Chapter 1
Economic Growth and Greenhouse Gas (GHG) Emissions: Policy Perspective from Past Indian Studies

Understanding the impact of climate change on the economy's performance has become an important issue for all the countries: developed, developing, or emerging. Some see this problem as more acute in case of developing countries which are on high growth trajectories (Aggarwal and Narain 1991). The emissions of greenhouse gases (GHGs) have increased over time (Das et al. 2007; Sharma et al. 2006; Intergovernmental Panel on Climate Change (IPCC) 2010; Stern 2007; GEA 2012). The IPCC in its fourth assessment report mentioned that the changes in atmospheric concentration of GHGs and aerosols, land cover, and solar radiation alter the energy balance of the climate system and become drivers of climate change. According to this report, the annual carbon dioxide (CO_2) concentration growth rate has been larger during the last 10 years (1995–2005 average 1.9 parts per million (ppm) per year) than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average 1.4 ppm per year). The global atmospheric concentration of methane has increased from a preindustrial value of about 715 parts per billion (ppb) to 1732 ppb in the early 1990s, and is 1774 ppb in 2005. The global atmospheric nitrous oxide concentration increased from a preindustrial value of about 270 ppb to 319 ppb in 2005. The precipitation has become spatially variable and the intensity and frequency of extreme events have increased. The sea level also has risen at an average annual rate of 1–2 mm during this period. However, the continued increase in concentration of GHGs in the atmosphere is likely to lead to climate change resulting in large changes in ecosystems, leading to possible catastrophic disruptions of livelihoods, economic activity, living conditions, and human health (IPCC 2010).

Historically, the industrialized countries have been the primary contributors to GHG emissions. Only 25% of the global population living in Annex I countries emit more than 70% of the total global CO_2 emissions and consume 75–80% of many of the other resources of the world (Parikh et al. 1991). But, because of their high population and economic growth rates, the fossil fuel use led CO_2 emissions from developing countries are likely to soon match or exceed those from the industrialized countries (Sathaye et al. 2006). Therefore, if the responsibility for emissions increase in the past lies largely with the industrialized world, then the late-industrializing countries are likely to be the source of an increasing proportion of future increase of GHGs.

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1.1 Climate Change and Economic Growth: Global Context

It is now widely accepted in climate change literature that the global economy is highly vulnerable to global warming, with sectors most directly and heavily impacted being agriculture, coastal resources, energy, forestry, tourism, and water (Pearce et al. 1996 and Bach et al. 2001). But the economies of some countries are more vulnerable to climate change than those of others because of varying share of these sectors in economic growth (Blackman and Harrington 2000). Late-industrializing countries in general have a larger share of their economic activity coming from agriculture and forestry (Darwin et al. 1995). They also tend to be in the lower latitudes where the impacts of these sectors will be most severe. The low latitudes tend to be too hot for reasonably profitable agricultural activities and any further warming will further reduce agricultural productivity and thereby agricultural profitability here. Up to 80 % of the damages from climate change may be concentrated in low latitude countries (Mendelsohn 2006).

It is generally agreed that the countries in Africa will experience declining yields in the long run. For example, agricultural production in Guinea-Bissau where agricultural sector adds value of up to 62 % of gross domestic product (GDP) is estimated to contribute only 32.7 % of GDP (without carbon fertilization) by 2080. The impacts on development and food security, as well as on nutrition, will be enormous (Mendelsohn 2006).

1.2 Climate Change and Economic Growth: Indian Context

Indian economy is highly vulnerable to global warming caused by GHG emissions. The Indian Network for Climate Change Assessment report (INCCA 2010) indicates that the average annual surface air temperature in India is increasing by 0.40℃ with not much variation in absolute rainfall. The sea level has increased at a rate of 1.06–1.25 mm/year during the last four decades across the coastal India. The same report has predicted that the temperature in India will be increased by 2–40℃ by 2050s. The climate sensitive sectors such as agriculture, forestry, coastal, and water resources will be adversely affected because of climate change. A devastating impact of climate change in India will be the rise in the sea level, resulting in the inundation of coastal areas. Coupled with these, the increase in cyclones accompanied by enormous volume of sea water would bring about mass devastation of human life as well as the economy. Estimate suggests that due to 1 m increase in the sea level, 7 million people would be displaced; about 5764 km^2 land and 4200 km stretch of roads would be lost (www.adb.org).

