Institute of Economic Growth
University Enclave, University of Delhi
Delhi 110007, India
Tel: 27667101/288/424; Fax: 27667410
Website: www.iegindia.org

Carbon Taxes vs Productivity Shocks: A comparative analysis of the costs in a CGE framework for India

Basanta K. Pradhan
Joydeep Ghosh

IEG Working Paper No. 317

2012

RECENT WORKING PAPERS

Title	Author (s) Name	Paper No.
Skills, Informality and Development	Arup Mitra Dibyendu Maiti	E/306/2010
Club-Convergence and Polarisation of Sates: A Nonparametric Analysis of Post-Reform India	Sabyasachi Kar Debajit Jha Alpana Kateja	E/307/2010
Business Group Ownership of Banks: Issues and Implications	Ashis Taru Deb	E/308/2010
Does Participatory Development Legitimise Collusion Mechanisms? Evidence from Karnataka Watershed Development Agency	G. Ananda Vadivelu	E/309/2011
Policies for Increasing Non-farm Employment for Farm Households in India	Brajesh Jha	E/310/2011
Nagaland's Demographic Somersault	Ankush Agrawal Vikas Kumar	E/311/2012
Does Access to Secondary Education Affect Primary Schooling? Evidence from India	Abhiroop Mukhopadhyay Soham Sahoo	E/312/2012
Reexamining the Finance-Growth Relationship for a Developing Economy: A time series analysis of post-reform India	Sabyasachi Kar Kumarjit Mandal	E/313/2012
Fiscal Consolidation in India	Sanhita Sucharita	E/314/2012
The Impact of Carbon Taxes on Growth Emissions and Welfare in India: A CGE analysis	Basanta K. Pradhan Joydeep Ghosh	E/315/2012
An Investigation into Changes in Nagaland's Population between 1971 and 2011	Ankush Agrawal Vikas Kumar	E/316/2012

Carbon Taxes vs Productivity Shocks: A comparative analysis of the costs in a CGE framework for India

Basanta K. Pradhan
Joydeep Ghosh

सत्यमेव परमो धर्मः IEG Working Paper No. 317

2012

ACKNOWLEDGEMENTS

This paper is the outcome of the POEM project (POEM: Policy Options to engage Emerging Asian economies in a post-Kyoto regime), funded by the European Commission (Seventh Framework Programme). Seven institutions from India, China, and Europe are part of this project. A previous version of the paper was presented at the POEM workshop (organised by the Institute of Economic Growth, Delhi) held at the India International Centre, New Delhi on 6 September 2012.

Basanta K. Pradhan is Professor at the Institute of Economic Growth, Delhi.
email: basanta@iegindia.org

Joydeep Ghosh is Consultant at the Institute of Economic Growth, Delhi.
email: jghosh@iegindia.org

Carbon Taxes vs Productivity Shocks: A comparative analysis of the costs in a CGE framework for India

ABSTRACT

The main objective of this paper is to compare the costs of future global climate change mitigation regimes with those of future climate change-induced agricultural productivity shocks using a recursive dynamic CGE model in the case of India. The cost to the economy due to productivity shocks is on average about 70 per cent more than that of mitigation policies, along with milder productivity shocks. There is a strong case for the adoption of mitigation policies to reduce the level of emissions to protect the agriculture sector in India. Climate policies could be a means to not only reduce emissions but also support agricultural growth in the future.

Keywords: climate change, agriculture, CGE model, India

JEL codes: Q54, Q52, Q56, D58

1. INTRODUCTION

There is growing concern around the world about the impact of greenhouse gases (GHG) on the environment and economy. Primarily responsible for global warming, GHG emissions (especially CO_2 emissions) are closely linked to economic growth. Since fossil fuels are the primary source of energy, the consumption (burning) of fossil fuels inevitably lead to GHG emissions. Countries have not been able to de-link the association between the use of fossil fuels and economic growth until now (Narain et al. 2009). The scientific evidence points to increasing risks of serious, irreversible impacts from climate change (global warming) associated with business-as-usual (BAU) paths for emissions (Stern 2007). There is an urgent need to cut emissions to scientifically acceptable levels since the costs associated with climate change are significantly higher than the costs of mitigation (Stern 2007). The main objective of this paper is to compare the economic costs of global climate policy regimes with those of climate change-induced agricultural productivity shocks, in the case of India. A dynamic CGE framework is used for the analysis. The paper contributes to the literature by trying to answer the crucial question: are the costs of carbon mitigation policies higher than the benefits? The implications of climate policies on growth, welfare, and CO_2 emissions are also analysed.

There is considerable debate in the literature regarding the nature and costs of climate change, what actions should be taken to counter it, and how fast those actions need to be taken. Nordhaus (2007) has pointed out that the results obtained by Stern (2007) depend crucially on the assumption of a near-zero time discount rate and might not hold if the assumptions are more consistent with today's real interest rates and savings rates. Weitzman (2009) has analysed the implications of structural uncertainty for the economics of low-probability, high-impact catastrophes (like climate change). The paper shows that the economic consequences of fat-tailed structural uncertainty can outweigh the effects of discounting in climate change policy analysis.

Climate change is a global issue and therefore requires a high level of international cooperation to tackle it. International negotiations have been launched to address the issue of climate change. The UN Framework Convention on Climate Change (also known as the Kyoto Protocol) came into effect in 1997, with the purpose of limiting the release of GHG into the atmosphere. Under the Kyoto Protocol, industrialised countries agreed to cut their emissions by 5.2 per cent of 1990 levels, by 2008-12, but missed this target by a significant margin. The Copenhagen Accord (2009) recognises the scientific view that the increase in average global temperature should be below $2^{\circ C}$ over the long term. Most countries have accepted the Copenhagen Accord, and have pledged to reduce emissions. According to the IPCC's Fourth Assessment Report (IPCC 2007), if Annex 1 (industrialised) countries cut their

1990 emission levels by 25–40 per cent by 2020, and major developing economies cut their emissions substantially, atmospheric GHG concentration could stabilise at around 450 parts per million (ppm) CO_2 equivalent. This GHG concentration is associated with a medium likelihood (at least 50 per cent chance) of limiting global average temperature to less than 2˚C. The targets and actions that countries have pledged in the Copenhagen Accord are lower than IPCC-suggested emission reductions to keep the average global temperature increase below 2˚C (OECD 2010).

