International Trading of Emission Rights : Its Implications for India

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Abstract

Developing countries including India have been absolved of any responsibility towards reducing emissions in the first commitment period, 2008-2012, of the Kyoto Protocal. However, India is the fifth-largest emitter of fossil-fuel-derived carbon dioxide, and its total emissions are growing rapidly. India's participation, therefore, in any future developing country commitment regime is a foregone conclusion. It is also obvious that, future negotiations on climate change will fix emission rights or entitlements for each country based on some commonly acceptable equity principle.

This study examines the consequences of India's participation in a globally tradable carbon emission permits regime based on : (1) Grandfathered Emissions Allocation (GEA) scheme in which permits are allocated on the basis of emissions level of a predetermined year, say, 1990, (2) Dynamic Equal Per Capita Emissions Allocation (DEPCEA) scheme in which the aggregate emissions entitlements for India in different years are arrived at by multiplying the average global per capita emissions (1 tonne per capita as in 1990) with India's population for the corresponding years, (3) Static Equal Per Capita Emissions Allocation (SEPCEA) scheme in which the aggregate emissions entitlements for India in different years are taken to be the product of average global per capita emissions and India's population for a predetermined year, 1990, using a computable general equilibrium model of the Indian economy.

The results show losses in GDP and poverty alleviation in case of GEA, but gains for both in the cases of DEPCEA and SEPCEA. The gains are expectedly higher for the former, as it is the more generous allocation system for India.

Key words: CGE model, carbon emissions, economic growth, poverty reduction, India, climate change, carbon tax policy, tradable emission permits.

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1. Introduction

Developing countries including India have been absolved of any responsibility towards reducing emissions in the first commitment period, 2008-2012, of the Kyoto Protocal. This is not surprising as India's per capita carbon emission is very low. It is only 0.33 tonnes per annum, which is roughly one-fourth of the world average per capita emission of 1.20 tonnes per annum. However, in aggregate terms, India is the fifth-largest emitter of fossil-fuel-derived carbon dioxide, and its total emissions are growing rapidly. India's participation, therefore, in any future developing country commitment regime is a foregone conclusion. Moreover, the fact that India has a real stake in a global policy regime to stabilise global carbon emissions is being realised in Indian policy circles. More specifically, Indian policy makers are beginning to see the need to understand the implications for India of a Kyoto-type global emissions trading regime inclusive of the developing countries.

According to the Kyoto Protocal, the industrialised countries (the Annex B countries) are required to cut their combined emissions to 5% below 1990 levels by the first commitment period, 2008-2012. The developing countries have been exempted frm any obligation towards reducing emissions in the first commitment period. This, however, is no reason for developing countries like India to become complacent. On the contrary, the developing countries have a major role to play in the ongoing negotiations on climate change. In fact, as Chander (2004 : 272) argues : "they (developing countries) have a stake in the ongoing negotiations on the form and mechansim of emission trade. The negotiations on climate change should ultimately aim at fixing pollution rights or entitlements for each country according to some agreed upon equity principles, and the Kyoto Protocol can be and may be viewed as a step in this direction". In other words, once competitive emissions trade among Annex B countries is institutionalised, the developing countries will be able to better assess the potential gains from such trade, and might be tempted to participate in a global emissions trade in the post-Kyoto phase of climate change negotiations.

If India were to participate in a global regime of tradable emission permits, what mode of emission entitlements would its policy makers press for ? Informed discussion is already taking place in Indian policy circles around this question. This paper attempts to further enlighten the policy makers on the *pros* and *cons* of the three main modes of allocation of emission permits. The three main types of emissions allocation schemes that we consider are :

(1) Grandfathered Emissions Allocation (GEA) scheme in which permits are allocated on the basis of (aggregate) emissions level of a predetermined year, say, 1990,

(2) Dynamic Equal Per Capita Emissions Allocation (DEPCEA) scheme in which the aggregate emissions entitlements for India in different years are arrived at by multiplying the average global per capita emissions (1 tonne per capita as in 1990) with India's population for the corresponding years.

(3) Static Equal Per Capita Emissions Allocation (SEPCEA) scheme in which the aggregate emissions entitlements for India in different years are arrived at by multiplying the average global per capita emissions (1 tonne per capita) with India's population for a predetermined year, say, 1990.

It is well known that the developed countries favour the grandfathered emissions allocation scheme, while the developing countries - particularly, China and India - advocate the equal per capita emissions allocation scheme (EPCEA). What is not so well recognised or understood, however, are the implicational differences between the two variants – *dynamic* and *static* - of the EPCEA scheme. In fact, critics of the EPCEA scheme either apply their criticisms non-discriminatingly to both the variants, or implicitly assume that the dynamic variant of EPCEA is the only variant. On a closer scrutiny, almost all the criticisms of EPCEA seem to apply to the DEPCEA, but not to the SEPCEA. For example, the criticism that the aggregate allowable emissions for a country would increase under the EPCEA, actually holds only for the DEPCEA, and not for SEPCEA. In the latter, the 1990 population of a country is taken for each of the future years; hence, for a *given* global per capita emissions, the aggregate emissions allocated for that country will remain unchanged for all the years. By additivity, it follows that, for a *given* global per capita emissions, the aggregate world emissions will also remain the same for all the future years. Most importantly, the SEPCEA would not (as does the DEPCEA) discriminate *in favour of* countries with rising populations and *against* countries with stable or declining populations. In other words, the SEPCEA would, as argued by Parikh and Parikh (1998), ensure equity between the developed and developing countries, and, simultaneously, discourage the latter from increasing their populations.

This paper, therefore, analyses the impact of India's participation in a globally tradable emission permits regime with (i) GEA, (ii) DEPCEA, and (iii) SEPCEA on carbon emissions, GDP and poverty in the Indian economy, with the help of a top-down, quasi-dynamic, neoclassical type price-driven computable general equilibrium (CGE) model. The impact on poverty of any adjustement in the policy regime is an important consideration in case of India, which has about 30%-40% of its population living below the poverty line, as the adjustment burden borne by this vulnerable segment of the population must be minimised. To be able to assess the impact of the proposed climate policies on poverty, we had to move from the standard single-representative-household based CGE model, to a CGE model with multiple households differentiated on the basis of consumption expenditure limits. Our model consequently has an elaborate income and consumption distribution mechanism, in which factoral incomes are first mapped onto 15 income percentiles and then onto five consumption expenditure classes. The bottom consumption expenditure class corresponds to those below the poverty line, which implies that the poverty ratio – i.e., the percentage of population below the poverty line – is endogenously determined in the model.

