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Environmental Impact of Population, Affluence and Technology in India: 60 Years Perspective

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Abstract

This paper analyses the environmental impact of population growth, increase in affluence and technology development in terms of the increase in primary energy use and CO_2 emission in India during the period 1990 through 2050. The analysis has been carried out for two time periods - 1990-2020 and 2020-2050. The period 1990-2020 reflects the historical perspective of the environmental impact of population growth, increase in affluence and technology development while the period 2020-2050 depicts the likely environmental impact of the projected population growth, predicted increase in the affluence and future technology development in the country. The analysis reveals that the dominant contributor to the increase in primary energy use and CO_2 emission has been and is likely to be the increase in the affluence. The analysis also suggests that although, the direct contribution of the population growth to the increase in the primary energy use and CO_2 emission may not be large, yet its second order effects in conjunction with the increase in affluence has been and is likely to be quite substantive. The analysis also indicates that technology advancement had and is likely to have only a limited impact on environmental concerns in India.

Introduction

The estimates prepared by the Enerdata, an independent research agency that specialises in the analysis and forecasting of energy and climate issues, suggest that the CO_2 emission in India increased by more than four times from around 523 million tons in 1990 to almost 2200 million tons in 2020 (Enerdata, 2021). During the same period, the energy use in the country is estimated to have increased from around 306 to around 908 million tons of oil equivalent. In 1990, India accounted for an estimated 2.6 per cent of total CO_2 emission in the world. This proportion increased to 7.1 per cent in 2020. CO_2 is one of the greenhouse gases and is universally used as an indicator of the impact of human activity on the environment. The emission of the greenhouse gases such as CO_2 from human activities disturb the radiative energy balance of the atmosphere system of the planet Earth. They exacerbate the natural greenhouse effect, leading to temperature changes and other disruption in the climate of the Earth which may endanger the very life on the planet. CO_2 makes up the largest share of greenhouse gases and, therefore, is a key factor in the ability of any country to mitigate the climate change. Climate change is also a global concern for sustainable development. It threatens ecosystems and biodiversity, affects water resources, human settlements and the frequency and scale of extreme weather events, with significant consequences for the production of food grains, human well-being, socio-economic activities, and economic output.

From the analytical perspective, total CO_2 emission in a country may be conceptualised as the product of per capita CO_2 emission and the population of the country. The increase in population leads to the increase in CO_2 emission even if there is no change in per capita CO_2 emission. Similarly, an increase in per capita CO_2 emission may lead to an increase in total CO_2 emission even if there is either no increase or even a decrease in population. The change in per capita CO_2 emission, in turn may be conceptualised and in terms of per capita energy use and the carbon content of the fuel used to produce energy. If the carbon content of the fuel used for producing energy is high, then CO_2 emission from the same amount of energy used will be more than when the carbon content of the fuel used for producing energy is low. Finally, the energy used is determined by the energy intensity of the gross domestic product or energy used per unit gross domestic product and per capita gross domestic product (Baumert et al, 2005).

On the other hand, the change in the size and age composition of the population also influences CO_2 emission. It is well known that demographic transition results not only in an increase in the size of the population but also in the change in population age composition leading to the ageing of the population. There are studies that have attempted to analyse the impact of the change in the population age structure on CO_2 emission (Dalton et al, 2008; Liddle, 2011; Liddle and Lung, 2010; Menz and Kuhling, 2011; Menz and Welsch, 2012; Okada, 2012). Although the age composition of the population can have direct or indirect effect on CO_2 emission (Kim et al, 2020), yet, to the best of our knowledge, there is no study that have analysed how changes in the age composition of the population in India, as the result of demographic transition, have contributed to the change in CO_2 emission in the country. The change in population age composition may have direct impact on CO_2 emission through the change in energy use. At the same time, it may also have an indirect impact on CO_2 emission by hindering output growth and slowing down economic activities (Aksoy et al, 2019; Shirbekk, 2004).

According to the estimates prepared by the United Nations Population Division, India's population is estimated to have increased from around 873 million to more than 1380 million during the 30 years between 1990 and 2020 (United Nations, 2019). This increase in the population of the country has been associated with the change in the age composition of the population. The young dependency ratio, defined as the ratio of the population aged 0-14 years to the population aged 15-64 years, decreased from 652 to 389 persons aged 0-14 years for every 1000 persons aged 15-64 years while the potential support ratio defined as the ratio of the population aged 15-

64 years to the population aged 65 years and above, decreased from 15 persons aged 15-64 years per person aged 65 years and older to 10 persons aged 15-64 years per person aged 65 years and above between 1990 and 2020. At the same time, the ageing index, defined as the ratio of the population aged 65 years and above to the population aged 0-14 years increased from 0.100 to 0.251.