The relationship between economic growth and the environment has attracted considerable attention in the literature. Pioneering work done by Grossman and Krueger (1995) has found no evidence of deterioration in environmental quality with economic growth. They have reported that for most environmental indicators, economic growth brings an initial phase of deterioration followed by a subsequent phase of improvement. According to the study, the turning points for the different pollutants vary, but come in most cases before a country reaches a per capita income of $8000. Per capita GHG emissions are lower in India than industrialised countries. The global average per capita GHG emissions was 4.22 tons of CO_2-equivalent in 2005, while the figure is about 1.2 tons (CO_2 emissions) in the case of India. A recent report (Ministry of Environment and Forests 2009) has pointed out that even with high growth rates, per capita emissions of India are likely to remain lower than that of developed countries. This argument is supported by the fact that the emission intensity of GDP (excluding agriculture) declined nearly 25 percent[1] between 1994 and 2007, a period of relatively high growth. India has set a voluntary target (Copenhagen pledge) to reduce its emission intensity of GDP by 20–25 per cent by 2020 over 2005. A number of initiatives is being taken both by the government and firms to achieve this objective; for example, the National Action Plan on Climate Change encourages the use of alternative sources of energy, and focuses on achieving energy efficiency.

Environmental policies have two components: (1) identification of an overall goal (such as emission levels) and (2) some means to achieve that goal. There are two main methods for achieving environmental goals (Stavins 2000). The first method is through market-based mechanisms (such as carbon taxes); the second method is through command-and-control policies (such as explicit directives regarding pollution levels or methods of production). Market-based mechanisms have certain advantages over traditional command-and control approaches for achieving environmental objectives; for example, these can help to achieve environmental objectives at the lowest possible overall cost to society by providing incentives for the greatest reductions in pollution by firms that can achieve these

[1] Prime Minister's statement at the Plenary of Rio+20 Summit, 21 June 2012

reductions most cheaply. Rather than equalising pollution levels among firms, market-based instruments equalise the incremental amount that firms spend to reduce pollution and provide incentives for companies to adopt cheaper and better pollution control technologies. Numerous studies have been conducted to analyse the impact of market-based instruments on the environment as well as the economy in general. Bovenberg and Goulder (1996) have examined the optimal setting of environmental taxes in economies where other distortionary taxes are present. The study concludes that the optimal tax rate on emissions of a given pollutant is generally less than the rate supported by the Pigovian principle. Moreover, lower the optimal rate, larger the distortions posed by ordinary taxes. Garbaccio et al. (1998) have examined the use of carbon taxes to reduce CO_2 emissions in China. The authors found that after an initial decline, GDP and consumption exceeded baseline levels and that the revenue-neutral carbon tax serves to transfer income from consumers to producers and then into increased investment. The study shows that a 'double dividend' (lower CO_2 emissions and a long-run increase in GDP and consumption) could be achieved under certain assumptions (such as inelastic labour supply and revenue-neutral taxes). McKibbin et al. (1999) found that international trade and capital flows significantly alter projections of the domestic effects of emissions mitigation policy compared with analyses that ignore international capital flows, and that under some systems of international permit trading the US could become a significant permit seller. Parry (1999) examined the efficiency impacts of revenue-neutral carbon taxes and quotas (grandfathered carbon permits) in a second-best setting with pre-existing labour taxes. For each of these policies, the efficiency costs are considerably higher than would be if prior taxes were absent. The authors conclude that policies like carbon quotas and grandfathered carbon permits may be welfare-reducing regardless of the carbon-abatement level. In contrast, carbon tax policies can be welfare-improving (provided that the level of abatement is not too great) because the marginal social costs of emissions reduction start at zero. The findings suggest that ignoring pre-existing tax distortions can give rise to highly misleading conclusions about the sign as well as the magnitude of the welfare impacts from carbon abatement policies. Fisher-Vanden et al (1997) have analysed two alternative policy instruments (carbon taxes and tradable permits) to determine the comparative costs of stabilizing emissions at (1) 1990 levels; (2) two times the 1990 levels; and (3) three times the 1990 levels. The study finds that tradable permits represent a lower cost method to stabilise Indian emissions than carbon taxes. India's participation in a global tradable permits market using either of the allocation options is more cost-effective than independently imposed carbon taxes. Under an equal per capita emissions allocation scheme, India would benefit absolutely from participation in a global tradable permits market, but economic growth would be slowed under the grandfathered emissions allocation scheme.

The effects of climate change are likely to be severe for developing countries (Stern 2007). First, developing countries are at a geographic disadvantage because they are already warmer than developed countries on average and also suffer from high rainfall variability. Second, developing countries are heavily dependent on agriculture, the most climate-sensitive of all economic sectors. Third, their low incomes and vulnerabilities make adaptation to climate change particularly difficult. The impact of climate change on agriculture is of particular significance for India given that agriculture (and allied sectors) accounted for about 18 per cent of GDP in 2008–09,[2] and about 63 per cent of rural male workers and 79 per cent of rural female workers are engaged in this sector.[3] Indian agriculture is particularly vulnerable to climate change because it is mostly rainfed. Out of the total net sown area of 140.3 million hectares, about 60.9 million hectares is irrigated, while the rest is rainfed. According to IPCC (IPCC 2007b), the temperature in South Asia will increase by 0.5–1.2° C by 2020, 0.88–3.16° C by 2050, and by 1.56–5.44° C by 2080. An increase in temperature will cause shifts in crop growing seasons, increase the incidence of pests and diseases, and lower agricultural productivity.[4] Several studies have forecast the change in agricultural productivity due to climate change in South Asia/India. According to the International Food Policy Research Institute (IFPRI),[5] average yields in 2050 could decrease from 2000 levels by about 50 per cent in the case of wheat, 17 per cent in the case of rice, and about 6 per cent in the case of maize. According to the World Bank,[6] crop yields could decrease by up to 20 per cent in South Asia. Cline (2007) has reported that agricultural productivity in India could decrease by 30–40 per cent by the 2080s due to climate change. Auffhammer et al. (2006) have found that adverse climate changes due to brown clouds and GHGs contributed to the slowdown in rice harvest growth that occurred during the past two decades in India.