The rest of the paper is organised as follows. Section 2 presents the overall structure of the model, with special emphasis on the production structure, the production-CO_2 emission linkages and the income distribution mechanism. Section 3 presents the main features, such as, GDP growth, emissions growth, energy-GDP ratio and poverty ratio, of the base-line or the business-as-usual (BAU) scenario. In section 4, we report the simulation results of the three alternative policy scenarios in comparison with the BAU scenario. Section 5 concludes and suggests policy implications of our results. The Appendix gives the data tables related to the BAU scenario and policy simulations[1].

2. Model Structure

Our model is based on a neoclassical CGE framework that includes institutional features peculiar to the Indian economy. It is multi-sectoral and quasi-dynamic. The overall structure of our model is similar to the one presented in Mitra (1994). However, in formulating the details of the model - the production structure, the CO_2 emission generation and the income distribution mechanism - we follow an eclectic approach, keeping in mind the focus on the linkages between inter-fossil-fuel substitutions, CO_2 emissions, GDP growth and poverty reduction.

The model includes the interactions of producers, households, the government and the rest of the world in response to relative prices given certain initial conditions and exogenously given set of parameters. Producers act as profit maximisers in perfectly competitive markets, i.e., they take factor

1 For the equations of the CGE model used here the reader may refer to Ojha (2005).

and output prices (inclusive of any taxes) as given and generate demands for factors so as to minimise unit costs of output. The factors of production include intermediates, energy inputs and the primary inputs - capital, land and different types of labour. For households, the initial factor endowments are fixed. They, therefore, supply factors inelastically. Their commodity-wise demands are expressed, for given income and market prices, through the Stone-Geary linear expenditure system (LES). Also households save and pay taxes to the government. Furthermore, households are classified into five rural and five urban consumer expenditure groups. The government is not asssumed to be an optimising agent. Instead, goverment consumption, transfers and tax rates are exogenous policy instruments. The total CO_2 emissions in the economy are determined on the basis of the inputs of fossil fuels in the production process, the gross outputs produced and the consumption demands of the households and the government, using fixed emission coefficients.

The rest of the world supplies goods which are imperfect substitutes for domestic output to the Indian economy, makes transfer payments and demands exports. The standard small-country assumption is made implying that India is a price-taker in import markets and can import as much as it wants. However, because the imported goods are differentiated from the domestically produced goods, the two varieties are aggregated using a constant elasticity of substitution (CES) function, based on the Armington assumption[2]. As a result, the imports of a given good depends on the relation between the prices of the imported and the domestically produced varieties of that good. For exports, a downward sloping world demand curve is assumed. On the supply side, a constant elasticity of transformation (CET) function is used to define the output of a given sector as a revenue-maximising aggregate of goods for the domestic market and goods for the foreign markets. This implies that the response of the domestic supply of goods in favour or against exports depends upon the price of those goods in the foreign markets *vis-à-vis* their prices in the domestic markets, given the elasticity of transformation between goods for the two types of markets.

The model is Walrasian in character. Markets for all commodities and non-fixed factors - capital stocks are fixed and intersectorally immobile - clear through adjustment in prices. However, by virtue of Walras' law, the model determines only *relative* prices. The nominal exchange rate is chosen to be the numeraire and is, therefore, normalised to unity. Hence, the model determines endogenously the foreign

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[2] The Armington assumption states that commodities imported and exported are imperfect susbtitutes of domestically produced and used commodities. This assumption is necessary to take into account two-way trade and, at the same time, avoid an unrealistically high degree of specialisation (Armington, 1969).

savings in the external closure (Robinson, 1999). Finally, the model follows a savings-driven macro closure, in which aggregate investment is equated to aggregate savings - i.e., the sum of household, government and foreign savings.

2.1 Sectoral disaggregation

Our model is based on an eleven sector disaggregation of the Indian economy :

(i) Agriculture (agricult),
(ii) Electricity (elec),
(iii) Coal (coal),
(iv) Refined Oil (refoil),
(v) Natural Gas (nat-gas),
(vi) Crude Petroleum (crude-pet),
(vii) Transport (trans),
(viii) Energy Intensive Industries (enerint),
(ix) Other Intermediates including capital goods (otherint),
(x) Consumer goods (cons-good),
(xi) Services (services) .

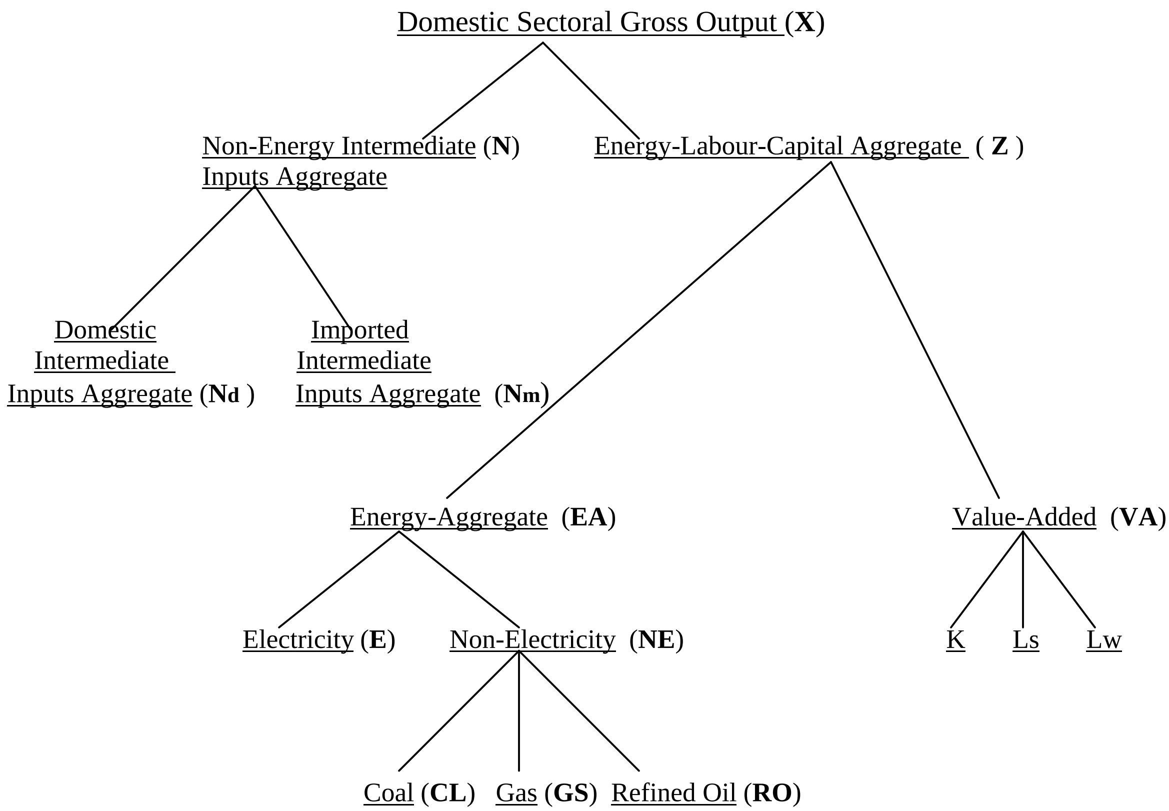
There are 5 energy sectors – elec, coal, refoil, nat-gas, crude-pet – and 6 non-energy sectors - agricult, trans, enerint, otherint, cons-good and services. The sectoral divison of the economy was decided after a perusal of the sectoral disaggregation in various other models - such as EPPA (Babiker *et al*, 2001 and Yang *et al*, 1996), SGM (Edmonds *et al*, 1993) and Murthy, Panda and Parikh (2000) - and bearing in mind the focus of our model on the possibilities of fuel switching in the provision of energy inputs in the production process.

