International Trade and Domestic Environmental Emission: A Computable General Equilibrium Analysis for India

Dr. J. K. Das*
Koushik Das**

Abstract

This paper examines General Equilibrium implications of International Trade and Globalization on social welfare and environmental emission. We have applied Computable General Equilibrium (CGE) modeling as relevant methodology in the same way Shoven and Whalley (1984) has done through construction of Energy/Environmental Social Accounting Matrix (SAM) and CGE model. This paper attempts to investigate the effects of Liberalized Trade on different macroeconomic aspects, energy consumption and Green House Gases (GHG) emission. With the help of an index of Pollution Terms of Trade (PTOT) our research finds that trade and globalization in most of the cases aggravated the problem of GHG emission and has made India 'Pollution Haven'.

Keywords: CGE, SAM, Trade Liberalization, PTOT.
JEL Classification: C68, F18, F41, Q5

Introduction

Environmental emission has received considerable attention in the recent past. Advocates of free trade sometimes point out that the developing economies are emerging as 'Pollution Haven'. Their lax environmental standards/laws have led to the migration of dirty manufacturing industries from developed nations (Copeland & Taylor, 1994) to the developing nations. Although free trade policy has expanded global production by employing resources in efficient lines of production, yet it could damage the economy by changing pollution levels through scale, technique and composition effects (Grossman & Krueger, 1993). Indian economy embarked upon a policy of Privatization, Liberalization & Globalization. This has not only increased energy consumptions but has led to the deterioration of environmental standards & Air pollution. Indian Policy Makers are working towards the development of low carbon emission strategies for India that could reduce carbon di oxide emission intensity by 25 - 30% by 2020. While formulating an appropriate Energy/Environmental policy a pertinent question arises, whether a developing country like India has become a 'Pollution

*Department of Commerce, University of Calcutta, West Bengal, INDIA
**Department of Economics, Chandidas College, Burdwan University, West Bengal, INDIA

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Haven' due to the migration of dirty manufacturing industries to India during the period of economic liberalization or not.

Therefore, it is important to understand how international trade during liberalized regime has affected India's energy consumption pattern and Green House Gas (GHG) emissions.

This paper makes an attempt to study the effects of trade policy on energy consumption pattern, environmental emission and different economic factors. In particular, we have studied the impact of trade liberalization, foreign capital inflows and greater use of energy saving technologies on different macro economic factors, energy consumption and domestic physical environment by formulating country specific Environmental Computable General Equilibrium Model (Conrad, 2005). To measure 'Pollution Haven' effect, Pollution Terms of Trade (PTOT) as proposed by Antweiler (1996) has been considered and trade policy effects have also been studied using PTOT.

For the study, we have applied Computable General Equilibrium (CGE) modeling approach as it seems to be the most appropriate methodology for policy simulations. For calibration of our model we have used Social Accounting Matrix (SAM) of India for the year 2003-04 constructed by Shaluja & Yadav (2006) and aggregated it into Energy/Environmental SAM as per our requirement.

CGE modeling owes its origins to the works of Adelman & Robinson (1978), Shoven & Whaley (1984), Dixon et al. (1982) and others. They have studied impacts of socially relevant policy changes over different macroeconomic aspects in an open economy applying general equilibrium framework. Among them, Shoven & Whaley (1984) examined trade and tax policies for the Canadian economy while Dixon et al. (1982) studied trade policies for the Australian economy using empirical General Equilibrium models. In Indian context, CGE models are constructed by Parikh et al. (1997), Panda and Quizon (2001) and many others. However, none of the studies include environmental externality exclusively in Indian context using CGE models.