On the other hand, the per capita gross domestic product in the country is estimated to have increased from 1813 (US$ at constant exchange rate, price and purchasing power parities of the year 2017) in 1990 to 6714 in 2019 but decreased to 6118 in 2020 because of the slowing of economic activities in the country as the result of the COVID-19 pandemic. At the same time, it is estimated that the energy intensity of the gross domestic product in the country decreased from around 193 Kg of oil equivalent per US$ at constant exchange rate, price and purchasing power parities of the year 2017 in 1990 to around 102 in 2019 but increased to 106 in 2020 whereas the emission intensity or the carbon intensity of the gross domestic product decreased from 0.330 Kg of CO_2 emission per unit gross domestic product in 2019 to around 0.251 in 2019 but increased to almost 0.256 in 2020. The change in the population stock of the country along with changes in per capita gross domestic product and the energy intensity and emission intensity of gross domestic product suggests that the increase in CO_2 emission in the country during the period 1990 through 2020 should be examined in the context of the change in the population stock and the change in the per capita gross domestic product of the country.

In this paper, we analyse the increase in CO_2 emission in India in the context of the change in population stock and per capita gross domestic product to examine the environmental impact of the population, affluence, and technology in the country during the 30 years between 1990 and 2020 by adopting a factor decomposition approach. We also explore the likely environmental impact of future population growth and the increase in per capita gross domestic product in the country in the next 30 years in terms of the increase in CO_2 emission. The paper provides an empirical perspective that may be relevant to policy and planning for environmental sustainability in India in the next 30 years.

The paper is organised as follows. The next section of the paper describes the analytical framework used in the present analysis. We first examine the trend in CO_2 emission in the country during the 30 years between 1990 and 2020 following the conjecture that the trend may not be the same during the 30 years under reference. Based on the trend analysis, we apply the factor decomposition technique to measure the contribution of several factors that contribute to CO_2 emission. The third section of the paper describes the data sources used for the analysis. The fourth section of the paper presents findings of the analysis which have been presented in two parts – the historical perspective that describes the changes during the period 1990 through 2020 and the future perspective that describes likely changes during the period 2020 through 2050. The last section of the paper summarises the findings of the analysis and their policy implications in the context of sustainable development.

Analytical Framework

The analytical frame adopted for the present analysis comprises of two parts. The first part of the analysis analyses the trend in CO_2 emission in the country during the 30 years between 1990 and 2020. The underlying assumption of the trend analysis is that the trend might have changed during the 30 years under reference. To account for the changing trend in CO2 emission, we apply the joinpoint regression analysis. The joinpoint regression analysis first identifies the time point(s) or change point(s) when the trend in CO_2 emission has changed. Once the time point(s) when the trend has changed is(are) identified, the regression analysis between two change point(s) is carried out assuming linear trend between two change point(s). The joinpoint regression analysis is different from the conventional piece wise regression analysis in the sense that the time point(s) when the trend has changed is(are) fixed a priori in the piece wise regression analysis but identified from the data themselves in the joinpoint regression analysis. Actual calculations have been carried out using the Jointpoint Trend Analysis Software developed by the National Cancer Institute of National Institute of Health of United States of America (National Cancer Institute, 2020). The software requires setting, in advance, the minimum and maximum number of joinpoints. Details of joinpoint regression model and method adopted for identifying changes in the trend are given elsewhere (Kim et al, 2000) and repeated here.

The second part of the analysis focuses on the contribution of change in a set of demographic economic and technological factors to the change in CO_2 emission, *I*, during a given time-period. The change in *I* may be conceptualized as the product of per capita CO_2 emission and the size of the population, *P*. In other words,

$$I = \frac{I}{P} * P \qquad (1)$$

Per capita CO_2 emission may, in turn, may now be broken down in terms of the carbon intensity of energy use which reflects the fuel mix used to produce energy, energy intensity of gross domestic product and per capita gross domestic product as follows

$$\frac{I}{P} = \frac{I}{E} * \frac{E}{G} * \frac{G}{P} \qquad (2)$$

where ($i = I/E$) is the carbon intensity of energy consumption or emission per unit consumption of energy; ($e = E/G$) is the energy intensity of the gross domestic product, or the energy consumed per unit gross domestic product and G/P is the per capita gross domestic product.