2.2 The production structure

Production technologies for all sectors are defined using nested CES functions, with the nesting structure of inputs differing across the sectors, or groups of sectors as in the EPPA model.

For the transport, energy intensive industries, other intermediates, consumer goods and services sectors, the following tree describes the production structure (fig. 1).

Fig. 1 : The production structure



Note : K – Capital ; Ls – Self-employed Labour ; Lw – Wage-labour.

In case of the remaining sectors, there are minor variations in the nesting structure. For coal, natural-gas, crude petroleum and refined oil, there is an extra layer at the top combining non-fixed factor inputs' aggregate (**NF**) and fixed factor input (**f**) to produce domestic gross output. In the electricity sector, the non-electricity inputs' bundle is formed in two stages instead of one – i.e., first coal and refined oil are combined to form coal-oil aggregate (**COIL**) and the latter subsequently combines with natural gas (**GS**) to form non-electricity inputs' aggregate (**NE**). In agriculture, at the top level of the nesting structure, the domestic gross output is produced as a combination of resource intensive bundle (**RS**) and value added

(**VA**), where the former is made up of land and energy-materials (**EM**) aggregate. The latter in turn is an Armington combination of non-energy intermediate inputs' bundle (**N**) and energy aggregate (**EA**).

In other words, for each sector there is a nested tree-type production function. At each level of the nested production function, the assumption of constant elasticity of substitution (CES) and constant returns to scale (CRS) is made[3]. For every level, the producer's problem is to minimise cost (or maximise profit) given the factor and output prices and express demands for inputs. It follows that for every level, the following three relationships hold : the CES function relating output to inputs, the first order conditions, and the product exhausation theorem. For all the levels taken together, the production system thus determines, for each sector, the gross domestic output, the input demands, value-added as well as the demands for wage-labour and self-employed labour[4].

2.3 Technological change

Energy-saving technological progress is incorporated in our model by making the autonomous energy efficiency improvement (AEEI) assumption used in other carbon emission reduction models such as, GREEN (Burniaux *et al*, 1992) and EPPA (Babiker *et al*, 2001). As in the EPPA and GREEN models, we also assume that AEEI occurs in all sectors except the primary energy sectors (coal, crude petroleum and natural gas) and the refined oil sector. The GREEN model assumes a one percent annual increase in energy efficiency, while in the EPPA model there is an even higher annual growth rate of energy efficiency – 1.4 percent initially, though it slows down over time according to a logistic function. However, we are of the opinion that the exogenous annual growth rates of energy efficiency assumed for India in these models are overly optimistic. India has embarked on the path towards energy efficiency after 1991, but its record in energy efficiency improvement in the last one decade is far from encouraging (Sengupta and Gupta, 2004). We have thus assumed a more modest annual growth rate of energy efficiency for the Indian economy – i.e., 0.8 percent.

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[3] Although, the domestic and intermediate inputs' aggregates themselves are fixed-coefficients aggregates of domestic and imported inputs respectively from the non-energy sectors.

[4] The capital stock in a particular period is given, so that the first-order condition effectively determines the sectoral return on capital.

2.4 Carbon emissions

CO_2 is emitted owing to burning of fossil fuel inputs. The major fossil fuels used in India are coal, natural gas, refined oil and crude petroleum. In addition to CO_2 emitted by fuel combustion, there may be CO_2 emanating from the very process of output generation. For example, the cement sector (a part of the enerint sector in our sectoral classification) releases CO_2 in the limestone calcination process. Finally, CO_2 emissions also result from the final consumption of households and the government.

We use fixed CO_2 emission coefficients to calculate the sector-specific CO_2 emissions from each of the three sources of carbon emissions. For the total CO_2 emissions generated in the economy, we first aggregate the emissions from each of the sources over the eleven sectors and subsequently sum up the aggregate emissions across the three sources.

2.5 Investment

Aggregate investment are distributed across sectors of orgin using fixed share parameters. On the other hand, total investment is split into its two distinct constituents - public and private – also using fixed share parameters. However, the allocation mechanisms for sectors of destination are different in the two cases of public and private investment. For public investment there is discretionary allocation, and the allocation ratios are set exogenously. On the other hand, for private investment the allocation ratios are *given* in a particular period, but are revised from period to period on the basis of sectoral relative returns on capital. The relative return on capital in any sector is given by the normalisation of the implicit price of capital in that sector to the economy-wide returns. This rule does not imply full factor price equalisation, but only a sluggish reallocation of investment from sectors where rate of return is low to ones having higher rates of return.

Needless to say, this bifurcation of total investment into its public and private components with their differing allocation mechanisms is an attempt to approximate the way investments are actually made in the Indian economy. Incidentally, it also allows for public investments to be directed towards "strategic" sectors disregarding short-run considerations of profit maximisation.

2.6 Capital stocks

Sectoral capital stocks are exogenously given at the beginning of a particular period. However, our model is recursively dynamic, which means that it is run for many periods as a sequence of equilibria. Between two periods there will be additions to capital stocks in each sector because of the investment undertaken in that sector in the previous period. More precisely, sectoral capital stocks for any year *t* are arrived at by adding the investments by sectors of destination, net of depreciation, in year *t-1* to the sectoral capital stocks at the beginning of the year *t-1*.

2.7 Labour markets and wage rates

For the non-agricultural sectors (i.e. sectors 2-11), the total labour supply available for employment is exogenously given. From this stock of labour those who are unable to find wage-employment resort to self-employment. In the agricultural sector, on the other hand, there is a fixed supply of self-employed labour (those owning land of whatever size) and, over and above, there is a pool of labour (landless) waiting to to find employment. Those who are unable to find wage employment become openly unemployed, rather than resort to self-employment.

