Energy Consumption Response to Climate Change: Policy Options for India

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Abstract

In this article, the contributions of energy use to the climate variation debates are explored. Analyses based on secondary data depict that global fossil fuel use has increased and dominated world energy consumption and supply which is quite similar to the Indian case. This increase in the global energy use has resulted in higher emissions. To account for the changes in carbon dioxide (CO_2) emission, this article follows an index decomposition analysis using data from PROWESS database of the Center for Monitoring Indian Economy (CMIE). Two factors are considered to account for the changes in emission intensity of Indian economy: (i) shift in output among three sectors of the India economy (Agriculture, Service and Manufacturing) and (ii) structural change due to change in aggregate output with respect to emissions change. Based on the estimates, we conclude that structural changes in the Indian economy from 1991 to 2007 played important major driving factor in reducing emissions compared to output shifts across sectors. Based on the findings and international experiences, few policy options for Indian economy, such as, energy pricing reforms, promoting investment in renewable energy technologies and creating public environmental awareness, are further suggested.

Keywords

Emission, energy consumption, climate change, post-globalization, policy instruments

Introduction

The three last centuries have seen mankind's substantial dependence upon an ever-growing use of fossil fuels for industrialization and urbanization (Cao, 2003; Reddish & Rand, 1996). Energy is and will continue to be a primary engine for economic development. There has been a rapid rise in the use of energy resources and consequently greenhouse gases (GHGs) emissions due to the structural changes in the Indian economy in the past fifty years. The energy mix in India has shifted towards coal due to higher endowment of coal relative to oil and gas; which has led to a rapidly rising trend of energy emissions intensities (IEA, 2007). The energy intensity of India is over twice that of the matured economies, which are represented by the Organisation for Economic Co-operation and Development (OECD) member countries (IEA, 2007). However, since 1999, India's energy intensity has been decreasing and is expected to decrease (Planning Commission, Government of India, 2001). The decline in energy intensity in the Indian economy could be attributed to several factors; (*i*) some of them being demographic shifts from rural to urban areas; (*ii*) structural changes towards less energy-intensive industries; (*iii*) impressive growth of services; (*iv*) improvement in efficiency of energy use; and (*v*) inter-fuel substitution.

Climate change is the long-term, significant change in the patterns, glaciations and related aspects of the global climate system. Mitigating the impact of climate change has dominated most public discourse not only by environmental economists but also by other environmental experts and scientists. The effects of energy consumption combustion are evaluated as greenhouse effects resulting from emissions of environmental pollutants such as carbon monoxide, hydrocarbon compounds, sulphur oxides, nitrogen oxides, methane and the particulates. Amongst several pollutants causing climate change, a great deal of attention has been given to carbon dioxide (CO_2) emissions as the major factor in the climate change and related issues. While

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the impact of other forms of air pollutants is primarily local or regional; CO_2 emissions are, above all, global in scale. Sources of CO_2 emissions often cited in the literature include the energy related component, especially, the combustion of fossil fuels. Others include the non-fuel use of energy inputs, and emissions from electricity generation using non-biogenic municipal solid waste and geothermal energy, emissions from industrial processes, such as cement and limestone production, etc.

This article is concerned with the contribution of energy consumption to the climate change debate and mostly focused on the post-globalized era of the Indian economy. An attempt has made to compare the recent scenarios of developing and the developed world along with the aggregate scenarios. In this connection, some useful questions could be raised: (*i*) to what extent is energy consumption responsible for CO_2 emission? (*ii*) What are the viable options for mitigating energy-related climate change for emerging economy such as India at the post-globalized era?

The structure of this article is the following. In the next section, we undertake a brief review of the origin of the climate change debacle. Next, we examine the role of energy to climate change. Thereafter, we outline some policy options for mitigating climate change on the basis of a decomposition analysis of the CO_2 emission. The last section provides the summary and conclusion to the article.

Relationship between Energy Consumption and Emission

The phrase 'climate change' and 'global warming' and more recently 'global cooling' is increasingly assuming a topical dimension in global climatic and environmental discourse. It is one of the most challenging problems with which our contemporary world has been faced. It has become a subject of major international cooperation through the Intergovernmental Panel on Climate Change (IPCC) which was set up in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme. According to Girardet and Mendonca (2009), the origin of climate change can be traced to the impact of human activities that started about 300 years ago. As the industrial revolution unfolded, the increase in the use of coal, and then oil and gas, not only massively increased human productive power and mobility but was also a major contributor to the tenfold growth in human population, from some 700 million in 1709 to nearly 7 billion today (Girardet & Mendonca, 2009). Today, Japan, Korea, Brazil, Mexico, Venezuela, China, India and South Africa are on their path to becoming major industrial nations in their own right. China's industrial boom, for instance, is linked to a rapid increase in domestic energy consumption with millions of cars manufactured yearly. China's coal consumption, mainly in power station, is going up in similar rate.