Hertel and Rosch (2010) analysed the link between climate change, agricultural productivity, and poverty and found that the effects of climate change on poverty can be disaggregated into impacts on household consumption, on producer income, indirect impacts through factor markets, and impacts through non-priced goods. The impact on household consumption is due to reduced food availability and higher food prices. In countries where agriculture is a major employer in the economy, the earnings of poor, non-

---

[2] Annual Report 2010–11, Ministry of Statistics and Programme Implementation

[3] Key Indicators of Employment and Unemployment in India, 2009–10, NSS 66th Round, Ministry of Statistics and Programme Implementation

[4] http://www.cca.iari.res.in

[5] Climate Change: Impact on Agriculture and Costs of Adaptation, 2009

[6] http://climatechange.worldbank.org/content/south-asia

farm households might be significantly affected through changes in market wages when there is a significant shock to agricultural productivity and/or prices. The impact of climate change varies across countries, and there exists a potential for less affected countries to benefit by exporting agricultural products to more affected countries. According to Ahmed et al. (2012), if global maize production is lower than usual owing to supply shocks in major exporting regions, Tanzania can substantially increase its maize exports at higher prices even if it also experiences below-trend productivity.

India's position (Ministry of External Affairs, Government of India, 2009) on climate change is based on the Principle of Common but Differentiated Responsibilities and Respective Capabilities. The concept of equity (every citizen of the globe has equal entitlement to the planetary atmospheric resource) is another crucial dimension of India's position on climate change. Further, India gives the highest priority to social and economic development even in the context of climate change, and has advocated the convergence of per capita emissions in the future. India believes that efforts to use cleaner technologies in developing economies should be facilitated through the transfer of technology and financial resources from developed to developing countries. The use of cleaner technologies could lead to the creation of new industries and jobs. Given that small farmers constitute the bulk of agricultural households in India, any adverse effect on agricultural productivity (as a result of climate change) is likely to have a significant impact on the economy and rural livelihoods in particular. Below-average rainfall is one of the main factors for the persistently high food inflation India has witnessed in recent times. Therefore, it is imperative for India, along with other countries, to take urgent measures to stabilise/reduce the emissions level.

The rest of the paper proceeds as follows. Section 2 discusses the model developed for this study. Section 3 is devoted to the results and discussion. Section 4 concludes by mentioning the main implications of the study.

2. MODEL

Our model is a multi-sectoral, neoclassical-type, price-driven, recursive dynamic CGE model with features that capture linkages with the energy system. Some of these features are based on other energy/climate policy CGE models like DART (Klepper et al. 2003), EPPA (Paltsev et al. 2005) and EMPAX-CGE (RTI International, 2008). The model consists of 18 sectors—agriculture, coal, oil, gas, manufacturing 1 (food and beverages, textiles, wood, minerals), manufacturing 2 (paper, fertilisers, cement, iron and steel, aluminum, chemicals), manufacturing 3 (plant and machinery), oil products, electricity (thermal, CCS, hydro, nuclear, wind/solar, biomass), construction, road transport, rail/sea/air transport, and other services. There are two factors of production, namely, capital and labour.

Producers are assumed to maximise profits and they operate in perfectly competitive markets. The production structure of fossil fuel (coal, oil, and gas) and non-fossil fuel sectors (sectors other than coal, oil, and gas) are modeled differently. In the case of fossil fuel sectors, the top nest is a CES aggregation of capital–labor–aggregate intermediate input composite, and the fixed fossil fuel resource (part of capital of the sector). The capital – labour–intermediate composite is a Leontief function of the capital–labour composite and aggregate intermediate input. The capital–labour composite (aggregate value added) is in turn a CES aggregation of capital and labour. The production structure of the fossil fuel sectors thus takes into account the limited availability of fossil fuels in the economy.

In the case of non-fossil fuel sectors, the top nest is a Leontief function of aggregate intermediate input and energy–capital–labour composite. The energy–capital–labour composite is a CES function of the energy composite and capital–labour composite. The energy composite is a CES function of the non-electric composite and electric composite. The non-electric composite is a CES aggregation of coal, oil, gas, and oil products. The electric composite is a CES aggregation of renewable electricity composite and non-renewable electricity composite. The renewable electricity composite is a CES aggregation of hydro, nuclear, wind/solar, and biomass electricity while the non-renewable electricity composite is a CES aggregation of thermal and CCS electricity. The capital–labour composite is a CES function of capital and labour. The aggregate intermediate input is a Leontief function of intermediate inputs. The main features of the production structure of the non-fossil fuel sectors are the substitution possibilities between energy, capital, and labour on one hand, and the substitution possibilities between renewable and non-renewable sources of electricity on the other.

Figure 1: Production structure of fossil fuel sectors (coal, oil, and gas)

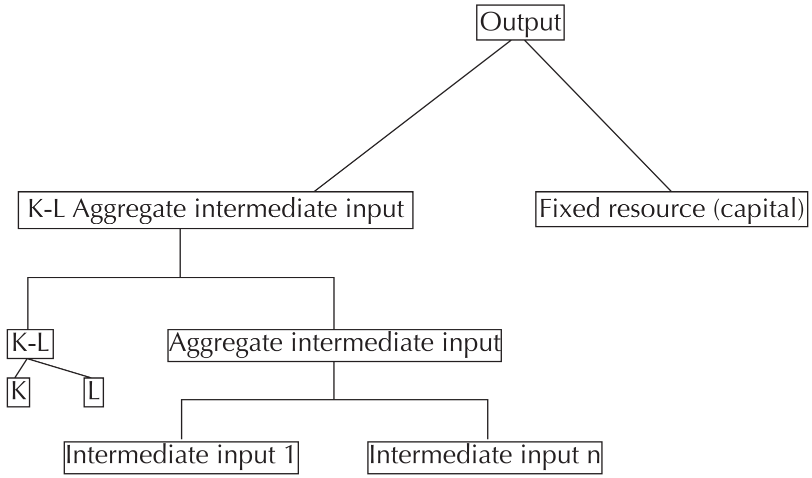
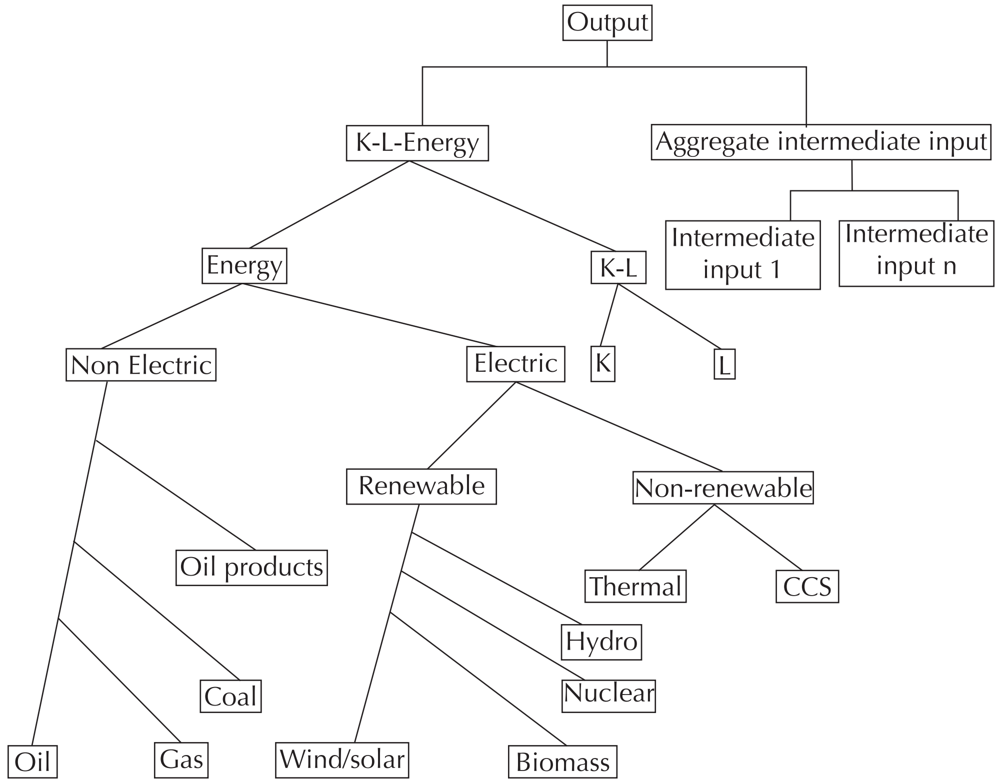