The real wage rates, for wage labour, in the current period are indexed to the previous period's wage rates. This rule is applied to both the agricultural and non-agricultural wage rates. In the non-agricultural sectors, those unable to find wage employment (at the adjusted wage rate) spill over into the pool of self-employed labour to clear the labour market. In other words, there is inflexible wage (keynesian) in the "organised sector" and a market-clearing remuneration rate for the self-employed in the "unorganised" sector (neo-classical).

2.8 Factor incomes and transfers

Factor incomes - i.e, self-employment incomes, wage incomes, incomes from rent accruing to fixed factors including land, and capital (profit) incomes are generated by summing the product of factor remunerations and their employment levels over all the sectors. From these, taxes are netted out to arrive at disposable incomes. To these five types of income is added a sixth type – transfer payments by government and rest of the world. Through these 'transfer payments' the government can recycle the total carbon tax revenues to the households. Factor incomes by region – rural and urban – are worked out for each of the six types of income using *fixed* shares to split these factor incomes into two parts, one for the rural and the other for the urban area[5].

2.9 Income distribution

The treatment of income and consumption distribution in our model is quite elaborate, as it should be. However, it needs to be stressed that there is hardly any degree of freedom in modeling the distribution of income in India. The mechanics of the income distribution is strictly guided by the type of data available. A detailed account of the income distribution module is provided in Narayana, Parikh and Srinivasan (1991) and Mitra (1994). Here we outline the main steps. (In what follows the account is the same for the rural and urban areas, and so we shall not make a distinction between the two).

Step 1 - We start with the factoral incomes and map them onto incomes accruing to 15 income classes[6] using a constant share income allocation scheme (obtained from secondary data sources of the Indian economy – see Appendix 3) for all the 6 types of income – self-employment income, wage income, capital income, incomes from land and fixed factors and transfer payments by government and rest of the world[7]. Given Y_h , the income accruing to class h, and θ_h , the share of households in class h in the total population (also known from data sources), we compute the mean and variance of income .

It may be noted here that, in case of across-the-board transfers of revenues earned from carbon taxes or sale of emission permits, these revenues are distributed across the 15 income classes according to the same constant share income allocation scheme applicable to the transfer payments above. To put it another way, in the across-the-board transfers case, the carbon tax or permit revenues are simply treated like additonal government transfers, and, hence, distributed across the 15 income classes in proportions same as those for routine government transfers.

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[5] The parametric values of the rural-urban split ratios are obtained from Pradhan *et al* (2000), and add up to one for each of the six sources of income.

[6] The 15 income classes are percentiles taken in tens, fives and ones. The first nine income classes are, from bottom to top, nine deciles, followed by the 10th class which is more than 90th percentile and upto 95th percentile, and, finally, we have the top five income classes – i.e., the 96th, 97th, 98th, 99th and 100th percentile.

[7] The constant shares – i.e., the exogenously given split ratios - for each income-type add up across the 15 income classes to one.

On the other hand, in case of the targeted transfers, the carbon tax or the permit revenues are distributed exclusively and equally to the lowest four income deciles. That is to say, each of the lowest four income classes (deciles) receive 25% of the revenues earned from carbon taxes or sale of permits, while the remaining 11 income groups or classes get nothing.

Finally, it must be stressed that, the lowest four income deciles or the poorest 40% of the population are conceptually and quantitatively different from what we call the poverty ratio (defined below in step_3). While the former specifies the relative income position of a section of the population, the latter is the share of population at or below a pre-defined minimum level of consumption necessary for sustenance. The relative income inequality in most economies change slowly, but that does not mean that poverty cannot be eradicated fast. The relative income position of the 'poor' might remain unchanged, but their consumption reach can be extended beyond the minimum sustenance level. Hence, poverty ratio can decline rapidly even when relative income inequality is stable. That said, it must be recognised that, in another sense which is important in this modeling exercise, there is an overlap between the two concepts. That is, if there is poverty in an economy, in the sense of absolute deprivation of basic minimum consumption, it obviously exists in the lower rungs of the income ladder. From the poverty removal policy point of view, therefore, it is the lowest four or three or two income deciles that have to be targeted.

Step 2- We first make the assumption that the distribution of population according to per capita income and per capita consumption expenditure is bivariate log-normal.

(a) Since the distribution of income and consumption expenditure is assumed to be bivariate log-normal, the mean and variance of the logarithm of per capita income is computed from the mean and variance of income of step 1.

(b) The bivariate lognormality assumption implies that log income and log consumption expenditure are linearly related, so the mean and variance of log per capita consumption expenditure can be easily calculated.

Step 3 – Given the mean and standard deviation of log income and log consumption expenditure, we derive the distributions of population, consumption and total income by 5 consumption classes. (The upper boundaries of the 5 consumption classes – cel_1, cel_2, cel_3, cel_4, cel_5 are taken from the consumption expenditure data published by the NSSO (National Sample Survey Organisation)-45th Round). More specifically, we find the shares of (i) population (ii) consumption and (iii) total income accruing to the households that fall under expenditure level cel_k , for k = 1,2,…,5, using the standardised cumulative normal distribution. The poverty ratio is the share of population with per capita consumption expenditure less than or equal to cel_5 .

Step 4- From the cumulative shares of the five consumption expenditure classes we arrive at the per capita expenditure and income for each these classes by simply taking the difference between the cumulative shares of the class in question and the preceding class.

Step 5 – Once we have the per capita consumption expenditure for each of the 5 consumption classes, we use the Stone-Geary linear expenditure system to determine separately the sectoral per capita consumption demands for each of these classes.

Step 6 – The sectoral per capita consumption demands for each class are then multiplied by the class-specific population, and the resulting product aggregated, first, over the five classes and, then over, the two regions to arrive at the commoditywise consumption demands.

2.10 Savings

Total household savings in the economy is an aggregate of the savings of the 10 urban and rural consumption expenditure classes. For each of the five rural and five urban classes, household savings is determined residually from their respective budget constraints, which state that household income is either allocated to household consumption or to household savings. Government savings is obtained as sum of the tax and tariff revenues, less the value of its consumption and transfers. Government revenue originates from the following five sources : taxes on domestic intermediates, tariffs on imported intermediates, taxes on consumption and investment, taxes on final imports and income taxes - i.e., taxes on wage, self-employed and capital (profit) incomes. All taxes (excluding carbon tax) are of the proportional and *ad valorem* type, and all the tax rates are exogenously given. Government expenditure takes place on account of government consumption and transfers to households, both of which are exogenously fixed. The CO_2 emission taxes are recycled to the households *via* the government, which means that they be included in (or excluded from) both the revenue and the expenditure of the government budget. Foreign savings in the model is expressed as the excess of payments for intermediate and final imports over the sum of exports earnings, net current transfers and net factor income from abroad The latter two, it may be noted, are exogenously given values in the model.