According to the 1992 World Bank projections, world population will be more than double by 2150 (World Bank, 1992). High population growth and increased urbanization invariably will lead to increased demand for energy, implying increased expected environmental damage as well. The increased concentrations of key GHGs are direct consequences of human activities. Energy production and consumption have various environmental implications, one of which is climate change. Among the many human activities that produce GHGs, the use of energy represents by far the largest source of emissions (IEA statistics on CO_2 emission, 2011). Energy consumption accounts for over 83 per cent of the global anthropogenic GHGs, with emissions resulting from the production, transformation, handling and consumption of all kinds of energy commodities. Energy use emissions are predominantly responsible for CO_2 emissions (92 per cent). Smaller shares correspond to agriculture, producing mainly methane (CH_4) and nitrous oxide (N_2O) from industrial processes not related to energy, producing mainly fluorinated gases and N_2O. GHG emissions from the Energy sector are dominated by the direct combustion of fuels, a process leading to large emissions of CO_2. A by-product of fuel combustion, CO_2 results from the oxidation of carbon in fuels (IEA, 2011). Responsible for about 92 per cent of the energy-related emissions, CO_2 from energy represents about 83 per cent of anthropogenic GHG emissions for the Annex 1 countries[1] (IEA, 2011). A key factor responsible for the higher energy-related emissions and climate change challenge is the increased global reliance on primary energy supply to drive economic growth and development. The global total primary energy supply (TPES) doubled between 1971 and 2009, primarily relying on fossil fuels. In other words, fossil fuels still account for most of the world energy supply. The figure shows that in spite of the growth of non-fossil energy (such as nuclear and hydropower) which are usually considered as non-polluting, fossil fuels have continue to maintain their dominance in TPES for the past 37 years under review. In 2009, it accounted for 81 per cent of the TPES in the world.

The high global dependence upon fossil fuels clearly is responsible for the observed upward trends in the global CO_2 emissions, as illustrated in Figure 1. Since the industrial revolution, CO_2 emissions from fuel combustion have

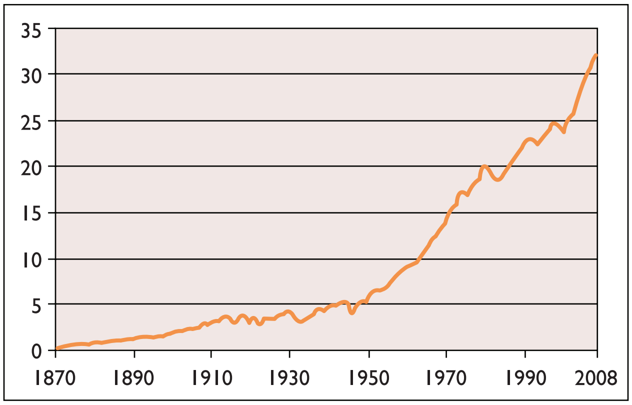

Figure 1. Trend in CO_2 Emission from Fossil Fuel (1870–2008; Gt CO_2)

Source: IEA statistics on CO_2 emission, 2011.

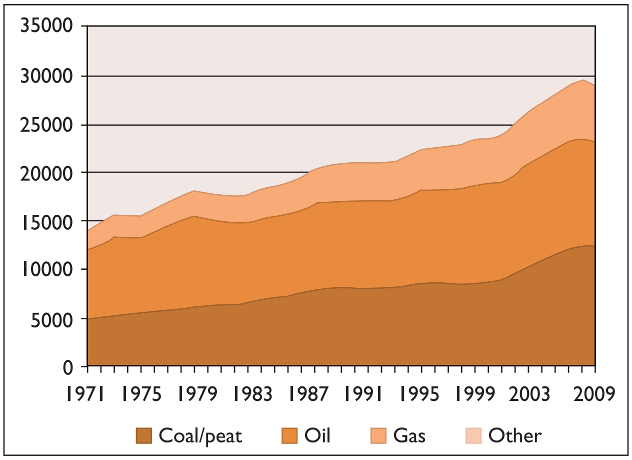

Figure 2. Global CO_2 Emission by Fuel Types (MT CO_2)

Source: IEA statistics on CO_2 emission, 2011.

witnessed a dramatic increase from its near zero level in the 1870s (IEA, 2010a; Quadrelli & Peterson, 2007) to about 29.4 million tons by 2008. The figure shows that CO_2 emissions from fossil fuels combustion in 2008 are increasing at a faster rate from 1870. Meanwhile, total global energy supply is projected to rise by 52 per cent between 2008 and 2030 (IEA, 2010a) and with fossil fuels remains at 81 per cent of TPES, CO_2 emissions are consequently expected to continue their growth unabated (unless some drastic measures are taken) and will reach 40.4 Gt CO_2 by 2030 (IEA, 2010a). The trend is expected to be intensified due to the projected high increase in world energy consumption demand by the BRICS (Brazil, Russia, India, China and South Africa) countries like China and India. It is projected that the shares of China in world energy consumption would outstrip that of the United States by the year 2020. It is obvious that the socioeconomic and technological characteristics of development paths of the industrializing countries will strongly affects energy-related emissions and hence, the rate and magnitude of climate change, climate change impacts, the capability for adaptation and mitigation of climate change emissions. However, the United States still dominates world energy consumption followed by China and India and doubtless the higher emitters of CO_2 energy-related emissions.

It may be important to further disaggregate the sources of energy-related CO_2 emissions. Available data on the contribution of fuel to global CO_2 emissions as at 2009 is shown in Figure 2. It can be seen that although coal represents only one-quarter of the world TPES in 2009, it accounted for 43 per cent of the global CO_2 emissions due to its heavy carbon content per unit of energy released. Compared to gas, coal is on the average nearly as twice emission intensive.[2] Without additional measures the supply of coal is projected to grow from 2,775 million tons of oil equivalent (Mtoe) in 2004 to 4,441 Mtoe in 2030 (Quadrelli & Peterson, 2007). In the future, coal is, therefore, expected to satisfy much of the growing energy demand of emerging developed countries like China and India, where energy intensive industrial production is growing rapidly and large coal reserves exist with limited reserves of other energy sources (Quadrelli & Peterson, 2007).