Social Accounting Matrix

CGE models are traditionally based on Social Accounting Matrix (SAM). SAM matrix is a representation of all transactions and transfers that take place between different production activities, various factors of production and different institutions like households, corporate and government within the country and with respect to rest of the world in a particular financial year. SAM, therefore, defines a comprehensive framework that can depict full circular flow of income from production activities to factor service providers like households. Each row of a SAM represents total receipts of any account and column represents expenditure of that account. Therefore row total is supposed to be equal to corresponding column total. An entry in the ith row and jth column represents receipts of ith account from the jth account.[1]

A SAM is database extension of input/output matrix (I/O). Use of I/O matrix is widely accepted with the pioneering work of Wassily Leontief (1986). I/O matrix however does not represent inter-relationship between factor's value added and agent's final expenditure. With the extension of an I/O table as well as the introduction of agent's behaviour and institutional characteristics, from where one can get essential features of a SAM. This can depict entire circular flow of income more effectively. Our environmental CGE model is based on schematic structure of SAM and for calibration of the model we have constructed Energy/Environmental SAM for India for the year 2003-04 based on Saluja and Yadav, 2006 (op cit)[2] Table 1 portrays structure of SAM.

Table 1: Schematic Structure of SAM

		Activities	**Commodities**	**Factors**	**Households**	**PVT Corp.**	**Pub.Ent**	**Govt.**	**Ind. taxes**	**Capital A/C**	**ROW**	**Total**
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
1	**Activities**		Gross output									Output
2	**Commodities**	Purchase of raw Material			Household consumption			Govt. consumption		Gross Fixed Capital Formation	Exports	Aggregate demand
3	**Factors**	Value added									Net factor income	Factor Income
4	**Household**			Endowment Of HH				Govt. transfer,			Net current transfer	Total Household income
5	**PVT corp.**			Operating Profits				Interest on debt				Income of Private Corporate
6	**Pub. Ent.**			Operating Surplus								Income of Public departmental
7	**Govt.**			Income from entrepr.	Income tax by Households	Corporate Taxes			Total indirect taxes		Net capital transfer	Total govt. earnings
8	**Ind. tax**	Taxes on intermediate			Taxes on Purchases			Taxes on purchases		Taxes on investment	Tax on exports	Total Indirect taxes
9	**Capital A/C**			Depreciation	Household Savings	Corporate savings	Public sector savings	Govt. savings			Foreign savings	Gross savings of economy
10	**ROW**		Imports									Foreign exchange payments
	Total	Total cost of production	Aggregate supply	Total factor endowments	Total use of HH income	PVT CORP income	Income of PSU	Aggregate govt. exp.	Total ind. tax	Aggregate investment	Foreign Ex. Recpt.	

Source: Shaluja & Yadav (2006)

Structure of Energy/Environmental CGE

Sectors and Agents

Following SAM of India, as produced by Saluja & Yadav (2006) and Ojha et al. (2009), for the year 2003-04, we grouped all sectors of the economy into seven aggregated sector i.e. 1) Primary sector consists of all agricultural products, minerals and other primary products such as iron ores, crude petroleum and agro process activities, 2) Secondary sector consists of mainly the manufacturing sector like cotton & textile, plastic, rubber and leather products, cement, different chemical products etc., 3) Tertiary sector consists of infrastructural services and other service sectors like education, health care services, public administration, bank and insurance, postal services, etc., and four separate energy sectors, viz. 4) Electricity 5) Coal 6) Natural Gas and Petroleum products and 7) Bio-mass.[3] We considered four types of agents in the economy i.e., a) Households b) Firms c) Government and d) Rest of the World (ROW). There are four types of households i.e. i) RHH-1 (Rural agricultural and other labour) ii) RHH-2 (Agricultural self employed and other households) iii) UHH-1 (Urban salaried class) and iv) UHH-2 (Urban casual labour and others). All other countries and regions are clubbed together into ROW.

Production and Factor Inputs

We have considered two basic factors of production i.e. labour and capital that take part in the production process within which substitution is possible through Cobb-Douglas production technology. Each production unit requires intermediate inputs following fixed coefficient type Leontief technology. Apart from intermediate inputs and basic factors, production sectors require energy inputs as fuel. We assumed four types of energy inputs a) Coal b) Natural Gas & Oil c) Electricity and d) Biomass.