2.11 Market equilibrium and macroeconomic closure

Market clearing equilibrium in the commodity markets is ensured by the condition that sectoral supply of composite commodity must equal demand faced by that sector. In the production structure of the model the domestic gross output of a sector is defined to be a combination of domestic sales and exports, based on a CET transformation function. In turn, the domestic sales part of the sectoral gross output and the final imports of that sector are aggregated through an Armington-type CES function to arrive at the sectoral composite commodity supply[8]. On the other hand, the demand for the composite commodity consists of intermediate demand, final demand - which in turn is an aggregation of consumption, investment and government demands - and change in stocks.

The model is Walrasian in spirit with the sectoral prices being the equilibrating variables for the market-clearing equations. The Walras' law holds and the model is, therefore, homogeneous of degree zero in prices determining only relative prices. The nominal excahnge rate serves as the numeraire, and is, therefore, fixed at one.

Finally, note that the model is neoclassical in nature and thus follows a savings-driven macro closure in which aggregate investment is determined endogenously as the sum of household savings, government savings and foreign savings.

2.12 Dynamics

The model is multiperiod in nature, where the unit of period is one year. However, it is not an an inter-temporal dynamic optimisation model; it is only recursively dynamic. That is, it is solved as a sequence of static single-year CGE models, where investment in the current year enhances the available capital stock and depreciation depletes that stock, resulting in net additions (reductions) to sectoral capital stocks between two periods. Likewise, the sectoral allocation ratios for private investment are revised from period to period on the basis of sectoral relative rates of return on capital. Hence, prior to solving the CGE model for any given year – other than the base-year – an interim-period-sub-model is worked out to update the sectoral capital stocks and the sectoral allocation shares of private investment.

3. The Baseline Scenario

Our CGE model has been calibrated to the benchmark equilibrium data set of the Indian economy for the year 1989-90. The basic data set of the Indian economy for the year 1989-90 has been obtained from the CSO-NAS (Central Statistical Organisation - National Accounts Statistics of India, various issues from 1989-90 to 1992-93) and the CSO–IOTT (Central Statistical Organisation (1997) - Input-Output Transactions Table - 1989-90). Other parameters and initial values of different variables have been estimated from the data available in various other published sources[9].

Given the benchmark data set for all the variables and the elasticity parameters, the *shift* and *share* parameters are calibrated in such a manner that if we solve the model using the base-year data inputs, the result will be the input data itself (Shoven and Whalley, 1992).

Finally, using a time series of the exogenous variables of the model, we generate a sequence of equilibria for the period 1990-2020. From the sequence of equilibria, with 5-year time intervals, the growth paths of selected (macro) variables of the economy are outlined to describe the base-line scenario.

3.1 The macro variables

In the base-line scenario, real GDP growth throughout the period 1990-2020 varies in the range 4%-9%. The GDP growth rate, which is 5.7% per year during 1990-95, slows down to less than 5% in the period 1995-2000. After that the growth rate picks up again to be in the range 6.5% – 9.5% per year till 2020 (table 5). The driving force of GDP growth in our model comes from growth in two main exogenous variables - investment and labour supply. Investment adds to the capital stock, inducing a substitution away from labour into capital. This results in an increase in labour productivity, measured as GDP per unit of labour. Growth in labour productivity coupled with the simultaneous growth in labour supply is what provides the main impetus to GDP growth.

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[8] Note that in the nesting structure diagram given above (fig. 1), these 2 functions are *not* shown. The nesting diagram starts with the sectoral gross output at the top, and goes down the vertical linkages of inputs.

[9] Full information on the data sources is available in Appendix 3 of the author's SANDEE working paper (Ojha, 2005).

3.2 Poverty ratio

The poverty ratio in the base-line scenario declines from 37.5% in 1990 to 2% in 2020 (tables 2, 3 and 4). However, the noteworthy fact is that the decline in poverty ratio is very much linked to the growth in GDP. That is to say, with the GDP growing faster after 2000, the decline in poverty also speeds up. In the first 15-year period, 1990-2005, the poverty ratio declines quinquennially by about 4-5 percentage points; in the later 15-year period 2005-2020 it declines quinquennially by about 7-8 percentage points.

3.3 Energy use

Total energy use increases by about 320% over the 30-year period 1990-2020. The annual growth rates of energy use and GDP decline more or less equally until 2000. However, after 2000, the growth rates of energy use, relative to the GDP growth rates, fall sharply. This is reflected in a declining energy use per unit of GDP beyond 2005. This happens because of increased substitution of capital in the production process, and modest autonomous energy efficiency improvement.

3.4 Carbon emissions

Total carbon emissions in the period 1990-2020 rise from 168 million tonnes to 559 million tonnes at an average rate of 4.1% per year. However, the growth rate is not uniform. It drops from more than 4% in the pre-2005 period to less than 4% in the post 2005 period (table 5). This is largely explained by the decline in the energy-GDP ratio after 2005. In the Indian economy most of the carbon emissions - as much as 72% of the total – emanate from the combustion of coal. The share of coal in the total emissions remains virtually unchanged throughout the period (table 7).

In assessing India's contribution to global carbon emisions, it is important to look at the per capita carbon emissions[10]. India's per capita emissions in 1990 turn out to be 0.21 tonnes. It increases quite rapidly over the 30-year period and goes up to 0.69 tonnes by the year 2020 (tables 2 and 4). Even this level of per capita emissions is considerably less than the global per capita emissions which is approximately 1 tonne per year.

4. Policy Simulations

We develop three alternative policy scenarios for India's participation in a globally tradable emissions trading regime under (i) GEA, (ii) DEPCEA, and (iii) SEPCEA

For the policy scenario 1, the emission quota is fixed at the (aggregate) emissions level of the year 1990. For policy scenarios 2, the emissions quota is fixed at 1 tonne per capita[11] based on the 1990 population as suggested by Parikh and Parikh (1998). The permit price for the simulations 1, 2 and 3, is exogenously given to be US$ 6 per tonne of carbon emission, which is Rs 100 per tonne at the 1989-90 exchange rate of Rs 16.60 per dollar. In reality, the permit price will emerge from a global trading system of permits, which, for example, has been modeled by Edmonds *et al* (1993) in the SGM. However, ours is a country-specific exercise focusing on how India stands to gain or lose from an internationally tradable permits regime. Moreover, the 'small-country' assumption applies and India's sale or purchase of permits does not affect the latter's world market price; for India, therefore, the world market price of permits is exogenuosly given. (Fisher-Vanden *et al*, 1997 and Murthy, Panda and Parikh, 2000).