Indian economy has historically been an insignificant contributor to the global climate change. According to the INCCA (2010) report, India ranks fifth in aggregate GHG emissions in the world, behind USA, China, EU, and Russia in 2007. But the emissions of USA and China are almost four times that of India in the same year. Also, India's per capita carbon dioxide equivalent (CO2EQ) emission is 1.5 t/capita in 2007 which is roughly one fourth of the world average per capita emission of 4.5 t per annum (INCCA 2010). The main cause of CO_2 emission in India is the low-energy efficiency of coal-fired power plants, scarcity of capital, and the long lead time required to introduce advanced coal technologies. However, as India is now a fast-growing economy, its total emission is bound to grow rapidly. Restricting arise in or even lowering the carbon emission intensity can be a good strategy for India while it is on its way towards fast economic progress.

India signed the United Nations Framework Convention on Climate Change (UNFCCC) on June 10, 1992 and ratified it on November 1, 1993. It ratified the Kyoto Protocol on August 26, 2002 and hosted the Eighth Conference of the Parties (COP 8) in October 2002 in Delhi. There are number of projects underway directly aimed at reducing GHG emissions funded by the Global Environment Facility (GEF). Most of these projects are on renewable energy sources and biomass (Das et al. 2007). On the other hand, government of India has submitted its First National Communication (NATCOM I) to the UNFCCC in June 2004 and Second National Communication report (NATCOM II) in May 2010. This report, being brought out by INCCA, provides updated information on India's GHG emissions.

In India, policymakers are exploring various policy options that would limit carbon emissions. Stronger environmental measures encouraging use of clean fuel and improving energy efficiency are few of them (MoEF 2009). Not surprisingly, clean development mechanism (CDM) has generated much enthusiasm in India.

Parikh and Parikh (2002) point to a number of areas where India has reduced GHG emissions because of policies aimed at other goals. The gradual removal of energy subsidies and move towards free-market pricing for energy sources has been important in scaling back demand for coal in response to a 370 % rise in the price of coal between 1980 and 1995. Electricity prices have risen even more over this period. Increased openness has meant that energy-efficient imported goods from white goods to motor vehicles have driven innovation in more energy-efficient Indian products.

The notable improvement in energy efficiency in India is well documented. It has been driven partly by policy and partly by price-induced incentives to conserve energy (Parikh and Parikh 2002). Also, the government of India has long promoted renewable energy sources. Other policies aimed at reducing local air pollution in the transport sector has also helped in lowering GHG emissions.

Again in the context of global climate change mitigation, the Annex-I countries, i.e., countries under Kyoto Protocol, committed to emission reduction targets, either voluntarily or by the protocol obligations, are allowed to trade among themselves the rights to emit GHGs (Bolin 1998). These rights are known as tradable permits. These rights materialize if at least some of the committed countries achieve additional GHG emissions abatement, over and above their committed abatement level. Countries for which the difference between assigned amounts and actual emissions is negative can potentially buy rights to emit from those for which the said difference is positive. It is obvious that tradable permits are market-based instruments meant to equalize marginal costs of abatement across countries.

However, there is considerable debate across the world about what can be the optimal policy response to mitigate GHG emissions. Economists, after weighing the costs and benefits, advocate a balanced mitigation program that starts with mild emission reduction targets which gradually increase in severity over the century. Scientists and environmentalists, in contrast, advocate more extreme near-term mitigation policies. What implications these two alternative approaches have for humankind is a burning research question. The balanced economic approach to the problem will address climate change with minimal reductions in economic growth, but is likely to impede human welfare in the long run. On the other hand, more aggressive near-term mitigation programs, recommended by the ecologists, would be harmful for economic growth, but helpful for the crumbling ecosystem on whose very existence depends the long-term survival and security of humanity (Stern 2007; IPCC 2010; Mendelshon 2009).