Information on the contributions of the four largest carbon emitters in the world[3] between 1971 and 2008 narrates that although the United States remained the largest CO_2 emitter up to 2007; its contribution is relatively stable over time. However, the rate at which it grows in India and in particular China is troublesome. In fact, China overtook the United States in 2007 as the world's largest annual emitter of energy-related CO_2, although as shown by IEA (2010a) the United States will still remains the largest in many years to come in terms of cumulative and per capita terms. In other words, it has been argued that China's emission rate of CO_2 is important to significantly affect world indicators. Quadrelli and Peterson (2007) have shown that the rise in China's per capita emissions (+17 per cent) causes global emissions to rise by 4 per cent. It is important to note that fossil fuels represents more than 80 per cent of China's energy mix; the country draws more than 60 per cent of its energy supply from coal alone (IEA, 2010a).

Generation of electricity and heat was by far the largest producer of CO_2 emissions and was responsible for 39 per cent of the world CO_2 emissions in 2008. Globally, evidence (from IEA, 2010a) indicates that this sector is noted for its heavy reliance on coal, the most carbon intensive of fossil fuels and thus amplifying its share in worldwide emissions of CO_2. Climate scientists have observed that CO_2 concentrations in the atmosphere have been increasing significantly over the past century, compared to the rather steady level of the preindustrial era (about 280 parts per million in volume or ppmv). The 2012 concentration of CO_2 (394 ppmv) was about 40 per cent higher than in the mid-1800s, with an average growth of 2 ppmv/year in the last 10 years. Significant increases have also occurred in levels of CH_4 and N_2O. The Fifth Assessment Report from the Intergovernmental Panel on Climate Change (Working Group I) states that human influence on the climate system is clear (IPCC, 2013). Some impacts of the increased GHG concentrations may be slow to become apparent since stability is an inherent characteristic of the interacting climate, ecological and socio-economic systems. Even after stabilization of the atmospheric concentration of CO_2, anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks.

As suggested by Spence (2009), emissions will, and should be permitted to, increase for the foreseeable future, mitigated by planning and policy efforts towards energy efficiency and low-carbon energy sources. The recently proposed Greenhouse Rights Development framework details a similar approach and suggests a development threshold of welfare below which people should not expected to share the costs of climate change mitigation (Baer et al., 2008). Even though decoupling was not as strong globally in the second sub-period as in the first, the good performance of several countries across the entire income spectrum indicates the potential for wider improvements as governments engage with the task of increasing energy efficiency and energy conservation, thereby slowing the growth of CO_2 emissions.

Akbostanc et al. (2011) calculated the CO_2 emissions of Turkish manufacturing industries by using the fuel consumption data at ISIC revision 2, four digit level. This study covers 57 industries, for 1995–2001. Log Mean Divisia Index (LMDI) method is used to decompose the changes in the CO_2 emissions of manufacturing industry into five components; changes in activity, activity structure, sectoral energy intensity, sectoral energy mix and emission factors. Mainly, it is found that changes in total industrial activity and energy intensity are the primary factors determining the changes in CO_2 emissions during the study period. It is also indicated that among the fuels used, coal is the main determining factor and among the sectors, 3,710 (iron and steel basic industries) is the dirtiest sector dominating the industrial CO_2 emissions in the Turkish manufacturing industry.

Dong et al. (2013) used the LMDI factor decomposition model-panel cointegration test two-step method to analyze the factors that affect per-capita carbon emissions. The main results are as follows: (*i*) During 1997, Eastern China, Central China and Western China ranked first, second, and third in the per-capita carbon emissions, while in 2009 the pecking order changed to Eastern China, Western China and Central China. (*ii*) According to the LMDI decomposition results, the key driver boosting the per capita carbon emissions in the three economic regions of China between 1997 and 2009 was economic development, and the energy efficiency was much greater than the energy structure after considering their effect on restraining increased per capita carbon emissions. (*iii*) Based on the decomposition, the factors that affected per capita carbon emissions in the panel cointegration test showed that Central China had the best energy structure elasticity in its regional per capita carbon emissions. Thus, Central China was ranked first for energy efficiency elasticity, while Western China was ranked first for economic development elasticity.

Study by Farhani et al. (2014) explores the relationship between coal consumption, industrial production and CO_2 emissions in case of China and India for the period of 1971–2011. The structural break unit root test and cointegrating approach have been applied. The direction of causal relationship between the variables was investigated by applying the VECM Granger causality test. The results validate the presence of cointegration among the series in both countries. They also find the existence of inverted U-shaped curve between industrial production and CO_2 emissions for India but for China it is U-shaped relationship. Coal consumption adds in CO_2 emission. The causality analysis revealed that industrial production and coal consumption Granger cause CO_2 emission in India. In case of China, the feedback effect exists between coal consumption and CO_2 emissions. Due to the importance of coal in China and India, any reduction in coal consumption will negatively affect their economic growth as well as electricity supply.

Paper by Knight and Schor (2014) explores the relationship between economic growth and CO_2 emissions over the period 1991–2008 with a balanced dataset of 29 high-income countries. They present a variety of models, with particular attention to the difference between territorial emissions and consumption-based (or carbon footprint) emissions, which include the impact of international trade. The effect of economic growth is greater for consumption-based emissions than territorial emissions. They also find that over the study period there is some evidence of decoupling between economic growth and territorial emissions, but no evidence of decoupling for consumption-based emissions.

Li and Ou (2013) employ an extended Kaya identity as the scheme and utilize the Logarithmic Mean Divisia Index (LMDI II) as the decomposition technique based on analyzing CO_2 emissions trends in China. Change in CO_2 emissions intensity was decomposed from 1995 to 2010 and includes measures of the effect of Industrial structure, energy intensity, energy structure, and carbon emission factors. Results from this study illustrate that changes in energy intensity act to decrease carbon emissions intensity significantly and changes in industrial structure and energy structure do not act to reduce carbon emissions intensity effectively. In this connection, studying Indian case for the emission scenario becomes important in order to estimate the changes that attribute emission structure for the Indian economy context.