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[10] Note that the per capita emissions have been calculated on the basis of the 1990 population for all the years, so that a higher population in the years subsequent to 1990 is not allowed to undermine the total emissions in the economy.

[11] This is approximately equal to the world per capita emission in 1990.

The three policy simulations are summarised in table 1 given below.

Table 1 : The policy simulations

	Policy Instrument	**Carbon Emission Restriction**
Policy Simulation 1	Internationally Tradable Permits [Permit Price= $6 / tonne, i.e., Rs 100 /tonne]	Total carbon emissions fixed at the 1990 level of emissions
Policy Simulation 2	Internationally Tradable Permits [Permit Price = $6 /tonne, i.e., Rs 100/tonne]	1 tonne of carbon per capita based on the current year population
Policy Simulation 3	Internationally Tradable Permits [Permit Price = $6/tonne, i.e., Rs 100/tonne]	1 tonne of carbon per capita based on the 1990 population

4.1 The adjustment mechanism at work

The internationally tradable emission permits scheme in a participating country is implemented by the government of that country. We assume that, the government sells emission permits to the domestic producers at the world market price, and buys or sells permits in the international market, depending upon whether domestic demand for permits is in excess or short of the quota of permits allocated to India. The net revenue gains made by the government are recycled to the households. In fact, the sale of emission permits by the government to the domestic producers at the world market price is tantamount to imposing a carbon tax based on the proportion of each fuel's carbon content, i.e. Rs per tonne of carbon. This *virtual* tax results in price increases for each of the fossil fuels – coal, refined oil and natural gas. The extents of price increases of these fuels is determined by the carbon content of the respective fuels. The price increase is largest for coal, because coal has the highest carbon content, and smallest for natural gas which has the lowest carbon content. Producers respond by switching from coal towards refined oil and natural gas as a source of energy. At the same time, higher energy prices force a reduction in overall energy use. Carbon emissions are reduced on account of both fuel switching and overall reduction in fuel use. Usually (inter-fossil-fuel substitutions elasticities being low), the fuel reducing effect dominates over the fuel switching effect, resulting in a retardation of GDP growth. Typically, the adverse effect of reduced energy use on GDP growth diminishes over time as energy efficiency improvement coupled with a higher capital intensity in the production process results in a declining energy use per unit of GDP. Typically also, the slowdown in consumption growth is sharper than that in case of GDP growth. When production activity goes down, labour demand and wages decline leading to a fall in personal incomes (unless the additions to personal incomes from the recycled proceeds from the sale of emission permits are large enough to offset this fall). Moreover, higher energy prices end up as higher prices for consumer goods, thus lowering real consumption.

Moreover, looking at the carbon emissions in the BAU scenario, it is easy to see that India will be a net buyer of tradable permits anytime after 1990, in the internationally tradable permits scenario with a grandfathered emissions quota allocation. A net purchase of permits would amount to a transfer of wealth out of India. These transfer payments to the rest of the world lower disposable incomes and thereby consumption demands, thus, dragging further the GDP growth in India.

In the internationally tradable emission permits regime with equal per capita emissions allowances, India will be allowed a carbon emissions quota of 1 tonne per capita based on the 1990 population of 810 million under the SEPCEA, and based on the current year's population under the DEPCEA. From the trend in the carbon emissions in the BAU scenario (table 8), it is obvious that India will be a net seller of tradable permits, at least, for the next two or three decades. That is, countries with high per capita emissions would purchase permits from countries with low per capita emissions, such as, India. That would in effect imply a transfer of wealth into India. These transfer payments from rest of the world are recycled to the households. They, therefore, lead to an autonomous increase in consumption demand (like an increase in government expenditure), which, in turn, induces a higher demand-driven GDP growth[12]. Higher incomes boost consumption further, so that consumption rises faster than GDP. However, over time as the economy gets close to the upper limit of 810 million tonnes of total carbon emissions, the revenues earned from the sale of permits will shrink, and the GDP gains will become progressively smaller. In fact, in not so distant a future, the economy will turnaround from being a net seller of permits to a net buyer of permits.

4.2 Policy simulation 1

In policy scenario 1, India participates in an internationally tradable emission permits regime with grandfathered emissions allocation. Hence, its emissions quota is fixed at 168 million tonnes, i.e., the 1990 level of carbon emissions in the BAU scenario. However, there is scope for going beyond this limit through purchase of emission permits in the international market at the (given) world market price of Rs 100 per tonne of carbon emissions. As it turns out, India is a net buyer of tradable permits throughout the period, 1990-2020, and its carbon emissions after 1990 are far in excess of the fixed quota of 168 million tonnes (table 8).

However, with respect to the BAU scenario, there is a decline in annual carbon emissions all through the 30-year period. For the whole period, the cumulative emissions decline by 5.07%. Per capita emissions in this simulation also decrease. The decline in per capita emissions in the various years are in the range of 0.02-0.03 tonnes. In the last year, 2020, per capita emissions in this scenario are 0.66 tonnes, as against 0.69 tonnes of the BAU scenario.(tables 5 and 6).

GDP and consumption losses in this simulation relative to the BAU scenario are less than 1% (tables 2, 3 and 4).

Poverty increases marginally in simulation 1. The number of poor people in 2020 is 26.58 million, as against 26.15 million of the base-case (tables 2, 3 and 4).

It follows that, the costs imposed on the Indian economy due to losses in GDP and poverty reduction are significant in case of its participation in a globally tradable emissions permits regime with GEA based on India's 1990 emissions level.

4.3 Policy simulation 2

In policy simulation 2, India participates in an internationally tradable emission permits regime under DEPCEA. In such a policy regime, the carbon emission quota is fixed at 1 tonne per capita based on the current year population. In other words, the maximum permitted total emissions of carbon in any year is

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[12] Note that the dampening effect of the virtual carbon tax imposed by the sale of emission permits by the government to the domestic producers at the world market price on the GDP is far outweighed by the

fixed at as many tonnes as the *given* population in that year. For every tonne of carbon emitted less than the quota, the Indian economy earns $6, which is Rs100 at the base-year exchange rate, through the sale of a permit in a global market of permits, and the total revenue from the sale of permits is recycled to the households as transfers from the rest of the world.