1.3 Past Studies

In the context of burgeoning GHG emissions and their extremely adverse impact on the economy, different national and international institutes as well as individual environmental economists are forging together to undertake scientifically rigorous impact analysis. One such study has been done by Darwin et al. (1995) which analyses how climate change might affect water supplies and the availability of cultivable land, which in turn would impact the total world production of goods and services. According to this study, world output of processed food would decline from 0.002 to 0.58%. In other words, the new temperature and precipitation patterns under climate change are likely to reduce the average productivity of the world's existing agricultural lands. Further, land-use changes that accompany climate-induced shifts in cropland, and permanent pasture are likely to raise additional social and environmental issues. Although water supplies are likely to increase for the world as a whole under climate change, shortages could occur in some regions. Finally, climate change is likely to affect the structure of agriculture and food processing in the USA most unfavorably.

In a similar vein, Pohit (1997) attempted to analyze the impact of climate change on India's agriculture using a 10 sector-10 region global CGE model, with India being one of its ten regions. The general conclusion that emanates from this study is that there could be substantial welfare implications for the Indian economy in general depending on how one accounts for the carbon fertilization effect.

Study by Kumar and Parikh (1996) focuses on assessment of the climate change impacts on Indian agriculture. The study is organized under two stages, namely, the physical impact assessment and the economic implications of such physical impacts. The future climate change scenarios have been developed using results from equilibrium experiments of General Circulation Models (GCMs), along with the observed climatic changes. In order to assess the physical impacts of climate change on agriculture, the study follows the crop simulation modeling approach and to translate these impacts into socio-economic impacts, the Agriculture, Growth, and Redistribution of Income Model (AGRIM) is used. Finally, the welfare implications are assessed in terms of equivalent incomes and population proportions in various expenditure classes of the economy. The results of the study indicate that wheat crop, grown generally in the winter season, is likely to be affected more than rice crop following climate change; CO_2 fertilization effects seem to reduce the effects of climate change dramatically. The study shows that substantial number of people move from higher income classes to lower income classes as a result of climate-change-induced shocks, and social welfare is adversely affected.

Mckinsey and Evenson (1998) estimate the impact of a rise in normal temperatures and of increases in rainfall levels for different regions. The study incorporates technology-climate interactions enabling an assessment of the climate friendliness of the Green Revolution in Indian agriculture. Technological gains during the period of Green Revolution are incorporated in the study by modeling three activities as endogenous variables, which are the development and diffusion of high yielding variety (HYV), expansion of multiple cropped areas, and the expansion of area under irrigation. The results of this study indicate that a 1 °C rise in temperature has negative impact on the HYV adoptions. This is most negative in Gujarat and is positive in some regions such as Andhra Pradesh, Orissa, etc. While the temperature impact on multiple cropping is positive on an average, that on irrigation is uniformly negative. Increased rainfall has negative but small effects on HYV adoption, irrigation intensity, and multiple cropping.

Ravindranath et al. (2006) assesses the impact of climate change on forests in India. This assessment is based on climate projections of regional climate model of the Hadley Center (HadRM3) using the A2 (740 ppm CO2) and B2 (575 ppm CO2) scenarios of special report on emissions scenarios and the BIOME4 vegetation response model. The main conclusion is that under the climate projection for the year 2085, 77% and 68% of the forested grids in India are likely to experience shifts in forest types under A2 and B2 scenarios, respectively. There are indications for a shift towards wetter forest types in the north-eastern region and drier forest types in the north-western region in the absence of human influence. Increasing atmospheric CO2 concentration and climate warming could also result in a doubling of net primary productivity under the A2 scenario and nearly 70% increase under the B2 scenario.