Figure 2: Production structure of non-fossil fuel sectors



Households maximise utility subject to income and prices, and the household demand for commodities is modeled through the Linear Expenditure System (LES). Household income comprises income derived from labour and capital and transfers from the government and rest of the world. Households also save part of their incomes, and pay taxes to the government. Further, households are classified into nine categories: five of them are rural (self-employed in non-agriculture, agricultural labour, other labour, self-employed in agriculture and other households), and four of them are urban (self-employed, regular salaried, casual, and other households).

Government expenditure is on the consumption of goods and services, transfers to households and enterprises, and subsidies. Government income is from taxes (direct and indirect), capital, public and private enterprises, and rest of the world. Indirect taxes include excise duty (production tax), import and export tariffs, sales, stamp, service and other indirect taxes. Government savings, which is the difference between government expenditure and income, is determined residually.

CGE models allow for imperfect substitution between domestic goods and foreign goods. In other words, producers/consumers are free to sell/consume goods from the domestic or foreign market based on relative prices. The Armington function (CES type) is used to capture the substitution possibilities between domestic and imported goods. The import demand function, derived from the Armington function, specifies the value of imports based on the ratio of domestic and import prices. The CET function (CES type) is used to capture substitution possibilities between domestic and foreign sales. The export supply function, derived from the CET function, specifies the value of exports based on the ratio of domestic and export prices. The elasticity of substitution determines the relative ease with which substitution can take place between domestic and foreign goods in response to changes in relative prices.

The model is Walrasian in character. Markets for all commodities and factors clear through adjustment in prices. The consumer price index is chosen as the numeraire and is, therefore, fixed. Macro closures play an important role in determining the results of CGE models. Foreign savings are assumed to be fixed while the real exchange rate is flexible. Government consumption expenditure is fixed within a period, and government savings is residually determined. Both direct and indirect tax rates are fixed. The model follows an investment-driven closure, that is, aggregate investment is fixed. Aggregate savings (sum of household, government, corporate, and foreign savings) adjusts to satisfy the saving-investment balance. The household savings rate is fixed. Finally, full employment along with inter sectoral mobility is assumed in case of the two factors of production. The model is solved using the GAMS software (PATH solver).

Initially a baseline ('business-as-usual' or 'BAU') scenario is created by assuming exogenously determined growth in total factor productivity (TFP), labour force, government consumption expenditure, and aggregate investment. Capital accumulation takes place by adding aggregate investment to capital in the previous period. To capture future increases in energy efficiency, an energy efficiency growth rate is assumed. Future technological developments in the renewable electricity sectors are modeled by assuming efficiency growth in these sectors. Changes in the international price (exogenous) of fossil fuels are modeled keeping in view future price projections of these commodities. The baseline scenario is created keeping in view the OECD growth projection (OECD 2012) for India till 2050.

The main source of data for the analysis is the Social Accounting Matrix (SAM) for 2003-04 developed by Ojha et al (2009), which is based on the SAM constructed by Pradhan et al. (2006). The main difference between the two SAMs is the decomposition of the electricity sector into three separate sub-sectors, that is, hydro, nuclear, and non-hydro, in the SAM developed by Ojha. The non-hydro energy sector includes thermal, wind, and solar electricity. However, given India's energy mix, thermal is the main constituent of this group. Two modifications were done in the non-hydro sector for the purpose of this study. The first modification pertains to the disaggregation of non-hydro into thermal and wind/solar electricity. The second modification pertains to the creation of a sector (from thermal) that uses CCS technology (coal) to produce electricity. The CCS electricity sector is assumed to be similar to the thermal electricity sector but less efficient. The CCS technology sector produces electricity using clean coal (no emissions), although at a much higher cost.

3. RESULTS AND DISCUSSION

This study uses policy parameters (carbon prices and CO_2 emission allowances) from global climate models. Two different global emissions pathways were constructed that are compatible with meeting the 2°C target with a probability of about 50 per cent. The global CO_2 emissions pathways are constructed with the FAIR model (PBL, 2005) and they are intended to be compatible with a target of 2.9 W/m in 2100. The global emissions pathways are implemented through two instruments—globally coordinated carbon taxes (CT), and emission trading permits where the distribution of the permits is based on the Common but Differentiated Convergence (CDC) approach (Hohne et al. 2006). Global carbon taxes imply the global equalisation of marginal abatement costs. The CDC approach assumes that per capita emissions of all countries converge, but developing countries have to start their convergence trajectory only after reaching a certain threshold. The CDC regime is a staged implementation of per capita convergence regimes. In this approach, Annex 1 countries' per capita emission allowances converge within a certain time period (e.g. from 2010 to 2050) to an equal level for all countries. Individual non-Annex 1 countries' per capita emissions also converge within 40 years to the same level, but convergence starts from the date when their per capita emissions reach a certain percentage threshold of the (gradually declining) global average. Non-Annex 1 countries that do not pass this percentage threshold do not have binding emission reduction requirements. Either they take part in the Clean Development Mechanism or they voluntarily take on 'positively binding' emission reduction targets. The CDC approach aims at equal per capita allowances in the long run but takes into account historical responsibility, in contrast to the better known Contraction and Convergence approach.