Prices

Product prices are determined from the equality of price and average cost. Average cost comprises basic factor cost, cost of intermediate inputs that includes cost of energy inputs. Increasing returns to scale (IRS) is assumed through the presence of fixed cost in the production units.

Household Income and Expenditure

Households render factor services in terms of labour and capital and in return they receive factor payments in the form of wages and rentals. We have considered four types of households, two of them are rural type and other two are urban type. Households spend their income for consumption purpose. In this study, we have assumed linear expenditure system (LES) type demand function for households.

Government Income and Expenditure

Source of income for the Government are - a) Direct, indirect and corporate taxes b) Import (tariff)[4] and c) Income from entrepreneurial activities. We assumed that government's expenditure in any sector is exogenously determined i.e. determined in the government's budget and adjusted to benchmark SAM. The difference between government's income and expenditure is considered as government's savings.[5]

Investment and Savings

We considered Neo-classical type closure rule where investment is guided by savings. Total savings comprises i) Household savings ii) Government savings iii) Corporate savings and iv) Foreign savings. Total savings are converted into total investment.

Armington Function and Trade

International trade in our model is guided by Armington (1969) function. Total availability of composite commodity in the domestic economy is composed of domestically produced commodity demanded by the domestic people and foreign commodity. Both types are combined together in a Constant Elasticity of Substitution function.

Production of Output and Transformation

Total supply of domestic goods are produced by factors of production like labour, capital and intermediate inputs to meet the domestic demand for goods and services and exports. Both exports and domestic demand of the produced goods and services is combined together in a Constant Elasticity of Substitution (CES) type transformation function.

Factor Prices and Equilibrium

We have considered two basic factors of production i.e. labour and capital. Total supply of basic factors is fixed in value terms and factor prices are flexible. Physical quantity of labour or capital may change in different simulation experiments following the dynamic demand and supply equilibrium mechanism in the factor markets. The Demand for factors originates from the production of goods and services.

Equilibrium in Commodity Market

In the commodity market, total supply of the composite commodity is constituted by domestic as well as imported ones. Demand for the composite commodity is generated from households' consumption, government consumption expenditure, total investment demand and demand for intermediate inputs. Composite commodity price is determined by the demand and supply of composite commodity.

GDP and Welfare

GDP has been computed by adding all sectoral outputs. Social welfare is linked with private household consumption.

Evaluation of Green House Gases

Green house gases are generated due to the consumption of fossil fuels during the production of output of the different industries. Like Mukhopadhyay and Chakraborti (2005) we have calculated emission as follows:

$$F_{GHG} = C * L1 * Z \qquad (1)$$

F_{GHG} is a scalar representing total quantity of emission from fossil fuel combustion. We have considered three types of GHG emission a) CO_2, b) SO_2 and c) NO_x. C is a vector of dimension (1xm), representing emission coefficients for a particular type of GHG from m[6] different types of primary fuels. L1 represents a matrix (mxn) of energy consumption coefficients for different sectors. Z is a vector of dimension (nx1) representing output of n different sectors.

Different emission coefficients corresponding to various fossil fuels are computed following IPCC (Inter Governmental Panel on Climate Change) guidelines.

Carbon/Sulfur/Nitrogen-di-oxide emission coefficient. = (Carbon./Sulfur/Nitrogen content in the fuel)(% of fuel oxidized)*(Specific gravity)*(Molecular weight ratio)*

Energy/Environmental Welfare Function

To account for benefits of improved environmental quality, we have assumed that each consumer has a CES utility function defined over the standard utility aggregate and environmental quality, which is inversely related to the amount of environmental damage done by the emissions. The welfare function is given below:

$$\tilde{W} = F(W, Q) \quad (2)$$

Exact functional form can be assumed as follows:

$$\tilde{W} = \left[W^{-\sigma} + Q^{-\sigma}\right]^{-\frac{1}{\sigma}} \quad (3)$$