We turn now to the role of policy in climate change mitigation. To assess the impact of carbon taxes for the Indian economy, Gupta and Hall (1997) interweave a micro-level analysis of technological alternatives to reduce carbon emissions into a macro-econometric model. This interwoven model is especially helpful for assessing the effects of carbon tax financed investments in carbon-abating technologies. However, the issue of income distribution remains unaddressed as it is a macro model. Alternative policy scenarios built with the help of this model are compared mainly in terms of their implied carbon emissions and GDP, not with respect to their distributional implications.

Fischer-Vanden et al. (1997) employed a nine-sector computable general equilibrium (CGE) model of the Indian economy, based on the Indian module of the Second Generation Model (SGM) version 0.0. The SGM model is a typically neoclassical price driven CGE model, which is used to evaluate the effects of carbon taxes and participation in globally tradable permits regime on carbon emissions and economic growth. The SGM model assumes a single representative household and, hence, suppresses the income distribution aspect of an economy. However, it captures successfully the trade-off between carbon emissions and GDP growth. To evaluate the impact of carbon taxes on growth as well as distribution, the concerned model must include an endogenous income distribution mechanism. A model which does precisely that is that of Murthy, Panda, and Parikh (2007). This is an integrated top-down bottom-up model for the Indian economy which includes specific technological options and an income distribution module in an activity analysis framework. The model is multi-period and multi-sectoral and is formulated to be a programming model which allows for inter-temporal dynamic optimization. While the endogenous income distribution mechanism of the model is useful in computing the poverty ratios under different scenarios pertaining to carbon taxes and India's participation in an internationally tradable emission permits regime, the model, because it uses the activity analysis framework, is more like a planning model based on supply-side consistency rather than a market driven model which equates demand and supply through endogenous determination of prices. The CGE model of Ojha (2009) for India, however, embodies both an endogenous price system which balances demand and supply, and an endogenous income distribution module which enables the calculation of poverty ratios. It is therefore just appropriate for simulating the effects of carbon taxes and participation in a globally tradable emission permits regime on GDP and poverty.

Our review of literature brings forth research gaps. It is observed from the above review of literature that most of the studies in the subject of climate change impact analysis are for the vulnerable sectors of the economy like agriculture, forestry, fisheries, etc. On the other hand, there are some other sectors which may not be vulnerable but they may be making significant contributions to GHG emissions as well as on economic growth. For example, the manufacturing sector together contributes almost 27 % of total GHG emissions in the year 2006−2007 (INCCA 2010) and their share in GDP for that year is almost 18 % (CSO, National Accounts Statistics 2009). Therefore, growth in manufacturing sector will have significant impact on GHG emissions in India. In the year 2006−2007, thermal electricity sector alone contributes 37.8 % of total GHG emissions (INCCA 2010). Almost 86 % of energy in India comes from the thermal electricity sector (CSO, energy statistics 2009). So the growth of the Indian economy will depend on the growth of the thermal electricity sector, which in turn will lead to increase in GHG emissions in India. Again, as every sector is dependent upon and feeds every other sector through input-output linkages, the growth of a sector will have direct and indirect impacts on GHG emissions.

In India, policymakers are trying to provide different policy options for mitigating climate change impact in India. Energy efficiency improvement is one of them. Climate change experts are of the opinion that energy efficient technology will reduce future GHG emissions but not economic growth (MoEF 2009). On the other hand, the reduction in CO2EQ emission from economic activities by decoupling economic growth and GHG flow has been incorporated into the climate change mitigation policy agenda globally since the last two decades. To define appropriate policy interventions, a clear understanding of how emissions are generated and the economic and technological factors that influence the country's GHG profile is a must. This necessitates an in-depth study of this particular issue. Hence, this is another glaring research gap in this subject.