Initially, a baseline ('BAU') scenario is created keeping in view a projected growth path of the economy. The growth path (Table 1) is based on the OECD growth projection for

India until 2050. The growth rate during 2005–10 roughly corresponds to the actual growth rate achieved during this time period. For the period 2010–15 the growth rate (7.6 per cent) is based on current growth rates and the target for the Twelfth Plan (8.2 per cent). The growth rate during 2005-30 is 7.7 percent while it is 6.7 per cent during 2005-50.

Eight simulations were run for the purpose of this paper. The first two simulations (SIM 1 and SIM 2) correspond to two different global climate policy regimes. In the third simulation (SIM 3), the impact of an annual 0.6 per cent decline in agricultural productivity growth is analysed. This simulation captures the likely impact of climate change-induced agricultural productivity loss for India, as predicted by Cline (2007). The next two simulations (SIM 4 and 5) are intended to shed light on the effects of climate change-induced agricultural supply shocks outside India. Foreign agricultural supply shocks are likely to increase the world price of agricultural commodities; however, the degree to which the world price increases depends on how other countries are affected by climate change. If other countries are equally affected (SIM 4: SIM 3 + increase in world price of agriculture by the same amount as the agricultural price (consumer) increase observed in SIM 3) by climate change as India, the scope for cheaper imports of agricultural products is reduced, but if other countries are less affected (SIM 5: SIM 3 + increase in world price of agriculture by 50 per cent of the agricultural price increase observed in SIM 3), there is a possibility for cheaper imports of agricultural products. The last two simulations are concerned with the possible mitigation of agricultural productivity loss as a result of the climate policy regimes. In the sixth simulation (SIM 6), the impact of the CT regime along with lower productivity loss (no agricultural productivity growth from 2020) is analysed, while in the seventh simulation (SIM 7) the impact of the CDC regime along with lower productivity loss is analysed (no agricultural productivity growth from 2020). The intuition behind the last two simulations is that climate policies could lead to milder productivity shocks compared to scenarios where there are no climate policies. Finally, in the last simulation (SIM 8: SIM 7 + increase in factor supply (labour and capital) from revenues generated as a result of trade in emission permits), the impact of capital formation and job creation as a result of trade in emission permits is analysed.

Two different climate policy regimes were analysed that are compatible with meeting the 2°C target over the long term. The first regime is a global carbon tax (‘CT’ regime / SIM1), while the second regime (‘CDC’ regime / SIM 2) is based on emissions trading permits where their distribution is based on the Common but Differentiated Convergence (CDC) Approach. The data (year-wise carbon prices and emission allowances; see Appendix) to implement the policy regimes were obtained from a global climate CGE model called DART (Klepper et al. 2003). The global CO_2 emissions pathways of DART follow the global

CO_2 emissions pathways of the FAIR model discussed above. In the case of the CDC regime, international capital flows take place as a result of trade in emission permits. In our model, international capital flows are modeled as foreign savings (i.e. foreign investments in India). The policy regimes are imposed after 2012. In the model, the carbon price is applied on the consumption of coal, gas, and oil products because the consumption of these products is directly linked to CO_2 emissions. GDP growth rate slows down under both the climate policy regimes after 2020 (Table 1). The growth rate falls from 7.4 per cent to 7.3 per cent under both regimes during 2020–25, and from 4.3 per cent to 3.2 per cent in the CT regime and 3 percent in the CDC regime, respectively, during 2045–50. Energy prices increase and the real wage rates of labour and capital fall under the climate policy regimes. The relatively larger impact on GDP growth in the CDC regime could be attributed to higher carbon prices in the CDC regime. The CDC regime leads to transfer payments to countries (such as India) that are able to sell emission permits. This in turn usually leads to higher demand/ growth in such countries, and lower growth/demand in industrialised countries. Carbon prices rise since developing countries grow faster and production in these countries is on average more carbon-intensive. Therefore, carbon prices are higher in the CDC regime than in the CT regime, rise over time in general, and significantly after 2040. The economic intuition behind the rapid increase in carbon prices after 2040 would be that opportunities for abatement are many in the beginning but increasingly difficult to find over time.

Carbon dioxide emissions (Figure 3) increase from 1220 million tons (1.1 tons per capita) in 2005 to 5396 million tons (3.3 tons per capita) in 2050 in the BAU scenario. According to the NCAER CGE study (MoEF, GoI, 2009), per capita emissions would be 2.77 tons of CO_2 equivalent in 2030-31. According to the present study, the figure is 2.57 tons of CO_2 emissions in 2030, implying that the projections (BAU scenario) of this paper are similar to that of the NCAER study. The imposition of climate policy regimes significantly cut CO_2 emissions into the atmosphere. However, there is an upward trend until 2040, and thereafter a downward trend in emissions. In the CT scenario, emissions peak at 3267 million tons (2.1 tons per capita) in 2040, and thereafter decline to 2631 million tons (1.6 tons per capita) in 2050. In the CDC scenario, emissions peak at 3232 million tons (2.1 tons per capita) in 2040, and thereafter decline to 2475 million tons (1.5 tons per capita) in 2050. Again, the relatively larger impact on CO_2 emissions is due to higher tax rates in the CDC scenario.

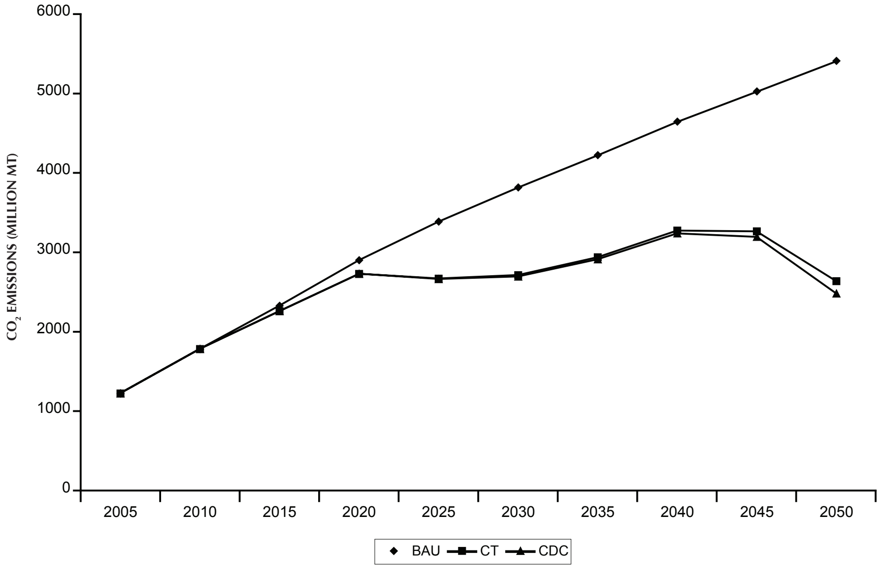
In general, there is welfare[7] loss (Table 2) under both policy regimes, but more under the CT regime. For example, the equivalent variation in percentage terms is -6.29 under the CT regime while it is -5.10 under the CDC regime, in 2050. There is relatively lower welfare