The per capita gross domestic product can be obtained in terms of the labour productivity ($p = G/L$) and the ratio of the working age population to the total population as follows

$$\frac{G}{P} = \frac{G}{L} * \frac{L}{W} * \frac{W}{P} \qquad (3)$$

where L is the labour force and W is the working age population. Equation (2) may now be expanded as

$$\frac{I}{P} = \frac{I}{E} * \frac{E}{G} * \frac{G}{L} * \frac{L}{W} * \frac{W}{P} \qquad (4)$$

The ratio of the working age population to the total population is a measure of the age composition of the population which is popularly used to reflect the demographic dividend. It can be expanded further by taking into consideration, the ratio of the proportion of the old population to the total population so that equation (4) becomes

$$\frac{I}{P} = \frac{I}{E} * \frac{E}{G} * \frac{G}{L} * \frac{L}{W} * \frac{W}{O} * \frac{O}{P} \qquad (5)$$

where the ratio ($s=W/O$) is the potential support ratio (United Nations, 2019) and ($o=O/P$) is the proportion of the old population. Equation (1) can now be expanded as

$$I = \frac{I}{E} * \frac{E}{G} * \frac{G}{L} * \frac{L}{W} * \frac{W}{O} * \frac{O}{P} * P, \text{ or}$$

$$I = i * e * p * l * s * o * P \qquad (6)$$

Equation (6) suggests that CO_2 emission are influenced by seven factors, two of which, carbon intensity of energy consumption and energy intensity of gross domestic product, are related to the production technology while the third factor, (G/L) is the labour productivity which, in combination with the proportion of labour force to the working age population determines the level of affluence. Finally, potential support ratio and the proportion of the old population to the total population reflects the age composition of the population.

Using equation (6), the change in the CO_2 emission (I) can be decomposed as

$$\nabla I = I_2 - I_1 = (i_2 * e_2 * p_2 * l_2 * s_2 * o_2 * P_2) - (i_1 * e_1 * p_1 * l_1 * s_1 * o_1 * P_1) \qquad (7)$$

It may be noticed that the logarithmic mean of I_2 and I_1 is defined as

$$LM = \frac{I_2 - I_1}{ln(I_2/I_1)} = \frac{\nabla I}{ln(I_2/I_1)} \qquad (8)$$

So that

$$\nabla I = LM * ln(I_2/I_1) \qquad (9)$$

Or

$$\nabla I = LM * \left[\ln\left(\frac{i_2}{i_1}\right) + \ln\left(\frac{e_2}{e_1}\right) + \ln\left(\frac{p_2}{p_1}\right) + \ln\left(\frac{l_2}{l_1}\right) + \ln\left(\frac{s_2}{s_1}\right) + \ln\left(\frac{o_2}{o_1}\right) + \ln\left(\frac{P_2}{P_1}\right)\right] \qquad (10)$$

Or

$$\nabla I = \partial_i + \partial_e + \partial_p + \partial_l + \partial_s + \partial_o + \partial_P \qquad (11)$$

Equation (11) is a seven-factor decomposition model that may be used to analyse the change in CO_2 emission. It measures the impact of the change in population on the environment in terms of the change in the population stock – size and age composition – as the result of demographic transition which is captured in terms of the increase in population size and the change in the population age composition measured in terms of the proportion of the old population and the potential support ratio. On the other hand, the impact of the change in the affluence on the change in CO_2 emission is measured through the change in labour productivity and the change in the proportion of the working age population in the labour force. The two factors, in combination, determine the per capita output of the economy which reflects the level of affluence. Finally, the impact of the evolution of the technology on the environment in terms of the change in CO_2 emission is captured through the change in the energy intensity of the output of the economy and the change in the carbon or emission intensity of the energy used. The emission intensity of the energy used depends upon the fuel mix used to produce energy. The emission intensity is high when those fuels are used for producing energy which have high carbon content such as coal and petroleum products. On the other hand, the emission intensity of solar energy is zero which means that there is no CO_2 emission in the use of solar energy, irrespective of the size and age composition of the population and irrespective of the size of the economic activity. Equation (11) permits analysing how change in the population stock, change in the affluence and the evolution of the technology impacts the environment in terms of CO_2 emission.