Decomposition of CO_2 Emission: The Indian Case[4]

India's development path is based on its unique resource endowments, the overriding priority of economic and social development and poverty eradication. In charting out a developmental pathway which is ecologically sustainable, India has a wider spectrum of choices precisely because it is at an early stage of development. India is faced with the challenge of sustaining its rapid economic growth while dealing with the global threat of climate change. This threat emanates from accumulated GHG emissions in the atmosphere, anthropogenically generated through long-term and intensive industrial growth and high consumption lifestyles in developed countries. Climate change may alter the distribution and quality of India's natural resources and adversely affect the livelihood of its people. With an economy closely tied to its natural resource base and climate-sensitive sectors such as agriculture, water and forestry, India may face a major threat because of the projected changes in climate. India emits more than 5 per cent of global CO_2 emissions, and emissions continue to grow. CO_2 emissions have almost tripled between 1990 and 2009. The WEO 2010 New Policies Scenario projects that CO_2 emissions in India will increase by almost 2.5 times between 2008 and 2035. Large shares of these emissions are produced by the electricity and heat sector, which represented 54 per cent of CO_2 in 2009, up from 40 per cent in 1990. CO_2 emissions in the Transport sector accounted for only 9 per cent of total emissions in 2009, but transport is one of the fastest-growing sectors (Figure 3a).

In 2009, 69 per cent of electricity in India came from coal, another 12 per cent from natural gas and 3 per cent from oil (Figure 3b). The share of fossil fuels in the generation mix grew from 73 per cent in 1990 to 85 per cent in 2002. The share of fossil fuels has declined steadily since then, falling to 81 per cent in 2006, although increasing back up to 84 per cent in 2009. Although electricity produced from hydro has actually increased during this period, the share fell from 25 per cent in 1990 to 12 per cent in 2009.

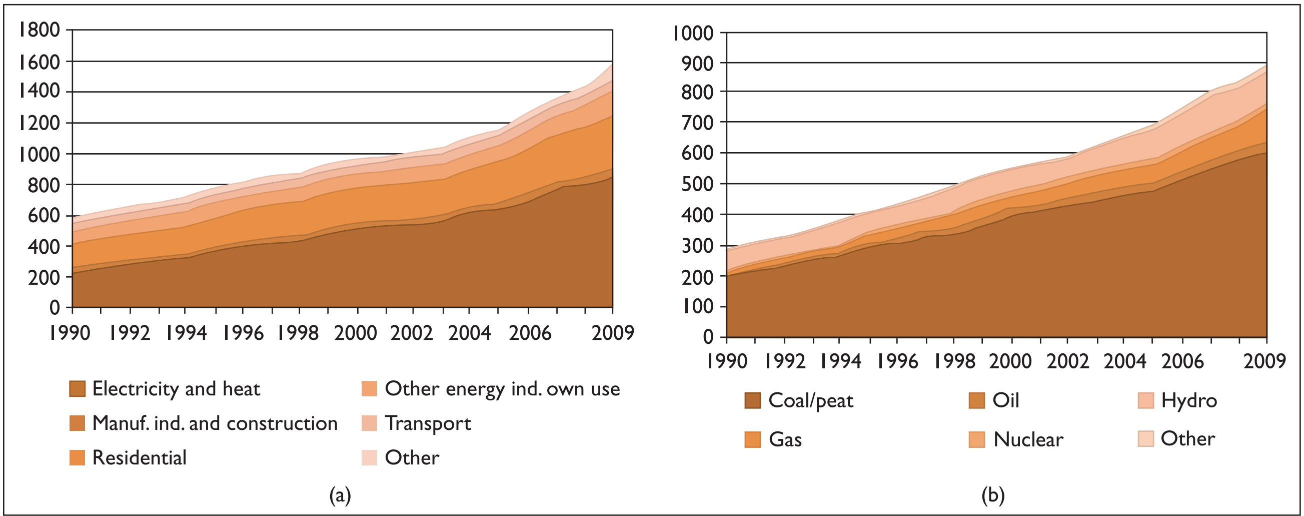

Figure 3. (a) CO_2 Emission by Sector and (b) Electricity Generation by Sector in India

Source: IEA statistics on CO_2 emission, 2011.

India is promoting the addition of other renewable power sources into its generation mix and had an installed capacity of 17 GW of renewable energy sources on 30 June 2010. Under its National Action Plan on Climate Change, India plans to install 20 GW of solar power by 2020. With an installed wind capacity of 12 GW in 2010, India has the world's fifth-largest installed capacity of wind power of the BRICS countries, India has the lowest CO_2 emissions per capita (1.4 T-CO_2 in 2009), about one-third that of the world average. However, due to the recent large increases in emissions, the Indian ratio is more than two times that of its ratio in 1990 and will continue to grow. India's per capita emissions in 2035 will, however, still be well below those in the OECD member countries today. In terms of CO_2/GDP, India has continuously improved the efficiency of its economy and reduced the CO_2 emissions per unit of GDP by 16 per cent between 1990 and 2009.

To understand the factors affecting the increase in CO_2 emission in India, we have followed the index decomposition analysis. Most importantly we have focused on the post-1991 case for the Indian economy. In analyzing the increase in CO_2 emission, we have used the three important sectors of the economy and their output changes from 1991. The three sectors of Indian economy the Agriculture, the Manufacturing and the Service sector are considered. The detail methodology followed in the study is narrated to explain the underlying concept with reference to the decomposition of a change in the aggregate emission intensity of Indian Economy. We are following the two-factor case in which a change in the aggregate intensity is decomposed to give the impacts of structural change and sectoral output change using the intensity approach.