Here F has a CES functional form, W is the measure of welfare obtained from benchmark CGE model as well as imperfectly competitive CGE model. Q is the environmental quality which can be defined by the following relation.

$$Q = \overline{Q} - D \quad (4)$$

$$D = s.Emis \quad (5)$$

Where $\overline{Q}$ refers to the 'endowment' of environmental quality and D is the damage from emissions. 's' stands for social marginal value of damage and its value is assumed to be Rs 0.50 per Kg. of CO2 emissions. Rupee value of damage is computed from the total value of emissions generated through the production process. We assumed that marginal value of damage from emissions is constant and the share of initial (benchmark) damages to the endowment of environmental quality $(D/\overline{Q})$ is 0.25.

Modeling 'Pollution Haven' in CGE

To make an exact link between trade and environment we modeled 'Pollution Haven' by computing PTOT proposed by Antweiler (1996). PTOT is computed considering the ratio of pollution content of export and pollution content of import. Pollution content of export and import can be given by:

$$F_{GHG\ (EXPORT)} = C * L1 * (I - A_d)^{-1} * E \quad (6)$$

$$F_{GHG\ (IMPORT)} = C * L1 * (I - A_d)^{-1} * M \quad (7)$$

Here E and M are (nx1) vectors representing export and import of the domestic economy in different sectors. Here Ad is the matrix of domestic input/output coefficient. Hence, (I-Ad)-1 is the Leontief (1986) domestic inverse matrix. Here, we assume identical technology as of domestic production[7] for the import from ROW. Here $C * L1 * (I - A_d)^{-1}$ represents both direct and indirect requirements of pollution intensities within export and import. PTOT for India with rest of the world can be given by:

$$\text{PTOT} = F_{GHG\ (EXPORT)} / F_{GHG\ (IMPORT)} = C * L1 * (I - A_d)^{-1} * E/C * L1 * (I - A_d)^{-1} * M \quad (8)$$

A country gains environmentally from trade in relative terms whenever pollution content of its imported goods is higher than that of its exported goods. Whenever, PTOT value is greater than unity, it indicates country's export contains higher pollution than the pollution received through imports. PTOT is thus an indicator of 'Pollution Haven' effect.

Database and Calibration of Model Parameter

After specifying Energy/Environmental CGE model, model parameters are estimated from benchmark data-set. We have used Energy/Environmental SAM (ESAM) constructed by segregating separate energy sectors. In, our ESAM we have seven sectors. Three of them are conventional production sectors i.e 1) Primary sector 2) Secondary manufacturing sector 3) Tertiary sector and four of them are energy sectors, (except energy sectors namely) 4) Electricity 5) Coal 6) Petroleum & Natural Gas and 7) Biomass. viz leaving aside electricity, others are primary energy sectors and emit GHG on their burning. Fixed cost is assumed to be 10% of the total capital expenditure in any sector.

Table 2: Energy/Environmental SAM of India
C1= Primary sector, C2=Secondary sector, C3= Tertiary sector

Sectors	C1	C2	C3	ELECTRO	COAL	PET&GAS	BIOM	Labour	Capital
C1	7795512	19675421	2885178	4005	0	10979292	249035	0	0
C2	4795324	61137368	18376979	1011829	428356	20934259	116553	0	0
C3	3536190	34679621	26072452	3089016	256640	1378108	326254	0	0
ELECTRO	90576	4847750	3131644	3839476	136246	280372	5054	0	0
COAL	15781	2267665	23700	1475563	9303	138241	597	0	
PET&GAS	1033114	3988647	1063671	1627990	28677	684705	89	0	0
BIOM	198236	772220	0	2444	0	0	10713	0	0
Labour	34310321	31448912	63431332	1843554	830950	483287	1614337		