The exact procedure followed in this simulation is to fix an upper bound for total emissions. The actual total emissions of carbon, restrained by the virtual tax imposed on the domestic producers through sale of permits by the government at the world market price of Rs 100 per tonne, turns out to be much less than the upper bound for each period. That is, the upper bound is not binding in any of the years. The difference between maximum permissible emissions and the actual emissions is multiplied by the permit price to arrive at the total revenue from the sale of permits, which is then recycled to the households like additional transfer payments from the government. In the process, the model generates a set of equilibrium values for GDP, consumption, poverty ratio etc.

In simulation 2, carbon emissions increase relative to the base-line scenario all through the thirty-year period. Cumulative carbon emissions for the thirty-year period increase by 12.2% (table 8). Per capita emissions also increase throughout the period, with the increases being in the range of 0.02-0.10 tonnes. However, what needs to emphasised is that, even in the last year, 2020, per capita emissions are only 0.79 tonnes, which is less than the world average of 1 tonne per capita (tables 4 and 6).

The infusion of additional transfer payments from the rest of the world, in the form of permit revenue, leads to substantial increases in GDP and consumption in this simulation. The consumption gains are higher than the GDP gains in each of the periods (tables 2, 3 and 4). Apart from the increases in consumption resulting from the increased transfers to households, there are 'second-round' increases in consumption when there is additional income generated from the demand-induced increase in production activities.

The poverty ratio declines substantially in scenario 2. The number of poor persons, relative to the base-line scenario, decreases by 6.6% in 1990, and by 25.6% in the year 2020. That is, in the final year, 2020, the number of people in poverty is only 19.47 million in this simulation, as compared to 26.15 million in the base-line scenario (tables 2, 3 and 4).

In short, India would increase its cumulative carbon emissions in the thirty-year period by about 12%, but would reap major gains in terms of GDP growth and poverty alleviation in a globally tradable emission permits regime with DEPCEA.

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stimulating effect exercised on the GDP by the autonomus increase in consumption expenditure.

4.4 Policy simulation 3

In policy simulation 3, India participates in an internationally tradable emission permits regime with SEPCEA. Hence, the carbon emission quota is fixed at 1 tonne per capita based on the 1990 population of 810 million for each of the thirty years, 1990 –2020. In that sense, policy scenario 3 is a stricter version of the policy scenario 2.

In simulation 3, as compared to simulation 2, there are smaller annual increases in carbon emissions relative to the base-line scenario. Cumulative carbon emissions for the thirty-year period increase by only 8.7%. Per capita emissions also increase throughout the period, with the increases being in the range of 0.03-0.04 tonnes. However, even in the last year, 2020, per capita emissions are only 0.75 tonnes, which is less than the world average of 1 tonne per capita (tables 2, 3 and 4).

The GDP and consumption gains in this simulation are predictably smaller than those in case of the simulation 2.

There is a significant decline in the poverty ratio in scenario 3. The number of poor persons, relative to the base-line scenario, decreases by 6.6% in 1990, and by 18.8% in the year 2020. As a result, in the final year, 2020, the number of people in poverty is only 21.24 million in this simulation, as compared to 26.15 million in the base-line scenario (tables 3 and 5).

In policy scenario 3, India remains a gainer in terms of GDP and poverty alleviation, while emitting only 8.7% more carbon in cumulative terms in the thirty-year period.

5. Conclusion

In this paper, three policy scenarios for India’s likely participation in a globally tradable emissions trading regime respectively under (i) GEA, (ii) DEPCEA, and (iii) SEPCEA, are compared using a CGE model.

In policy scenario 1, in which India takes part in global emissions trade with GEA, India suffers high cost through GDP diminuation and poverty accentuation. Cumulative carbon emissions for the thirty-year period decline by about five percent. Per capita emissions based on 1990 population which were already (i.e., in the business-as–usual scenario) below the world average per capita emissions decline further in this scenario.

Policy scenario 2 is concerned with India's participation in global emission trade under DEPCEA. Under this scheme, India, because of its increasing population, has an ever-increasing quota of emission permits, which, in turn, results in increasing amounts of transfer payments from rest of the world into India. This sets the consumption multplier into motion, leading to large gains in GDP and poverty reduction. However, cumulative emissions for the thirty-year period rise by approximately 12%. Interestingly, per capita population based on 1990 population still remain below the world average of one tonne per capita.

In policy scenario 3, India takes part in global emission trade with SEPCEA. That is, in this scenario, the reference population level is fixed at the 1990 level. India now does *not* have an ever-increasing quota of emission permits. Rather, its total allowable emission gets fixed at 810 million tonnes for each of the years in the thirty-year time horizon. This implies decreasing rather than increasing surplus emission permits to sell, and, hence, decreasing rather than increasing amounts of transfer payments from rest of the world into India. The windfall gains in GDP and poverty reduction are gone, but, India still makes significant gains on both these counts. Moreover, cumulative emissions increase by about 9 % only, and per capita emissions based on the 1990 population remain significantly lower than the world average.

It is obvious that, India's interest are best served by global emissions trade with DEPCEA. But the latter is not likely to be accepted internationally (by the developed countries). On the other hand, the GEA, which is perceived as unfair and inequitable to begin with by the developing ountries, will be strongly resisted by India – justfiably, as is evident from the results of the policy simulations. The SEPCEA represents by far the most reasonable arrangement for future global emissions trade inclusive of developing countries. It is also the best pursuable option for India. Hence, India must campaign actively for it.

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APPENDIX

Table 2 : BAU Scenario and the Policy Simulations : Selected Variables in 1990

	GDP (in billion Rupees)	Cons. (in billion Rupees)	Carbon Emissions (in million tonnes)	Per Capita Emissions based on 1990 popln. (in tonnes per capita)	Poverty Ratio (in percent)	No. of Poor (in million)	
BAU Scenario	4380.11	3211.25	168.00	0.21	37.45	303.35	
	GDP (%age diff. from BAU)	*Cons. (%age diff. from BAU)*	Carbon Emissions (%age diff. from BAU)	Per Capita Emissions based on 1990 popln. (in tonnes per capita)	Poverty Ratio (in percent)	No. of Poor (in million)	*No. of Poor (%age diff. from BAU)*
Sim 1	*0.00*	*0.00*	*0.00*	0.21	37.45	303.35	*0.00*
Sim 2	*6.69*	*6.81*	*13.70*	0.24	34.96	283.18	*-6.65*
Sim 3	*6.69*	*6.81*	*13.70*	0.24	34.96	283.18	*-6.65*