Let us assume that total emission of the economy is the sum of emission from '***n***' different sectors time '***t***'. The emission intensity is defined as a ratio of the emission of the Indian Economy of sector '***i***' at time '***t***' to the total output of the same sector (defined in terms of value added).

E_t = Total Emission of the economy
$E_{i,t}$ = Total Emission in sector i
Y_t = Total sectoral output
$Y_{i,t}$ = Output of sector i
$S_{i,t}$ = Output share of sector i (= $Y_{i,t}/Y_t$)
I_t = Aggregate carbon emission intensity (= E_t/Y_t)
$I_{i,t}$ = Carbon Emission intensity of sector i (= $E_{i,t}/Y_{i,t}$)

Let us express the aggregate emission intensity as a summation of the sectoral data as:

$$I_t = \sum_i S_{i,t} I_{i,t}, \tag{1}$$

Where, the summation is taken over the n sectors. We derive the general parametric Divisia method in a manner the same as that described in Liu and Ang (2007). Differentiating equation foregoing with respect to t yields the following:

$$I_t^{'} = \sum_t I_{i,t} S_{i,t}^{'} + \sum_t I_{i,t}^{'} S_{i,t}. \tag{2}$$

This involves the decomposition of two aggregate emission intensities. Now dividing equation 2 by I_t and integrating on both sides from year 0 to year t, we have:

$$In(I_t/I_0) = \int \Big(\sum_i I_{i,t} S_{i,t}^{/}/I_t\Big)dt + \int \Big(\sum_i I_{i,t}^{/} S_{i,t}/I_t\Big)dt \cdot \tag{3}$$

Let us define $\overset{*}{AC} = I_t/I_0$, where; $\overset{*}{AC}$ is the change in aggregate emission intensities. As we are considering the two-factor decomposition, $\overset{*}{AC}$ is defined as the change in the emission intensity in time ***t*** over time ***0***. Now equation 3 can be rewritten as the following expression:

$$\begin{aligned}\overset{*}{AC} &= \exp\Big\{\sum_i I_{i,t} S_{i,t}^{/}/I_t\,dt\Big\} \\ &\quad \exp\Big\{\sum_i S_{i,t} I_{i,t}^{/}/I_t\,dt\Big\} \\ &= \overset{\text{int}}{AC}\,\overset{str}{AC}\,\overset{res}{AC}\end{aligned} \tag{4}$$

Where $\overset{str}{AC}$ is estimated structural effect, $\overset{\text{int}}{AC}$ is the estimated intensity effect and $\overset{res}{AC}$ is the residual of the model. The structural effect captures the change in emission due to change in output and the intensity effect captures the change in emission due to change in emission intensity of the sector in context. The equations for the structural as well as the intensity effect are as follows:

$$\overset{str}{AC} = \exp\Big[\sum_i [\, I_{i,0}/I_0 + \beta_i\,(\, I_{i,t}/\,I_t - I_{i,0}/I_0)]\;(S_{i,t} - S_{i,0})\Big] \tag{5}$$

and

$$\overset{\text{int}}{AC} = \exp\Big[\sum_i [S_{i,0}/I_0 + \tau_i\,(S_{i,t}/\,I_t - S_{i,0}/I_0)]\;(I_{i,t} - I_{i,0})\Big] \tag{6}$$

Where, $0 \le \beta_i, \tau_i \le 1$

The result of the decomposition drawn using the General Parametric Multiplicative Divisia Method, is presented in

Table 1. Results of the Decomposition Based on the General Parametric Multiplicative Divisia Method

Year	$\overset{*}{AC}$	$\overset{str}{AC}$	$\overset{int}{AC}$	$\overset{res}{AC}$
1991	0.97	0.99	0.99	1.00
1992	0.74	1.44	0.73	0.71
1993	1.35	0.72	1.41	1.32
1994	1.03	0.94	1.04	1.04
1995	0.89	1.09	0.90	0.91
1996	0.94	1.03	0.94	0.96
1997	1.03	0.93	1.05	1.05
1998	1.04	0.94	1.04	1.06
1999	0.93	1.00	0.98	0.95
2000	0.97	1.02	0.96	0.99
2001	0.95	1.01	0.96	0.98
2002	0.93	1.04	0.94	0.95
2003	0.99	0.99	0.98	1.01
2004	0.99	0.99	0.98	1.02
2005	0.84	1.17	0.84	0.87
2006	0.96	1.01	0.97	0.99
2007	0.91	1.08	0.91	0.93

Source: Authors' own calculation using data from CMIE (accessed on 16 August 2011).

Table 1. It can be clearly visible from Figure 4 and Table 1 that the residuals are tending to one, which is similar to the characteristics of the multiplicative index of decomposition, and hence, the decomposition is assumed to be near perfect.

As compared to the intensity effect the changes in emission intensity is explained heavily by the structural change that is the change in emission intensity due to the change in output. Change in output is assumed to have higher emission due to higher energy consumption. Hence, we can see from the Table 2 that the changes in emission intensity is driven more by the change in the structural change of the economy and changes in the sectoral output change in

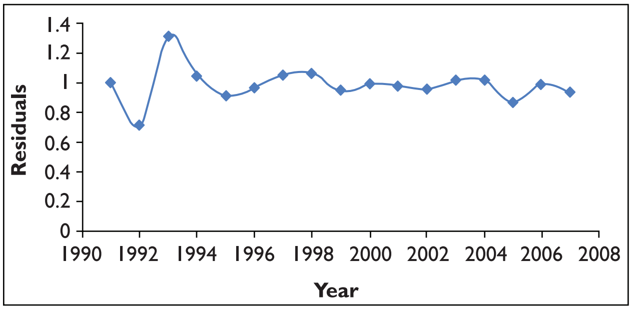

Figure 4. Output of the Residual Term in Decomposition Analysis based on General Parametric Multiplicative Divisia Method

Source: Authors' own calculation using data from CMIE (accessed on 16 August, 2011).