Data

The analysis is based on the data taken from different secondary sources. Estimates and projection of the population of the country and the age composition of the population used in the present analysis have been prepared by the United Nations Population Division (United Nations, 2019). Estimates of the output of the economy or the gross domestic product have been taken from the world development indicators database prepared by the World Bank for the period 1990-2020. while forecasts of the gross domestic product are those that have been prepared by the Organization for Economic Cooperation and Development (OECD, 2021). Estimates of the labour force, on the other hand, are modelled estimates that have been prepared by the International Labour Organisation. Finally, estimates of total energy consumption and CO_2 emission are prepared by Enerdata, an independent energy intelligence and consulting company (Enerdata, 2021). Enerdata collects energy related country specific information from various sources and prepares and provides consistent, internationally comparable estimates of different dimensions of energy production, energy consumption and CO_2 emission in the world and in its different countries.

Table 1 presents the basic data used in the present analysis. The population of India is estimated to have increased from 873 million in 1990 to 1380 million in 2020 whereas the working age population increased from 509 million to 928 million during this period and the old age population increased from 33 million to 91 million. At the same time, the size of the labour force is estimated to have increased from 317 million in 1990 to 495 million in 2019 but decreased to 473 million in 2020. On the other hand, the gross domestic product per capita increased 1813 million to 6714 million between 1990 and 2019 international $ at constant exchange rate, price and purchasing power parities of the year 2017 but decreased to 6118 million in 2020.

Table 1: CO_2 emission in India and factors that determine CO_2 emission, 1990-2030.

Year	CO_2 emission Mt	Energy use Mtoe	Gross domestic product per capita $ 2017 ppp	Labour force Million	Working age population Million	Old age population Million	Population Million
1990	523	306	1813	317	509	33	873
1991	562	318	1795	324	520	34	891
1992	594	330	1856	331	532	36	909
1993	626	338	1906	339	545	37	927
1994	667	351	1994	348	558	38	946
1995	725	371	2105	356	572	39	964
1996	760	383	2221	363	585	40	982
1997	795	398	2268	371	599	42	1001
1998	813	407	2364	380	614	43	1019
1999	874	431	2528	388	628	45	1038
2000	912	441	2579	397	644	46	1057
2001	927	448	2657	407	658	48	1075
2002	956	462	2712	417	672	50	1093
2003	987	474	2877	428	687	51	1112
2004	1040	500	3055	438	702	53	1130
2005	1085	515	3245	449	718	54	1148
2006	1155	533	3453	452	732	56	1165
2007	1256	568	3662	455	747	58	1183
2008	1338	604	3720	457	761	59	1201
2009	1472	663	3956	460	776	61	1218
2010	1570	701	4235	463	791	63	1234
2011	1662	734	4400	464	806	65	1250
2012	1810	766	4583	465	820	67	1266
2013	1859	779	4819	469	835	69	1281
2014	2024	822	5117	473	850	71	1296
2015	2035	835	5464	477	864	74	1310
2016	2062	852	5851	481	878	77	1325
2017	2182	883	6183	485	891	80	1339
2018	2290	919	6519	488	903	84	1353
2019	2319	940	6714	495	916	87	1366
2020	2191	908	6118	472	928	91	1380

Sources: Enerdata; World Bank; International Labour Organization and United Nations Population Division.

Trend in CO_2 Emission

The CO_2 emission is India is estimated to have increased from 523 million tons in 1990 to 2319 million tonnes, in 2019 but decreased to 2191 million tonnes, in 2020. This means that, between 1990 and 2019, the CO_2 emission in the country increased by 1796 million tonnes. This increase in CO_2 has been associated with an increase in the emission intensity of energy use (*i*) from 1.711 in 1990 to almost 2.5 in 2018 but then the emission intensity of energy use decreased to around 2.412 whereas the energy intensity of the gross domestic product (*e*) decreased from around 193 in 1990 to 103 in 2019 but increased to 108 in 2020 (Table 2).

On the other hand, the productivity of the labour force (*p*) increased from around 5000 international $ at 2017 purchasing power parity in 1990 to 18543 international $ at 2017 purchasing power parity in 2020 while the ratio of the labour force to the working age population decreased from around 62 per cent in 1990 to around 54 per cent in 2018 but decreased to less than 51 per cent in 2020 because of the COVID-19 pandemic. Finally, the potential support ratio or the ratio of the working age population (15-64 years) to the old population (65 years and above) decreased from around 15 to around 10 during this period and the proportion of the old population increased from less than 4 per cent to almost 7 per cent during between 1990 and 2020 (Table 2).