[7] Welfare is measured in terms of Hicksian equivalent variation.

loss in the CDC scenario due to price effects. In the CDC scenario, the inflow of capital (revenue) due to trade in emission permits causes the exchange rate to appreciate more relative to the CT scenario, causing consumer prices to fall relatively more in the CDC scenario. For example, the exchange rate appreciates by 8 per cent in the CDC scenario and by 2.9 per cent in the CT scenario, relative to the baseline, in 2050. This appreciation of the exchange rate leads to lower welfare loss in the CDC regime relative to the CT regime. Exports of certain sectors (like manufacturing) were found to decline (due to currency appreciation) in the CDC regime, and contributed to the reduction in GDP growth.

There is approximately a 26 per cent fall in CO_2 emission intensity of GDP between 2005 and 2020 in the baseline scenario and a 76 per cent decline between 2005 and 2050. In the climate policy regimes, the fall in emission intensity was found to be about 31 per cent and 87 per cent for 2005–20 and 2005–50, respectively. The fall in the emission intensity of GDP is due to the growth (exogenous) in energy efficiency over time, the gradual replacement of fossils fuels by renewable energy, and structural changes in the economy. The results indicate that India could be able to fulfill the Copenhagen Pledge (20–25 per cent reduction in emission intensity by 2020). The share of renewable energy in total primary energy consumption increases from 8 per cent in 2005 to 20 per cent in 2050 in the baseline scenario. The share increases to 28 percent in the CT scenario, and 29 per cent in the CDC scenario, in 2050. The increase in the share of renewable energy is mainly the result of the increase in the relative price of coal due to the imposition of the climate policy regimes. The share of thermal electricity decreases significantly over time due to the carbon tax. The marginally higher share of renewable energy in the CDC regime is due to higher carbon prices in the CDC scenario. The implication is that higher levels of carbon prices lead to higher penetration of renewable energy in the total energy mix. With regard to structural changes, it was observed that the share of the construction sector in GDP, which is relatively less energy-intensive and more capital-intensive, increased in the climate policy scenarios. There was a marginal decline in the share of the agriculture sector in the climate policy scenarios.

Figure 3: CO_2 emissions in different scenarios



Climate policies thus lead to higher energy efficiency in the economy and higher penetration of renewable energy in the total energy mix. Both these factors are crucial for sustainable growth in the future and likely to benefit capital more than labour (wage rate of capital falls relatively less in the simulations) as climate policies change production methods from being energy-intensive to capital-intensive. Second, the renewable energy sector is capital-intensive, and higher growth of the renewable energy sector as a result of climate policies is likely to benefit capital more than labour. Therefore, climate policies can be linked to structural changes in the economy and the differential impact on different segments of the population. The implications of climate policies for poor labour households assume significance in this context. The simulations reveal that poor labour households are more affected than other households, in terms of welfare loss. The results in general conform to the findings of similar studies for India (like Fisher-Vanden et al. 1997) who have reported GDP losses due to climate policies.

As discussed above, several studies have pointed out that climate change could have serious consequences on agricultural productivity growth in the future. Some simulations were run to assess the implications of loss in agricultural productivity on the economy. The results indicate that reductions in agricultural productivity (total factor productivity) growth [8]could have significantly larger negative impacts on the economy than the climate policy regimes (SIM 1 and SIM 2). For example, the welfare losses (except in SIM 8, which is

[8] TFP growth in agriculture is assumed to be 1 per cent in the BAU scenario.

discussed later) due to productivity shocks are significantly higher than the losses observed in the climate policy regimes in 2050 (Table 2). The relatively high welfare loss is mainly due to high agricultural prices (Table 3) as a result of the productivity shocks. The welfare loss is the highest in SIM 4, in which the maximum increase in agricultural prices is observed. In this simulation, the climate change-induced productivity shock is the same both in and out of India. In other words, foreign countries (rest of the world) are equally affected (in terms of agricultural price increase) by climate change as India. In this situation, the country is not in a position to substitute domestically produced agricultural commodities by cheaper imports because of the higher world price. Therefore, there is a decline in agricultural imports in this simulation (Table 5). However, agricultural imports increase in the other simulations because it is cheaper to import from abroad. The observed impact on agricultural imports can be linked to the findings of Ahmed et al. (2012), who have reported that countries that are less affected by climate change could increase their agricultural exports to countries that are more affected by climate change. Thus, the welfare loss for India is relatively less if other countries are less affected (lower increase in agricultural prices) by climate change than India. Productivity shocks also lead to lower GDP growth rates (Table 1). Growth rates are considerably lower in the productivity simulations. Agricultural exports decline in the productivity shock scenarios and this has a negative impact on growth rates (Table 4).

Table 1: Impact on GDP growth (%)

PERIOD	BAU	SIM 1	SIM 2	SIM 3	SIM 4	SIM 5	SIM 6	SIM 7	SIM 8
2005-10	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
2010-15	7.6	7.6	7.6	7.1	7.1	7.1	7.6	7.6	7.6
2015-20	8.2	8.2	8.2	7.6	7.6	7.6	8.1	8.1	8.2
2020-25	7.4	7.3	7.3	6.7	6.7	6.7	6.9	6.9	7.2
2025-30	6.8	6.7	6.7	6.1	6.1	6.1	6.3	6.3	7.4
2030-35	6.5	6.4	6.4	5.7	5.7	5.7	6.0	6.0	7.4
2035-40	6.3	6.3	6.3	5.5	5.4	5.4	5.8	5.8	6.7
2040-45	4.6	4.4	4.3	3.7	3.6	3.7	3.8	3.8	4.6
2045-50	4.3	3.2	3.0	3.3	3.2	3.3	2.5	2.4	4.6

Table 2: Impact on welfare (equivalent variation %)