Table 2. Percent Changes in Emission Intensity due to Structural Change and Sectoral Change Intensity from the General Parametric Multiplicative Divisia Method

Year	% Change in $\overset{*}{AC}$	% Change in $\overset{str}{AC}$	% Change in $\overset{int}{AC}$
1991–1992	25.97	–44.11	27.21
1992–1993	–35.12	27.86	–41.19
1993–1994	–2.59	5.96	–4.39
1994–1995	11.06	–9.08	10.45
1995–1996	6.00	–3.49	5.66
1996–1997	–3.01	6.88	–5.04
1997–1998	–4.11	5.79	–3.65
1998–1999	7.02	–0.10	1.67
1999–2000	3.12	–1.90	4.16
2000–2001	4.52	–1.42	3.73
2001–2002	6.94	–4.08	6.20
2002–2003	1.20	0.69	1.59
2003–2004	0.78	0.58	1.73
2004–2005	15.72	–16.69	16.35
2005–2006	3.75	–1.07	3.34
2006–2007	9.00	–7.83	9.40

Source: Authors' own calculation using data from CMIE (accessed on 16 August 2011).

Indian economy. In case of the year 1992, we can see that the positive change of 25.97 percent in the energy intensity as compared to the 1991 is driven by –44.11 per cent change in structural change in the output, and 27.21 per cent change in sectoral energy intensity. The change in the energy intensity is not consistence from 1991 to 2007, so as the case with both the sectoral emission intensity change and the structural effect. Higher production leads to higher emission for the Indian economy for the three sectors.

We can observe the variation in the total emission intensity, sectoral emission intensity and the change in sectoral output intensity due to the structural effect from Figure 5. It can be clearly noticed from the figure that the emission intensity change in Indian economy in mainly due to the change in the structural output change and yielded a negative relation. Once there is a negative change in the sectoral share of output, the emission intensity of the different sectors of the economy are rising and vice versa. However, the sectoral emission intensity has a positive relationship with the total emission intensity of the Indian economy. It can be noted that the change in the emission due to the structural change of the economy is largely due to the

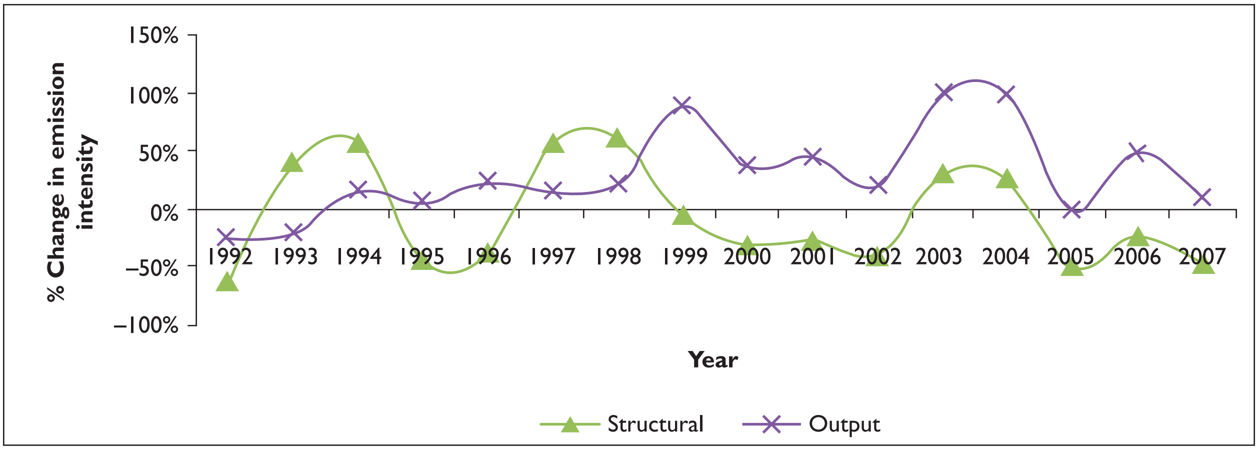

Figure 5. Percent Changes in Structural Change and Sectoral Energy Intensity

Source: Authors' own calculation using data from CMIE (accessed on 16 August, 2011).

implementation of the LPG policy. The LPG policy enhanced the possibilities of making Indian economy globally competitive and hence, higher production was recorded for sectors such as manufacturing and services industries. As the output of the economy from the three sectors (Agriculture, Manufacturing and Service) increased, which lead to a positive change in the emission.

Policy Options for India

Analysis based on the decomposition analysis has resulted that the structural change and output change are negatively related while we consider the emission change from 1991 to 2007 for the Indian economy. Therefore, at the post-globalized scenario, Indian economy should concentrate more on stabilizing the structural change in the economy and use of more technological sophisticated machines and aim of shifting towards clean energy sources. Growth in output that is the change in the structure of the sectors are one of the characteristics of an developing economy; however, shifting to clean energy and advancement in technology suitable to reduce emission will enhance positive benefits to climate change scenario for Indian economy. From the review and international experience and suggestions we can divide the policy intervention in seven broad areas from regulations and standards to institutional initiatives. It is important to note that irrespective of any policy choice, mitigating the impact of energy related climate change will require the following four key considerations.