It may be seen from table 1 that the increase in CO_2 emission in the country has not been uniform during the 30 years period under reference. The application of the joinpoint regression analysis informs that the trend in CO_2 emission in India changed four times during the 30 years between 1990 and 2020 (Table 3). During the period 1990 through1996, the annual percentage increase (API) in CO_2 emission in the country was 6.531 per cent which, however, decreased substantially to 3.914 per cent during the period 1996 through 2005. However, the API in CO_2 emission shot up to 7.658 per cent during the period 2005 through 2012 and then decreased to 3.960 per cent during the period 2012 through 2018. After 2018, CO_2 emission in the country decreased, instead increased, probably and so obviously because of the disruption of economic activities due to COVID-19 pandemic in the country and the lockdown measures taken to control the pandemic. For the entire period 1990 through 2020, the average annual percentage increase (AAPI) in CO_2 emission in the country was 4.949 per cent (Table 3). However, the rapid increase in CO2 emission during the 7 years period 2005-2012 accounted for more than 43 per cent of the total increase in CO_2 emission during the entire period 1990-2020. By comparison, the increase in CO_2 emission during the period 2012-2018 accounted for less than 30 per cent of the total increase in CO_2 emission during the 30 years between 1990 and 2020 whereas the increase in CO_2 emission during the period 1996 through 2005 accounted for less than 20 per cent of the total increase in CO_2 emission during the 30 years between 1990-2020. If the CO_2 emission in the country would have not increased very rapidly during the period 2005-2012, the total increase in CO_2 emission during the 30 years between 1990 and 2020 would have been substantially lower. It is clear from table 3 that the increase in CO2 emission in the country has not been linear during 1990-2020. The increase in CO2 emission has been substantially slower during 1996-2005 and during 2012-2018 compared to the increase during the period 1990-1996 and during the period 2005-2012.

Table 2: Contributors to CO2 emission in India, 1990-2020.

Year	Emission intensity of energy use	Energy intensity of gross domestic product	Gross domestic product per worker	Proportion of labour force to working age population	Potential support ratio	Proportion of old population
	i	*e*	*p*	*l*	*s*	*o*
1990	1.711	193	5001	0.623	15.3	0.038
1991	1.765	199	4940	0.623	15.1	0.039
1992	1.801	196	5091	0.623	15.0	0.039
1993	1.851	191	5208	0.623	14.9	0.040
1994	1.899	186	5422	0.623	14.8	0.040
1995	1.952	183	5702	0.622	14.7	0.040
1996	1.987	175	6002	0.621	14.5	0.041
1997	1.998	175	6111	0.620	14.3	0.042
1998	1.996	169	6348	0.619	14.2	0.042
1999	2.028	164	6759	0.618	14.1	0.043
2000	2.069	162	6865	0.617	14.0	0.044
2001	2.068	157	7022	0.618	13.7	0.045
2002	2.069	156	7109	0.620	13.6	0.045
2003	2.083	148	7479	0.622	13.4	0.046
2004	2.082	145	7876	0.624	13.3	0.047
2005	2.108	138	8293	0.626	13.2	0.047
2006	2.168	132	8907	0.617	13.0	0.048
2007	2.212	131	9529	0.609	12.9	0.049
2008	2.215	135	9764	0.601	12.8	0.050
2009	2.220	138	10467	0.593	12.7	0.050
2010	2.241	134	11291	0.585	12.6	0.051
2011	2.266	133	11862	0.576	12.5	0.052
2012	2.362	132	12482	0.567	12.3	0.053
2013	2.387	126	13156	0.562	12.2	0.054
2014	2.462	124	14006	0.557	12.0	0.055
2015	2.439	117	14999	0.552	11.7	0.056
2016	2.419	110	16107	0.548	11.4	0.058
2017	2.471	107	17082	0.544	11.1	0.060
2018	2.491	104	18083	0.540	10.8	0.062
2019	2.466	103	18543	0.540	10.5	0.064
2020	2.412	108	17900	0.508	10.2	0.066

Source: Author's calculations based on table 1.