	SIM 1	SIM 2	SIM 3	SIM 4	SIM 5	SIM 6	SIM 7	SIM 8
2015	-0.05	-0.05	-2.50	-2.56	-2.53	-0.05	-0.05	-0.05
2020	-0.14	0.08	-5.19	-5.32	-5.26	-0.47	-0.40	-0.32
2025	-0.89	0.04	-7.91	-8.14	-8.03	-2.88	-1.94	-0.54
2030	-1.63	0.45	-10.71	-11.06	-10.90	-5.38	-3.24	5.03
2035	-1.99	-0.46	-13.59	-14.09	-13.87	-7.56	-5.92	13.34
2040	-2.09	-1.44	-16.53	-17.19	-16.89	-9.56	-8.72	18.37
2045	-2.93	-2.62	-19.47	-20.33	-19.95	-12.38	-11.73	21.05
2050	-6.29	-5.10	-22.52	-23.62	-23.15	-17.95	-16.04	31.36

Table 3: Impact on consumer price of agriculture (% change relative to baseline)

	SIM 3	SIM 4	SIM 5	SIM 6	SIM 7	SIM 8
2015	4.5	4.6	4.5	-0.1	-0.1	-0.1
2020	9.0	9.2	9.1	0.3	0.3	0.3
2025	13.2	13.6	13.4	2.1	2.0	2.0
2030	17.4	17.9	17.7	3.8	3.6	3.6
2035	21.2	21.8	21.6	5.6	5.4	5.1
2040	24.7	25.6	25.2	7.6	7.3	6.6
2045	27.9	28.9	28.5	8.2	7.8	6.9
2050	30.6	31.9	31.4	4.1	2.8	2.4

Table 4: : Impact on agricultural exports (% change relative to baseline)

	SIM 3	SIM 4	SIM 5	SIM 6	SIM 7	SIM 8
2015	-9.8	-9.8	-9.8	0.0	0.0	0.0
2020	-19.0	-18.9	-19.0	-1.3	-1.4	-1.2
2025	-27.4	-27.3	-27.4	-7.3	-9.2	-5.3
2030	-35.0	-35.0	-35.0	-13.0	-17.3	-4.4
2035	-41.9	-41.9	-41.9	-18.6	-21.8	-2.0
2040	-48.1	-48.0	-48.0	-23.9	-25.5	-2.7
2045	-53.5	-53.5	-53.5	-28.5	-30.0	-3.9
2050	-58.4	-58.3	-58.3	-32.3	-37.1	3.4

Table 5: Impact on agricultural imports (% change relative to baseline)

	SIM 3	SIM 4	SIM 5	SIM 6	SIM 7	SIM 8
2015	7.1	-2.6	2.1	-0.1	0.0	-0.1
2020	14.5	-4.9	4.1	0.7	1.1	0.8
2025	21.7	-6.7	6.2	2.9	9.4	5.1
2030	29.0	-8.0	8.3	4.5	21.4	14.7
2035	36.6	-8.4	10.9	7.1	20.4	28.0
2040	44.0	-8.3	13.6	10.2	17.2	38.6
2045	50.7	-7.9	16.2	10.6	17.0	44.9
2050	57.2	-7.0	19.0	3.7	24.8	54.4

A comparison of the costs (in terms of change in net present value of GDP) of mitigation policies with those of productivity shocks clearly reveals that mitigation policies are less expensive for the economy over the long run (Table 6). The cost to the economy due to productivity shocks is on average more than five times that of mitigation policies (in the absence of productivity shocks). However, the cost to the economy due to productivity shocks is on average about 70 per cent more than that of mitigation policies along with productivity shocks (likely to be milder over the long term if appropriate mitigation policies are adopted). The results indicate the significance of agricultural productivity growth in determining economic prosperity in India. Therefore, there is a strong case for the adoption of mitigation policies and other initiatives to stabilise/reduce the level of emissions in order to sustain future growth in agriculture and the economy. In particular, for countries like India that are dependent on climatic factors for economic well being, climate change mitigation policies assume a lot of significance. The selection and design of the mitigation policy is of particular relevance because some types of policies could damage the economy more than others. As mentioned above, Fisher-Vanden et al. (1997) have reported that India's participation in a global tradable permits market is more cost-effective than independently imposed carbon taxes. If properly designed, some policies could even benefit the economy in the long run. The last simulation (SIM 8) of this paper tries to ascertain the effects on the economy, if revenues from permit trading are used for capital formation and job creation (increase in the supply of capital and labour). This simulation is similar to SIM 7 except that in this simulation the aggregate supply of factors is increased. Higher growth rates and welfare gains (but lower emissions) are observed in this simulation. There is less increase in the consumer price of agriculture and less damage to agricultural exports relative to the other simulations. The wage rate of capital was found to increase in the later periods, and the share of agriculture in GDP also increased in this simulation. The implication is that increase in the supply of capital and labour more than compensates the damage (due to the productivity shock) on the agricultural sector. Therefore, climate policies could be a means to not only reduce emissions but also finance agricultural growth in the future.

Table 6: Comparison of costs of climate policy and agricultural productivity shock scenarios

Simulation	NPV GDP (% change relative to baseline) Discount rate 0 %	NPV GDP (% change relative to baseline) Discount rate 3 %
SIM 1 (climate policy: CT)	-2.9	-2.3
SIM 2 (climate policy: CDC)	-3.2	-2.4
SIM 3 (decline in agricultural productivity growth)	-16.3	-13.8
SIM 4 (SIM 3 + increase in world price of agriculture by same % as increase in domestic consumer price in SIM 3)	-16.9	-14.3
SIM 5 (SIM 3 + increase in world price of agriculture by 50 % of increase in domestic consumer price in SIM 3)	-16.6	-14.1
SIM 6 (climate policy: CT + no agricultural productivity growth from 2020)	-9.9	-7.9
SIM 7 (climate policy: CDC + no agricultural productivity growth from 2020)	-10.0	-8.0
SIM 8 (SIM 7 + capital formation and job creation using the revenues from permit trading)	5.7	4.5

4. CONCLUSIONS

The main objective of this paper was to compare the costs of future global climate change mitigation regimes with those of future climate change-induced agricultural productivity shocks in the case of India. The cost to the economy due to productivity shocks is on average about 70 per cent more than that of mitigation policies along with productivity shocks (likely to be milder if appropriate mitigation policies are adopted). The results indicate the significance of sustaining agricultural productivity growth in the future for achieving higher growth and welfare. Therefore, there is a strong case for the adoption of mitigation policies and other initiatives to stabilise/reduce the level of emissions to protect the agriculture sector. Climate policies could be a means to not only reduce emissions but also finance agricultural growth in the future. Labour households (rural and urban) experience relatively higher income losses than non-labour households due to climate policies. The welfare loss is relatively less if other countries are less affected by climate change than India as the country can then import agricultural commodities at a cheaper price from foreign markets. However, the welfare loss is higher if other countries are equally affected, in terms of agricultural price increase.

