to increased energy consumption in turn leading to high carbon emissions in the state (Manaloor & Sen 2009).

Our estimates for carbon emissions based on coal consumption is, however, only for the 15 major states of India.[4] Nevertheless, average per capita emission of these states is quite close to the national per capita CO_2 emissions (available from World Bank indicators online) estimated by considering carbon dioxide produced during consumption of solid, liquid and gas fuels and gas flaring (Figure 2).

FIGURE 2. PER CAPITA CARBON EMISSIONS AT NATIONAL LEVEL AND OUR ESTIMATES



The Gini coefficients of carbon emissions, irrespective of the method chosen, have shown increasing trend indicating that inequality in carbon emissions across the states is actually increasing over the years (Table 5). Also during the period of our study, rapid economic growth was observed in many states of India. A consequence of high growth rates, as mentioned earlier, has been increase in income inequalities. A number of studies have observed increasing regional disparities and urged the need for reducing inequalities across the states, and a rise in the per capita income of less developed states. Other indices of carbon inequality are shown in the Table 6.

TABLE 5. GINI COEFFICIENT IN CARBON EMISSIONS

Year	**Gini coefficient (CO_2 emissions)**	
	Using production method	Using consumption method
2000	0.242	0.270
2001	0.372	0.317
2002	0.360	0.275
2003	0.369	0.271
2004	0.381	0.279
2005	0.406	0.277
2006	0.410	0.279
2007	0.414	0.285
2008	0.384	0.314

Source: Author's own calculations

TABLE 6: CARBON AND INCOME INEQUALITY INDICES AT THE SUB-NATIONAL LEVEL

Year	Quasi Gini coefficient (CO_2 emission)	Gini coefficient (GDP)	Kakwani Index	Theil Index
2000	0.043	0.207	-0.164	0.048
2001	-0.045	0.208	-0.252	0.121
2002	-0.049	0.211	-0.260	0.087
2003	-0.054	0.209	-0.262	0.092
2004	-0.029	0.208	-0.238	0.096
2005	-0.053	0.218	-0.271	0.110
2006	-0.013	0.224	-0.237	0.115
2007	0.011	0.225	-0.214	0.118
2008	0.042	0.226	-0.184	0.111

Source: Author's own calculations

The Kakwani index is equal to the Quasi Gini coefficient index for carbon emission *minus* the Gini coefficient index for GDP. It shows how much regressive or progressive the carbon emissions are in relation to per capita income. Kakwani index has remained negative throughout our period of analysis indicating relatively lesser inequality in carbon emissions than in per capita GDP. The Lorenz curve plotted below also proves this point.

FIGURE 3. LORENZ CURVES FOR PER CAPITA GDP AND PER CAPITA GHG

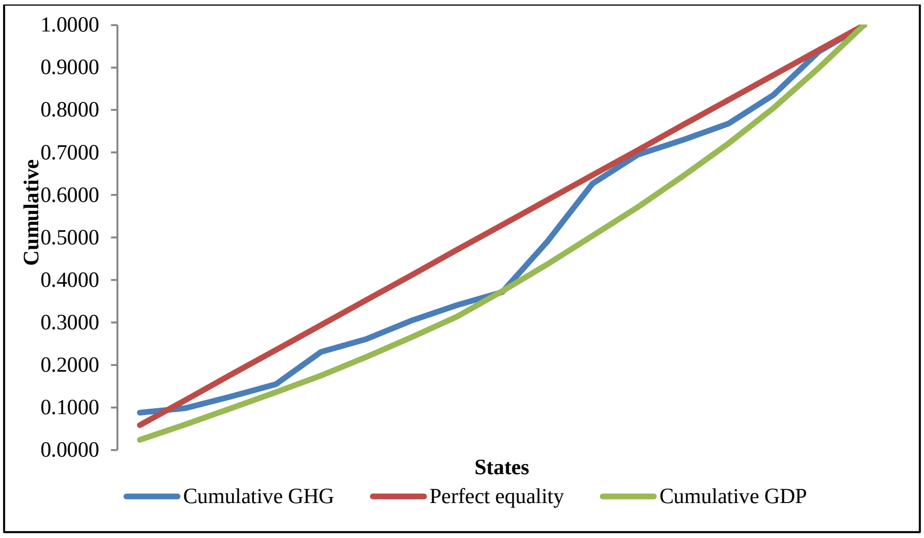
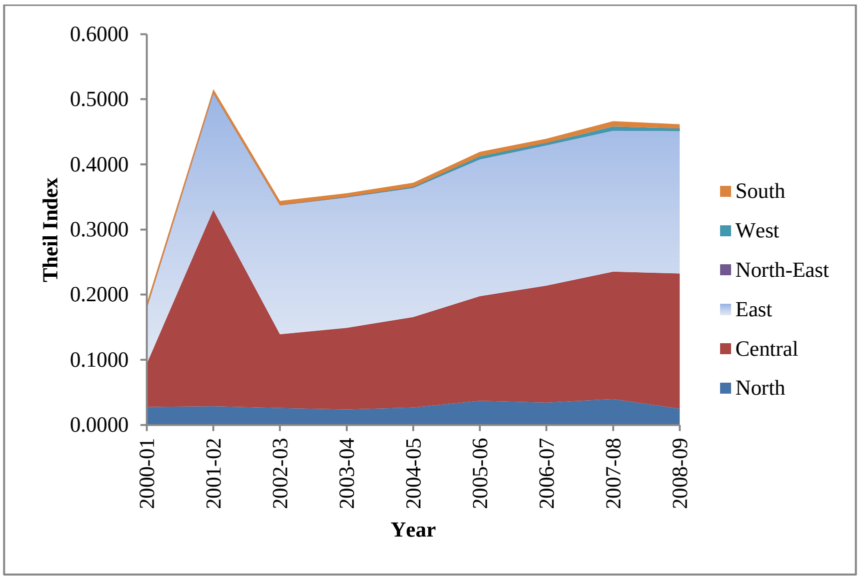