Apart from the energy efficiency improvement measures, there are three other policy measures for emissions abatement: command and control, carbon taxes, and participation in emissions trading (Ellis and Tirpak 2006). But the command-and-control measure has some serious limitations. Firstly, command-and-control measures have been shown to be statically and dynamically inefficient as compared to market-based instruments (MBIs) such as carbon taxes (Pearson 2000). Secondly, under a command-and-control measure, in order to reduce carbon emissions, it is the output of goods produced that has to contract as there is limited scope for substitution across (fuel) inputs. The loss in output in turn translates into a deadweight loss in welfare (Harrington and Morgenstern 2004). However, in case of MBIs like carbon taxes, the government can plough back the tax revenue productively to yield benefits for the economy over and above those resulting from lower emissions, thus, reducing the net loss in welfare. The government can also substitute the carbon tax for some other more distortionary tax and thus generate efficiency gains for the economy, i.e., reap double-dividend (Pearson 2000). Though the market-based incentive policies seemingly have direct and indirect advantages in India, their net impacts on the economy must be precisely evaluated and compared through a suitable empirical GHG emissions abatement model, so that they can be prioritized.

The role of clean development mechanism (CDM) and other mechanisms of the Kyoto Protocol in India's energy future are unclear (Murthy et al. 2007). The CDM allows late-industrializing countries to generate Kyoto permits that can be traded in an international market from the projects that otherwise would not have been undertaken and thereby reducing emissions below a baseline. A CDM project must be voluntary, generate "real, measurable, and long term benefits related to the mitigation of climate change," and generate "reduction in emissions that are additional to any that would occur in the absence of the certified project."[1] The main problem with the CDM is the problem of determining the baseline emissions that would otherwise have occurred as well as the amount of administrative cost involved in having CDM projects evaluated and approved. Probably the most attractive aspect of the CDM approach is the application to changes in land-use practice and forestation of degraded areas. However, India is already investing a lot of resources on reforestation independently of the CDM mechanism and it is difficult to define what is additional to baseline. Therefore, it seems that more direct policies aimed at changing the future composition of energy generation in India need to be considered.

[1] Page 12 of the test of the Kyoto protocol. Please see http://unfccc.int/resource/docs/convkp/kpeng.pdf.

Though researchers in India have made significant contributions in domestic and international climate policy formulation, there is a huge gap between policy prescription and implementation. Policy guidance in the form of a proper appraisal of the likely policy options with regard to their capability to benefit or harm the economy is urgently needed to make the ongoing policy debate conclusive and purposeful.

1.4 Study Goals

In the backdrop of the above research gaps in the area of climate change mitigation analysis, we have set the following objectives for our book:

1. To build an appropriate database and a methodology to assess the impact of economic growth on GHG emissions and that of sectoral output growth on energy demand, and employment.
2. To analyze empirically the factors driving changes in GHG emissions in India in order to bring out the importance of the emission intensities of different sectors in devising a climate change mitigation strategy of India.
3. To formulate an empirical model, such as a computable general equilibrium (CGE) model, to analyze the economy-wide impact of market-based policy instruments for mitigation in India.

1.5 Framework for Assessment

Assessments of impact of economic growth on climate change are not easy due to the complex relation between environment and economic activities (Jian 1996). The economy and environment interact with each other in myriad ways. To produce goods for consumption, a production process needs to depend on the environment to provide material resources and energy. The material resources and energy provided by the environment are transformed in the production and consumption processes to satisfy human wants, and the by-products discarded by the humans are then discharged back into the environment. Thus, environment is not only a provider of material and energy resources for the benefit of people inhabiting the earth, but also provides sink service for wastes generated from production and consumption. The environmental services are after all available in finite amounts and can therefore put a limit to the economic growth of the global economy.

There is eventually a limit to the environment's assimilative capacity by which it absorbs wastes discharged from the economy (Jian 1996). When the amount of wastes discharged into the environment is larger than the environment's assimilative capacity, environmental degradation occurs. The degradation of environmental quality has direct negative effects on both the utility of consumers and the stock of resources. The decrease in the quantity and quality of resources in turn has an indirect impact on consumer's utility or satisfaction by reducing productivity.