Table 3: Trend in CO_2 emission in India during 1990-2020. Results of joinpoint regression analysis

Period	Annual per cent increase (APC)	95% confidence interval		't'	'p'
		Lower	Upper		
1990-1996	6.531	5.801	7.267	19.396	< 0.001
1996-2005	3.914	3.462	4.367	18.606	< 0.001
2005-2012	7.658	6.922	8.399	22.708	< 0.001
2012-2018	3.960	3.008	4.920	8.912	< 0.001
2018-2020	-1.265	-5.868	3.563	-0.563	0.581
1990-2020	4.949	4.518	5.383	22.981	< 0.001

Source: Author's calculations

Decomposition of the Increase in CO_2 Emission

Table 4 decomposes the increase in CO_2 emission in the country during the period 1990-2020 into several factors that account for the change in CO_2 emission in conjunction with equation (11). This decomposition exercise suggests that the change in four factors – emission intensity of energy use (*i*), productivity of the labour force (*p*), proportion of the old population (*o*) and the size of the population (*P*) - had accounted for an increase of 3055 million tonnes in CO_2 emission in the country during the period 1990-2020 whereas the change in three factors – energy intensity of gross domestic product (*e*), proportion of workers in the working age population (*l*) and the potential support ratio (*s*) – had accounted for a decrease of 1387 million tonnes, in the CO_2 emission during this period so that the net increase in CO_2 emission in the country was 1668 million tonnes, during the period 1990-2020. The increase in the per capita gross domestic product, alone, accounted for an increase of 1416 million tonnes in CO_2 emission in the country during the period under reference. By comparison, technological advancement, reflected in terms of the change in the emission intensity of energy use (*i*) and energy intensity of gross domestic product (*e*) had resulted in a decrease of only 281 million tonnes in CO_2 emission during this period. On the other hand, increase in the size of the population and the ageing of population as the result of demographic transition accounted for an increase of 1170 million tonnes in CO_2 emission whereas the decrease in the potential support ratio had resulted in a decrease of 469 million tonnes in the CO_2 emission so that population factors accounted for an increase of 701 million tonnes in CO_2 emission in the country between 1990-2020. It is clear from the decomposition analysis that technology development in the country during the period 1990-2020 could hardly compensate for the increase in CO_2 emission resulting from the increase in the affluence or the gross domestic product per capita and the change in the population stock – increase in the size of the population and the change in the age composition of the population as reflected through the decrease in the potential support ratio.

Table 4 also decomposes the increase in CO_2 emission in the country during different time intervals of the period 1990-2020 in which the trend in CO_2 emission has been different as revealed through the joinpoint regression analysis. The very rapid increase in CO_2 emission during the period 2005-2012 appears to have been associated with a substantial increase in the emission intensity of the energy use and a very substantial slowdown in the decrease in the energy intensity of the gross domestic product. The emission intensity of energy use in the country increased, instead decreased, from 2.11 in 2005 to 2.36 in 2012. By comparison, the emission intensity of the energy use increased from 1.99 to 2.11 only during the period 1996-2005 and from 2.36 to 2.49 during the period 2012-2018. On the other hand, the energy intensity of the gross domestic product decreased only marginally from 138 in 2005 to 132 in 2012 compared to a rapid decrease from 175 to 138 during the period 1996-2005 and from 132 to 104 during the period 2012-2018. Moreover, the proportion of the labour force or workers to the working age population also decreased very rapidly from 63 per cent to 57 per cent during the period 2005-2012 whereas this proportion virtually remained unchanged during the period 1996-2005 while the decrease in this proportion slowed down during the period 2012-2018.

Table 4: Decomposition of the increase in CO_2 emission in India in different time periods

Increase in CO_2 emission attributed to the change in	Period					
	1990-1996	1996-2005	2005-2012	2012-2018	2018-2020	1990-2020
Emission intensity of energy use (∂i)	95	54	161	109	-72	400
Energy intensity of gross domestic product (∂e)	-61	-217	-64	-483	70	-681
Gross domestic output per worker (∂p)	116	295	579	756	-23	1485
Participation opportunity (∂l)	-1	7	-141	-98	-136	-237
Potential support ratio (∂s)	-34	-86	-99	-266	-122	-469
Proportion of old population (∂o)	49	130	150	327	138	637
Population size (∂P)	75	142	139	135	45	533
Total increase in CO_2 emission (∇I)	237	325	725	481	-99	1668