1. Environmental effectiveness: The extent to which the policy meets its intended environmental objectives or realizes positive environmental outcomes.
2. Cost effectiveness: The extent to which the policy can achieve its objectives at minimum cost to the society.
3. Distributional considerations: The incidence or distributional consequences of the policy. Fairness and equity are dimensions of this though there are other dimensions to distribution.
4. Institutional feasibility: The extent to which a policy instrument is likely to be viewed as legitimate, gain acceptance, adopted and implemented (IPCC, 2007).

Table 3 presents an overview of some available policy instruments.

Under the Energy Conservation Act (2001), energy intensive industrial sectors, that is, thermal power stations, fertilizer, cement, iron and steel, aluminium, railways, textile and pulp and paper, are required to employ a certified energy manager, conduct energy audits periodically, and adhere to specific energy-consumption norms that may be prescribed. Currently, almost every Industrial sector is characterized by a wide band of energy efficiencies in different units. Several of them are at global frontier levels, but some others have relatively poor performance. As an approach to enhancement of overall energy efficiency in each sector, the efficiency band-width of the sector is divided into bands. To promote technology upgradation in the SMEs (small and medium enterprises) sector, it would be essential to evolve sector-specific integrated programmes for technology development. This would require external support for significantly longer durations to address various technological barriers and promote energy efficiencies at the unit level. Most of the energy-efficient

Table 3. An Overview of Climate Change Policy Instruments

An Overview of Climate Change Policy Instruments	
Regulations and Standards	Specify abatement technologies (technological standards) or minimum requirements for pollution output (performance standards) to reduce emissions.
Taxes and Charges	A levy imposed on each unit of undesirable activity by a source Tradable Permits: Also know as marketable permits or cap-and-trade systems, this instrument establishes a limit on aggregate emissions by specified sources, requires each source to hold permits equal to its actual emissions, and allows permits to be traded among sources.
Voluntary Agreements	An agreement between a government authority and one or more private parties to achieve environmental objectives or to improve environmental performance beyond compliance to regulated obligations. Not all voluntary agreements are truly voluntary; some include rewards and/or penalties associated with joining or achieving commitments.
Subsidies and Incentives	Direct payments, tax reductions, price supports, or the equivalent from a government to an entity for implementing a practice or performing a specified action.
Information Instruments	Required public disclosure of environmentally related information, generally by industry to consumers. Include labelling programmes and rating and certification.
Research and Development	Direct government spending and investment to generate innovation on mitigation, or physical and social infrastructure to reduce emissions. Include prizes and incentives for technological advances.
Non-climate Policies	Other policies not specifically directed at emissions reduction but that may have significant climate-related effects.

Source: IEA (2007) and IPCC (2010).

equipment requires higher upfront investment. This means that there is no one-size-fits-all policy prescription to climate change mitigation. A combination of policy options is needed. In line with this, the following options are preferred:

1. Energy Pricing Reform

   The World Bank estimates for 1993 showed that developing countries and transition economies spent more than US$230 billion per year on subsiding energy (Cao, 2003). Energy products like coal in China, India, Poland and Turkey have been heavily subsidized (World Bank, 2000), just as Nigeria spends billions on petroleum subsidy. The implication of this has been inefficient use of energy as well as serving as a disincentive for controlling energy-related emissions. Efficient energy pricing will not only remove these price distortions but would sharply reduce the growth in energy consumption and could also cut world carbon emissions by 10 per cent (World Bank, 2000).[5]

2. Emission Taxes

   It is obvious that efficient pricing reforms that results in energy prices reflecting production may still be far from reflecting social cost. Emission taxes could prove useful in adjusting market prices to reflect externalities. A high taxes on carbon-intensive fuels like coal could reduce their consumption and hence, carbon emissions. In Mexico, an application of gasoline tax, among other measures, has helped to dramatically reduced GHG emissions coming from transportation (World Bank, 1992).

3. Promotion of Investment in Renewable Energy

   Ultimately, the mitigation of energy-related climate change rest upon the use of renewable energy including hydro, solar, wind, biomass and other forms of renewable, which are more environmentally friendly than conventional fuels (Cao, 2003). In many developing countries, there is a huge untapped and inefficiently utilized renewable energy resource which need specific national policy initiatives and international support, including finance, capacity building and technology transfer to be exploited. Environmental taxes on fossil fuels may be required to stimulate reactions in favour of renewable energy. Increased funding of R&D in renewable energy should also be pursued.

4. Improve Public Environmental Awareness

   Ignorance of the serious impact of their collective actions on climate change by the general public is an important cause of environmental damage and a serious impediment to finding solutions. Adequate environmental information is required to enlighten the public on the seriousness of the worsening environment they are living in, the costs to their health and quality of life. Such enlightenment would help to raise peoples' consciousness and enlist public support for environmental protection laws or policies. This could help to facilitate and augment official enforcement of environmental policies.

Conclusion

One of the major problems facing humanity in terms of achieving sustainable development is climate change. Many economic activities release GHGs within the earth's atmosphere. The article explored the role of energy in the climate change in particular case relating to the emission. Evidence has revealed that fossil fuels constitute the single largest human influence on the climate change debate, accounting for over 80 per cent of the anthropogenic greenhouse emissions. Given the fact that primary energy still dominates the world energy mix, reducing energy-related carbon emissions may require reducing the amount of fossil fuel consumption and hence, economic growth.