As most of the environmental problems can be directly attributed to the structure of production and consumption, it seems urgent and necessary and urgent to find ways to make these problems explicit within an accounting framework. In order to do this, it is important to develop a consistent accounting framework which will incorporate the economic as well as the environmental indicators. This work is an attempt to respond to the need to include, explicitly and directly, the two sets of indicators (economic and environmental indicators) into a unified and consistent framework which accounts for their relations to the economic system as a whole and provides the basis for diagnoses and eventually for policy-making.

However, the conventional national accounting system is not accommodative towards environmental indicators. Including environmental indicators in a comprehensive national accounting system, thus, poses an enormous challenge from a methodological standpoint. The ensuing analysis is best seen as a modest beginning in meeting this challenge. In order to overcome some of the limitations of the conventional national accounting system, more comprehensive systems have been developed, among which the traditional and extended input output (IO) tables and their generalized form as Social Accounting Matrices (SAMs) are the most prominent.

A SAM depicts the entire circular flow of income for an economy in a (square) matrix format. It shows production leading to the generation of incomes which in turn are allocated to institutions—households, enterprises, government, rest of the world, etc. The disposable incomes (which is nothing but earned incomes net of direct taxes) of these institutions are either spent on products or saved. Expenditures by institutions create demands which are met by domestic production from domestic industries as well as from imports. The advantage of incorporating both the economic and environmental indicators in a common social accounting matrix framework is that their interrelations can become more transparent for policymakers. Therefore, the extension of a conventional SAM to include environmental indicators can be considered as the first logical step in the efforts to simultaneously account for the interrelationships between economic and environmental activity.

Another advantage of SAM is its enabling of multiplier analysis. With the help of the SAM multiplier, we can analyze the direct, indirect, and induced impact of exogenous factors in the economy. Therefore, if we interrelate the economic indicators with the environmental indicator in a SAM framework, then that environmental social accounting matrix (ESAM) will help us to analyze the impact of economic growth on climate change.

To analyze the factors which are responsible for the GHG emissions, many researchers follow the structural decomposition analysis (SDA) to distinguish the factors and their impacts on GHG emissions (Mukhopadhyay 2001). As suggested in the literature, we need an integrated database which will provide data on IO coefficients as well as data on GHG emissions. The ESAM will eminently serve that purpose.

Finally, we apply the method of CGE model to analyze the impact of carbon mitigation policies in India. This CGE model used here is an integrated top-down model which assimilates the economy and environment in a single modeling framework. Unlike IO type models, CGE models are characterized by nonlinear and price-endogenous features and the inclusion of resource constraints. They thus effectively reflect real-world problems. Devarajan (1988) specifically lists three reasons why CGE models, rather than other types of economy-wide models, are preferred for policy analysis. The first reason is that price matters. CGE models are distinguished by their price endogenous features. Prices and quantities are determined simultaneously in simulating the results of an external shock or a policy change. The second reason is that interactions matter. CGE models are specifically designed to include many markets (such as goods and factor markets), many institutions (such as firms, households, and government), and their interactions. The third reason is that economic structure matters. CGE model focuses on the issue of economic structure. In addition to its internalization of market mechanisms, the CGE approach leaves room for nonmarket activities. Therefore, due to these advantages, the CGE approach is more capable of simulating the results of a policy change or an external shock than are other previous predecessor models such as IO models.

1.6 Scheme and Scope of This Study

Following this introductory chapter, the rest of this book is organized as follows: Chapter 2 provides the concepts and construction of the social accounting matrix for India. Chapter 3 describes the method of constructing ESAM with the environmental indicators which are significant for climate change analysis. Chapter 4 describes the estimation of SAM multiplier and its application to show the impact of economic growth on climate change. Chapter 5 illustrates IO structural decomposition analysis to analyze the factors determining change in GHG emissions in India. In Chap. 6, we have described the structure of the India CGE model for climate change mitigation policy analysis and its underlying assumptions. The results of this CGE model are described in Chapter 7, and, thereafter, Chapter 8 summarizes the study and provides concluding remarks with hints about future scope of research.

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