References

Ahmed, S.A., Diffenbaugh, N.S., Hertel, T.W., Martin, W.J., 2012. Agriculture and Trade Opportunities for Tanzania: Past Volatility and Future Climate Change. Review of Development Economics. 16(3), 429 – 447.

Auffhammer, M., Ramanathan, V., Vincent, J.R., 2006. Integrated Model shows that Atmospheric Brown Clouds and GHG have Reduced Rice Harvests in India. PNAS. 103 (52), Dec 26, 2006.

Bovenberg, A.L., Goulder, L.H., 1996. Optimal Environmental Taxation in the presence of other taxes: General-Equilibrium Analyses. American Economic Review. 86(4), 985-1000.

Cline, W.R., 2007. Global Warming and Agriculture: Impact Estimates by Country, Center for Global Development and Peterson Institute for International Economics, Washington DC, USA.

Fisher-Vanden, K. A., Shukla, P.R., Edmonds, J.A., Kim, S.H., Pitcher, H.M., 1997. Carbon Taxes and India. Energy Economics. 19, 289 – 325.

Garbaccio, R. F., Ho, M.S., Jorgenson, D.W., 1998. Controlling Carbon Emissions in China. Kennedy School of Government, Harvard University, USA.

Grossman, G. M., Krueger, A.B., 1995. Economic Growth and the Environment. The Quarterly Journal of Economics, May 1995.

Hertel, T.W., Rosch, S.D., 2010. Climate Change, Agriculture, and Poverty. Applied Economic Perspectives and Policy. 32(3), 355-385.

Hohne, N., den Elzen, M., Weiss, M., 2006. Common but Differentiated Convergence (CDC): A New Conceptual Approach to Long Term Climate Policy. Climate Policy. 6, 181-199.

International Food Policy Research Institute (IFPRI), 2009. Climate Change: Impact on Agriculture and Costs of Adaptation, 2009.

Intergovernmental Panel on Climate Change (IPCC), 2007. Climate Change 2007: Synthesis Report.

Intergovernmental Panel on Climate Change (IPCC), 2007b. Summary for Policymakers. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 7-22

Klepper, G., Peterson, S., Springer, K., 2003. DART 97: A Description of the Multi-regional, Multi-sectoral Trade Model for the Analysis of Climate Policies. Working Paper 1149. Kiel Institute for World Economy, Kiel, Germany.

McKibbin, W. J., Shackleton, R., Wilcoxen, P.J., 1999. What to Expect from an International System of Tradable Permits for Carbon Emissions. Resource and Energy Economics. 21, 319 – 346.

Ministry of Environment and Forests, Government of India, 2009. India's GHG Emissions Profile: Results of Five Climate Modelling Studies.

Ministry of External Affairs, Government of India, 2009. The Road to Copenhagen: India's Position on Climate Change Issues.

Ministry of Statistics and Programme Implementation, Government of India, 2011. Annual Report 2010-11.

Ministry of Statistics and Programme Implementation, Government of India, 2011. Key Indicators of Employment and Unemployment in India, 2009-10, NSS 66th Round.

Narain, S., Ghosh, P., Saxena, N.C., Parikh, J., Soni, P., 2009. Climate Change: Perspectives from India, United Nations Development Program (UNDP), India.

Nordhaus, W.D., 2007. A Review of the Stern Review on the Economics of Climate Change. Journal of Economic Literature. 45(3), 686–702.

OECD, 2012. OECD Environmental outlook to 2050. Organisation for Economic Co-operation and Development, OECD Publishing.

Ojha, V.P., Pal, B.D., Pohit, S., Roy, J., 2009. Social Accounting Matrix for India, (http://ssrn.com/abstract=1457628).

Organizaton for Economic Cooperation and Development (OECD), 2010. Costs and Effectiveness of the Copenhagen Pledges: Assessing Global Greenhouse Gas Emissions Targets and Actions for 2020.

Paltsev, S., Reilly, J.M., Jacoby, H.D., Eckaus, R.S., McFarland, J., Sarofim, M., Asadoorian, M., Babiker, M., The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4, Report No. 125, August 2005.

Parry, I.W.H., Williams III, R.C., Goulder, L.H., 1999. When can Carbon Abatement Policies increase Welfare? The Fundamental Role of Distorted Factor Markets. Journal of Environmental Economics and Management. 37, 52 – 84.

PBL Netherlands Environmental Assessment Agency, 2005. Framework to Assess International Regimes for differentiation of commitments (FAIR) (http://www.pbl.nl/en/publications/2005/Website_FAIR viewed on July 18, 2012).

Pradhan, B.K., Saluja, M.R., Singh, S.K., 2006. Social Accounting Matrix for India: Concepts, Construction and Applications, Sage Publications, New Delhi.

RTI International, 2008. EMPAX-CGE Model Documentation (Interim Report), March 2008. Research Triangle Park, North Carolina, USA.

Stavins, R.N., 2000. Market based Environmental Policies. In Portney, P.R., Stavins, R.N. (Eds.), Public Policies for Environmental Protection. Resources for the Future, Washington DC.

Stern, N., 2007. The Economics of Climate Change: The Stern Review, Cambridge University Press, Cambridge, UK.

Weitzman, M.L., 2009. On Modeling and Interpreting the Economics of Catastrophic Climate Change. The Review of Economics and Statistics. XCI(1), 1-19.

World Bank, 2007. Growth and CO_2 emissions: How does India compare to other countries? Background Paper, India – Strategies for Low Carbon Growth.

World Bank (http://climatechange.worldbank.org/content/south-asia viewed on July 18, 2012)

www.oecd.org/env/cc/econ (viewed on May 15, 2012)

www.cca.iari.res.in (viewed on July 17, 2012)

www.indiainbusiness.nic.in (viewed on July 17, 2012)

Appendix A

Table A1: Policy parameters (carbon prices and emission allowances) for the different climate policy regimes

	2015	2020	2025	2030	2035	2040	2045	2050
Carbon price ($ per ton of CO_2) (CT/SIM1)	1.9	6.8	34.4	69.7	104.9	141.9	212.6	408.0
Carbon price ($ per ton of CO_2) (CDC/SIM2)	1.9	6.8	34.7	71.1	107.2	145.7	222.4	440.8
Allowance (million MT of CO_2) (CDC/SIM2)	2316	2944	3589	4233	3997	3762	3526	3290