In case of Indian economy empirical estimates based on a decomposition analysis found that the structural changes in the economy are more important to reduce emission. However, the output changes are surely increasing the CO_2 emission largely due to use of fossil fuel. Hence, improving energy efficiency, reforms of inefficient energy pricing, imposition of carbon emission taxes, promoting investment in renewable energy and creating public environmental awareness are some of the mitigation strategies suggested for the Indian economy.

Notes

1. Annex I Countries include Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco (included with France), the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom and the United States.
2. See further evidence in IEA (2010a) for the IPCC default carbon emissions factors from the 1996 IPCC Guidelines which are 15.3 t C/TJ for gas, 16.8 to 27.5 t C/TJ for oil products and 25.8 to 29.1 t C/TJ for primary products.
3. The top ten CO_2 emitting countries in the world as of 2008 were China, the United States, the Russian Federation, India, Japan, Germany, Canada, the United Kingdom, the Islamic Republic of Iran and Korea, in that order. These ten countries account for 19.1 Gt CO_2 out of the world's 29.3 Gt CO_2 in 2008.
4. For detail methodology please, see B. W. Ang, 1994, *Energy Economics, V-16, No. 3.*
5. It is important to note that the removal of energy subsidies has always faced the problem of trade-off between worsening the level of poverty for the majority of the population and improving the environmental quality. Again, it is usually reasoned that one-stop removal of such subsidies may worsen the environmental problems because the affected poor may substitute poorer quality fuels for the cleaner but now (with removal of subsidies) dearer fuels.

References

Akbostanc, E., Tunç, G. I., & Türüt-Asık, S. (2011). CO2 emissions of Turkish manufacturing industry: A decomposition analysis. *Applied Energy, 88*(6), 2273–2278.

Baer, P., Tom, A., Kartha, S., & Kemp-Benedict, E. (2008). Greenhouse development rights: Towards an equitable framework for global climate policy. *Cambridge Review of International Affairs, 21*(4), 649–666.

Cao, X. (2003). Climate change and energy development: Implications for developing countries. *Resources Policy, 29*, 61–67.

Carbon Dioxide Information Analysis Center (CDIAC). (2009). Oak Ridge National Laboratory. Retrieved from http://www.esd.ornl.gov/iab/iab2-15.htm

Carbon Dioxide Information Analysis Center (CDIAC). (2010). Oak Ridge National Laboratory and British Petroleum. Retrieved from http://www.columbia.edu/~mhs119/UpdatedFigures/

Dong, F., Long, R., Chen, H., Li, X., & Yang, Q. (2013). Factors affecting regional per-capita carbon emissions in China based on an LMDI factor decomposition. *PLoS ONE, 8*(12), 1–10.

Energy Conservation Act (2001). Ministry of Power, Government of India. Retrieved from http://powermin.nic.in/acts_notification/energy_conservation_act/

Farhani, S., Shahbaz, M., & Ozturk, I. (2014). Coal consumption, industrial production and CO2 emissions in China and India. Working Paper 2014–225. IPAG Business School. Retrieved from http://www.ipag.fr/fr/accueil/la-recherche/publications-WP.html

Girardet, H. & Mendonca, M. (2009). *A renewable world: Energy, ecology, equality.* World Future Council, UK: Green Books ltd.

International Energy Agency (IEA). (2007). Data cited by Planning Commission, India.

International Energy Agency (IEA). (2010a). *CO_2 emissions from fuel combustions, highlights*. Paris, France: OECD/IEA.

International Energy Agency (IEA). (2010b). CO_2 emissions from fuel combustions, annual historical series (1971–2008). Retrieved from www.iea.org/statistics/

IPCC. (2007). Climate change 2007: Mitigation of climate change. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press.

IPCC. (2010). Climate change assessments: Review of the processes and procedures of the IPCC. Inter Academy Council. Retrieved from http://reviewipcc.interacademycouncil.net/report/Climate%20Change%20Assessments,%20Review%20of%20the%20Processes%20&%20Procedures%20of%20the%20IPCC.pdf

IPCC. (2013). Climate change: The physical science basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Retrieved from https://www.ipcc.ch/report/ar5/wg1/

Knight, K. W. & Schor, J. B. (2014). Economic growth and climate change: A cross-national analysis of territorial and consumption-based carbon emissions in high-income countries. *Sustainability, 6*(6), 3722–3731.

Li, W. & Ou, Qing-Xiang. (2013). Decomposition of China's carbon emissions intensity from 1995 to 2010: An extended kaya identity. *Mathematical Problems in Engineering, 2013* (pp. 1–7), Article ID 973074 (Hindawi Publishing Corporation).

Liu, N. & Ang, B. W. (2007). Factors shaping aggregate energy intensity for industry: Energy intensity versus product mix. *Energy Economics, 29*(4), 609–635.

Prowess (2011). Center for Monitoring Indian Economy. Retrieved from https://prowess.cmie.com/

Quadrelli, R. & Peterson, S. (2007). The energy-climate challenge: Recent trends in CO_2 emissions from fuel combustion. *Energy Policy, 35*(11), 5938–5952.

Reddish, A. & Rand, M. (1996). The environmental effects of present energy policies. In J. Blunden, & A. Reddish (Eds), *Energy resources and environment* (pp. 43–91). Hodder and Stoughton & the Open University.

Spence, M. (2009). Climate change, mitigation, and developing country growth. Commission on Growth and Development Working Paper No. 64. Washington, DC: The World Bank. Retrieved from www.growthcommission.org/storage/cgdev/documents/gcwp064812web.pdf

World Bank (1992). World development report 1992: Development and the environment. Oxford University Press.

World Bank (2000). *Fuel for thought: An environmental strategy for the energy sector*. Washington DC, USA: The International Bank for Reconstruction and Development/World Bank.