Source: Author's calculations

Projections for the Period 2020-2050

According to the medium variant of population projections prepared by the United Nations Population Division, the population of the country is likely to increase to more than 1639 million by the year 2050 (Table 5). This increase will be associated with a decrease in the potential support ratio to less than 5 working age persons for every old person and an increase in the proportion of old population to almost 14 per cent by the year 2050. At the same time, the gross domestic product per capita in the country is projected to increase to almost 21200 international $ at 2017 purchasing power parity. On the other hand, the energy intensity of the gross domestic product is projected to decrease to around 91 Koe per unit gross domestic product in 2036 and then increase to almost 100 Koe per unit gross domestic product by the year 2050. The emission intensity of energy use is, however, projected to decrease continuously to around 1.72 by the year 2050. These projections suggest that the CO_2 emission in the country will increase to almost 6000 Mt by the year 2050 or an increase of 3770 Mt in the next 30 years. The increase in affluence or the increase in per capita gross domestic product will account for an increase of 4680 Mt in CO_2 emission whereas the change in population stock will account for an increase of 677 Mt in CO_2 emission during the next 30 years. By comparison, it is projected that technological advancement leading to changes in the energy intensity of gross domestic product and the decrease in the emission intensity of energy use is expected to account for a decrease of around 1559 Mt in CO_2 emission during this period.

Table 5: Projected CO_2 emission by the year 2050 in India

Particulars	2020	2050	Increase during 2020-2050	Contribution to increase in CO_2 emission
Emission intensity of energy use (*i*)	2.412	1.725	-0.688	-1264
Energy intensity of gross domestic product (*e*)	108	99	-8	-295
Gross domestic output per worker (*p*)	16827	48728	31901	4005
Participation opportunity (*l*)	0.541	0.642	0.101	645
Potential support ratio (*s*)	10	5	-5	-2751
Proportion of old population (*o*)	0.066	0.138	0.072	2780
Population size (*P*)	1380	1639	259	648
CO_2 emission (*I*)	2191	5961	3770	

Source: Author's calculations

Discussions and Conclusions

The period 2005-2012 has been a period of unprecedented economic growth in India. It is estimated that the gross domestic product of the country increased at a rate close to 10 per cent per year during this period (Chaurasia, 2019). The present analysis suggests that this period has also been the period during which the increase in CO_2 emission also increased at an unprecedented rate. This period is also characterised by only a marginal improvement in the energy efficiency of the gross domestic product and a significant increase in the emission intensity of energy use which implies an increase in the proportion of high carbon content fuels in the fuel mix. Another notable feature of this period was a very substantial decrease in the opportunity for participation in the social and economic production system as reflected through the marked decrease in the ratio of the labour force or workers to the working age population. This means that the rapid increase in affluence during this period has not been energy efficient. From the perspective of the perspective of the environment, this period may be regarded as the worst period as more than 43 per cent of CO2 emission in the country during the 30 years between 1990 and 2020 has been confined to these seven years only. Reasons for only a marginal improvement in the energy efficiency of the gross domestic product during this period are not known at present as the energy efficiency again improved rapidly during the period 2012-2018.

The present analysis also suggests that technological developments appear to have contributed little towards mitigating the environmental impact of population and affluence in India during the last 30 years. Technology has repeatedly been argued to be the answer for addressing environmental problems including CO_2 emission as the emission intensity of energy use if determined by the carbon content of the fuel used for producing energy, the higher the carbon content, the higher the emission intensity and the higher the emission even if other factors determining emission remain unchanged. However, the experience of the last 30 years in India suggests that technological change has contributed little to mitigate the challenge of increasing CO_2 emission in the country as the result of increase in affluence and the increase in the population stock.

There also appears little hope that technological changes in the next 30 years will contribute in a significant manner the increase in CO_2 emission in the country. The increase in affluence is expected to lead to a significant increase in CO_2 emission in the country and the improvement in both energy efficiency of the gross domestic product and the emission efficiency of energy use is expected to compensate for this increase only marginally. On the other hand, the increase in the population in the coming years is almost inevitable. The country has achieved replacement fertility, but population of the country will continue to increase in the coming years because of the momentum for growth built in the age composition of the population which remains young. The increase in population attributed to population momentum cannot be checked. It can, at best be delayed by adopting appropriate population policy. This means that the only hope for the country to counter the environmental impact of the increase in affluence in the country is to shift to a low carbon content fuel mix to produce energy. This appears to be a daunting task as 80 per cent of energy needs of the country, today, is met by three high carbon content fuels – coal, oil, and solid biomass (International Energy Agency, 2021).

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