Table 3 : BAU Scenario and the Policy Simulations : Selected Variables in 1995

	GDP (in billion Rupees)	Cons. (in billion Rupees)	Carbon Emissions (in million tonnes)	Per Capita Emissions based on 1990 popln. (in tonnes per capita)	Poverty Ratio (in percent)	No. of Poor (in million)	
BAU Scenario	5835.89	3927.65	208.09	0.26	32.48	292.35	
	GDP (%age diff. from BAU)	*Cons. (%age diff. from BAU)*	Carbon Emissions (%age diff. from BAU)	Per Capita Emissions based on 1990 popln. (in tonnes per capita)	Poverty Ratio (in percent)	No. of Poor (in million)	*No. of Poor (%age diff. from BAU)*
Sim 1	*-0.41*	*-0.43*	*-6.80*	0.24	33.27	299.44	*2.43*
Sim 2	*6.10*	*6.75*	*10.15*	0.28	30.20	271.84	*-7.02*
Sim 3	*4.90*	*5.19*	*8.90*	0.28	30.35	273.14	*-6.57*

Table 4 : BAU Scenario and the Policy Simulations : Selected Variables in 2020

	GDP (in billion Rupees)	Cons. (in billion Rupees)	Carbon Emissions (in million tonnes)	Per Capita Emissions based on 1990 population (in tonnes per capita)	Poverty Ratio (in percent)	No. of Poor (in million)	
BAU Scenario	36130.24	26438.79	559.46	0.69	2.01	26.15	
	GDP (%age diff. from BAU)	*Cons. (%age diff. from BAU)*	Carbon Emissions (%age diff. from BAU)	Per Capita Emissions based on 1990 popln. (in tonnes per capita)	Poverty Ratio (in percent)	No. of Poor (in million)	*No. of Poor (%age diff. from BAU)*
Sim 1	*-0.72*	*-0.74*	*-5.00*	0.66	2.04	26.58	*1.63*
Sim 2	*7.16*	*7.31*	*13.78*	0.79	1.50	19.47	*-25.56*
Sim 3	*1.84*	*2.15*	*8.14*	0.75	1.63	21.24	*-18.79*

Table 5 : Macrovariables and carbon emissions of the BAU scenario

	In billion Rupees			In million tonnes	*GDP (Growth Rate)*	*Cons. (Growth Rate)*	*Inv. (Growth Rate)*	*Carbon Emissions (Growth Rate)*
	GDP	Cons.	Inv. (exo.)	Carbon Emissions				
1990	4380.11	3211.25	1539.41	168.00				
1995	5835.89	3927.65	2182.17	208.09	*5.74*	*4.03*	*6.98*	*4.28*
2000	7489.00	4856.58	2944.81	257.74	*4.99*	*4.25*	*5.99*	*4.28*
2005	10161.08	6878.40	4108.38	315.75	*6.10*	*6.96*	*6.66*	*4.06*
2010	15265.34	10695.09	6364.87	383.74	*8.14*	*8.83*	*8.76*	*3.90*
2015	23290.88	16662.23	10022.66	464.50	*8.45*	*8.87*	*9.08*	*3.82*
2020	36130.24	26438.79	15667.16	559.46	*8.78*	*9.23*	*8.93*	*3.72*

Note : The growth rates for each of the quinquenniums are the annual growth rates.

Table 6 : Energy use

	E	*E (Growth Rate)*	E/GDP
	BAU Scenario	BAU Scenario	BAU Scenario
1990	565.46	*5.72*	0.1291
1995	752.84	*5.17*	0.1290
2000	975.07	*4.16*	0.1302
2005	1200.72	*3.04*	0.1311
2010	1397.54	*2.64*	0.1178
2015	1594.84	*2.40*	0.1043
2020	1798.64	*5.72*	0.0894

Note : E : Total energy use in 10^3 terajoules
E/GDP : Energy input per unit of GDP in 10^3 terajoules per billion rupees
The growth rates for each of the quinquenniums are the annual growth rates.

Table 7 : Carbon emissions (percentage share of fossil fuels)

	BAU Scenario		
	Coal	Ref. Oil	Nat Gas
1990	72.23	22.66	5.11
1995	72.46	22.54	5.00
2000	73.11	22.23	4.66
2005	73.25	22.52	4.23
2010	73.35	22.50	4.15
2015	73.14	23.80	3.06
2020	72.98	23.98	3.03

Table 8 : Carbon Emissions

	In million tonnes	In million tonnes			*Percentage difference from BAU Scenario*		
	BAU Scenario	*Sim. 1*	*Sim. 2*	*Sim. 3*	*Sim.1*	*Sim. 2*	*Sim. 3*
1990	168.00	168.00	191.02	191.02	*0.00*	*13.70*	*13.70*
1995	208.09	193.95	229.21	226.61	*-6.80*	*10.15*	*8.90*
2000	257.74	244.93	282.69	279.05	*-4.97*	*9.68*	*8.27*
2005	315.75	298.23	344.95	334.25	*-5.55*	*9.25*	*5.86*
2010	383.74	360.69	446.58	431.98	*-6.01*	*16.38*	*12.57*
2015	464.50	440.53	514.59	494.53	*-5.16*	*10.78*	*6.47*
2020	559.46	531.46	636.56	605.01	*-5.00*	*13.78*	*8.14*
					-5.07	***12.23***	***8.70***

Table 9 : Per Capita Carbon Emissions

	In tonnes per Capita (*based on 1990 population*)			
	BAU Scenario	Sim. 1	Sim. 2	Sim. 3
1990	0.21	0.21	0.24	0.24
1995	0.26	0.24	0.28	0.28
2000	0.32	0.30	0.35	0.34
2005	0.39	0.37	0.43	0.41
2010	0.47	0.45	0.55	0.53
2015	0.57	0.54	0.64	0.61
2020	0.69	0.66	0.79	0.75

Table 10 : Poverty ratio (in percent)

	BAU Scenario	Sim. 1	Sim. 2	Sim. 3
1990	37.45	37.45	34.96	34.96
1995	32.48	33.27	30.20	30.35
2000	28.41	29.12	26.60	26.74
2005	24.86	25.43	22.81	22.85
2010	16.26	16.63	15.00	15.36
2015	09.04	9.25	8.27	8.52
2020	02.01	2.04	1.50	1.63

Table 11 : Number of poor persons (in million)

	BAU Scenario	Sim. 1	Sim. 2	Sim. 3
1990	303.35	303.32	283.18	283.18
1995	292.35	299.44	271.84	273.14
2000	278.43	285.41	260.66	262.08
2005	263.54	269.61	241.75	242.25
2010	185.39	189.61	171.01	175.09
2015	110.31	112.85	100.86	103.96
2020	26.15	26.58	19.47	21.24