Figure 3 shows that equality in carbon emissions is closer to perfect equality than the per capita GDP. This yields negative Kakwani index suggesting lower concentration in carbon emissions than per capita GDP. Clarke-Sather, Jiansheng, Qin, Jingjing and Yan (2011) in case of China for a somewhat similar period, also found lower concentration levels for carbon emissions for Chinese provinces than in per capita GDP. A similar trend of negative Kakwani indices has been found in other cross-country studies also (Cantore & Rosa 2007). Further, our study also found that as in China, the Kakwani Index in India at the sub-national level is actually declining over the years implying that the gap between inequality in carbon emissions and inequality in incomes is narrowing.

Decomposing carbon emissions between different regions arrived from the Theil index reveals that inequality in per capita carbon emissions in relation to population remained high during 2000-09 in the Eastern and Central regions (Figure 4). It may be mentioned that the regional classification used in our study mirrors the geographical location of the state. Thus based on this dichotomy, 17 major states can be grouped into six different regions: North (3 states); Central (3); East (4); North-East (1); West (2) and Southern (4) regions. The figure also illustrates inequality in per capita carbon emissions emerging within the regions. The high population of the central and eastern regions (approximately 49 per cent of the country's total population in 2008-09) also accounts for the high carbon emissions in these two regions.

FIGURE 4. DECOMPOSITION OF THEIL INDEX BETWEEN REGIONS



CONCLUSIONS

Considerable controversy exists on the magnitude and mitigation strategies of carbon emissions across countries. This is further complicated by countries being at different stages of economic development with varying per capita incomes and achieving conflicting objectives as: accelerating rates of economic growth which is also inclusive in nature, reducing poverty, improving people's wellbeing and reducing carbon emissions. Although studies exist at the national level on inequality in carbon emissions, this has been an underresearched area in the sub-national context. In this study we examined inequality in carbon emissions at the sub-national level in India. The study raised the questions such as: what are the current levels of carbon emissions at sub-national level in India? Are they skewed towards the richer states or whether it is the poorer states which are sharing the burden?

The study examined above questions by considering the data for the period 2000-01 to 2008-09 for 17 major states of India. The period covered is particularly significant as India achieved high economic growth during these years. In our study, we used a two step approach to investigate the questions raised above: first, we estimated the total carbon emissions for each state for the above time period and subsequently, by using the standard measures of inequality - coefficient of variation, Gini coefficient, Kakwani index and Theil index estimated carbon inequality across the states and regions. In order to build our estimates of carbon emissions, we considered data on consumption as well as production of fossil fuels (coal) in each state. This approach is justified as emissions can take place both during the production process and also in consumption (Planning Commission 2006).

Our results suggest that per capita carbon emissions were highest in the low income resource rich states of Chattisgarh, Jharkhand and Orissa located in the eastern and central regions of the country. On the other hand, certain high income developed states had low per capita emissions. If the total emissions are considered, the trends are not very clear as these are high in rich as well as in less developed states. Again, the regional trends reveal the predominance of the poorer central and eastern regions. These regions, although low in human development and with high poverty levels, are rich in natural resources.

The inequality in carbon emissions as demonstrated by Gini coefficients has increased over the years indicating that it is the poorer states which have to bear the burden. The concentration of inequality, as revealed by Kakwani index, is higher in the per capita GDP than in the carbon emissions. The decomposition inequality analysis using Theil index revealed high variations across eastern and central regions. Our study showed that inequality in per capita carbon emissions is lower than the inequality in income, a finding supported by other studies as well. A limitation of our study is the absence of time series data on coal consumption; to overcome this the study used fixed percentages of coal emissions. Firmer data, however, could have led to better results. Some of the policy implications emerging from our study are that technological improvements, improved carbon governance and capacity building (Nakamura 2012) are required to deal with carbon emissions at the sub-national level. In the less developed, but resource rich states high carbon emissions intensity further impacts on the health and well-being of their citizens. This is compounded by the poor resources availability to deal with carbon abatement. A mixture of policies which directly target the reduction of per capita carbon emissions and at the same time promote human development of these states will also lead to reduction in emissions inequality.

ENDNOTES

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[1] In the latest round of climate negotiations held at Durban in 2011, the extent of carbon emissions was a matter of much dispute. After much deliberation it was finally agreed among the participating countries (including USA, India and China) to settle on a new international legal framework for reducing carbon pollution by 2015.

[2] IPCC recommends Reference Approach (also called a top down approach) if sufficient data on the sectors consuming fuels is not available. The Reference Approach method estimates fossil carbon flow into the economy and adjusts for stored carbon in long life materials and for carbon not oxidized during combustion (For details see IPCC Guidelines for national Greenhouse Gas Inventories 2006).

[3] The states of Chattisgarh and Jharkhand were carved out in 2001 from Madhya Pradesh and Bihar respectively.

[4] The estimates for the states of Chattisgarh and Jharkhand are not given separately in the table as they are included in their parent state Madhya Pradesh and Bihar.

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