Capital	29878150	23724045	64478954	3366140	1787368	1600541	1289532		
RHH1	0	0	0		0	0	0	38556099	8909593
RHH2	0	0	0		0	0	0	22966890	45955245
UHH1	0	0	0		0	0	0	61509848	16734549
UHH2	0	0	0		0	0	0	8661430	5406382
Private corp		0	0			0			9557281
Public Enter		0	0			0	0		4626200
Government		0	0			0	0		3618000
Indirect taxes	-1306585	10857811	4659939	-1386185	37219	3647083	0		
Capital A/C	0	0	0	0		0	0		25363700
Rest of the world	12756258	28730550	7539989	0	500866	10720057	0		
Total	93480335	102795429	206164314	16499378	4005030	31456268	3612165	130721519	120352089

Table 3: Energy/Environmental SAM of India (Continued) (Values are in Rs. Lakhs)

Sectors	**RHH1**	**RHH2**	**UHH1**	**UHH2**	**PVT. Corp.**	**Pub. Enterprises**	**Government**	**Indirect. Tax**	**Capital a/c**	**Rest of the world**	**Total**
C1	9716069	14488790	10682460	2205372	0	0	241670	0	1803896	2978019	93480335
C2	12641795	15316343	13271477	585204	0	0	5157523	0	55622644	25376947	231376699
C3	17378870	24213911	32248310	6460400	0	0	26708609	0	3954168	15429297	206164314
ELECTRO	425448	448819	407674	124153	0	0	139012	0	0	0	14681270
COAL	18095	4684	17339	5281	0	0	5126	0	6740	15711	4005030
PET&GAS	**658583**	**368069**	**1487164**	**234711**	**0**	**0**	**287896**	**0**	**-1483021**	**1406098**	**20442082**
BIOM	1164329	944802	418176	101247	0	0	0	0	0	0	3612165
Labour	0	0	0	0						-312600	130721521
Capital	0	0	0	0						-1095200	120352089
RHH1	0	0	0	0	0	0	5207567	0	0	993035	53666294
RHH2	0	0	0	0	0	0	9824402	0	0	2157927	80904465
UHH 1	0	0	0	0	0	0	9113270		0	6175802	93533470
UHH2	0	0	0	0	0	0	1190924	0	0	2562618	17821354
Private Corp									1216819		10774100
Pub Enterpr.											4626200
Government	224068	3506373	1500237	2906519	6099400			24616465		-248200	40437165
Indirect taxes	1517569	2035126	13333662	440247			685090		5094808	-157127	24616465
Capital a/c	10308227	20323643	21205637	2945766	4674700	4626200	-16661127			-3426241	67692335
ROW	0	0	0	0							49026796
Total	53666294	80904465	93533470	17821354	10774100	4626200	40437165	24616465	67692335	49026796	

Simulation Experiments

We performed different simulation experiments to find the impact of international trade and globalization on domestic energy consumption, GHG emission and social welfare under, both perfect and imperfect competition. Three different types of trade liberalization policies have been experimented to find general macroeconomic impact and to test whether there is any evidence of 'Pollution Haven' and 'Dirty Industry Migration' in the context of Indian economy. Simulation experiments results have been described below:

Experiment -1&2: Gradual Trade Liberalization by 50% and 100% Tariff Reduction

We first examined the effect of gradual import liberalization through the reduction of import duty, first by reducing 50% and then by 100%. Immediate impact was the reduction of domestic import prices which led to an increase in domestic import and exchange rate depreciation owing to higher foreign currency demand. Profitable export market with higher domestic price of foreign currency increases export. However, government's income reduces with lower tariff revenue earnings and consequently transfer payment of the government to different types of household also declines. In addition, household's real income is affected by the reduction of composite commodity prices. We find that liberalization of trade benefits all types of domestic household, except the urban salaried class.

Trade liberalization expands domestic market and competition. This leads to an increase in domestic output and it exploits the benefit of increasing returns to scale.[8] Higher output in industrial manufacturing and in service sector increases energy consumption which are used as intermediate inputs in various production units. We find that electricity consumption has increased by 0.587 % and 1.4% respectively, in response to 50% and 100% tariff reduction. Since more than 55% of electricity production depends on coal, its consumption also increases along with liquid petroleum products and natural gas.

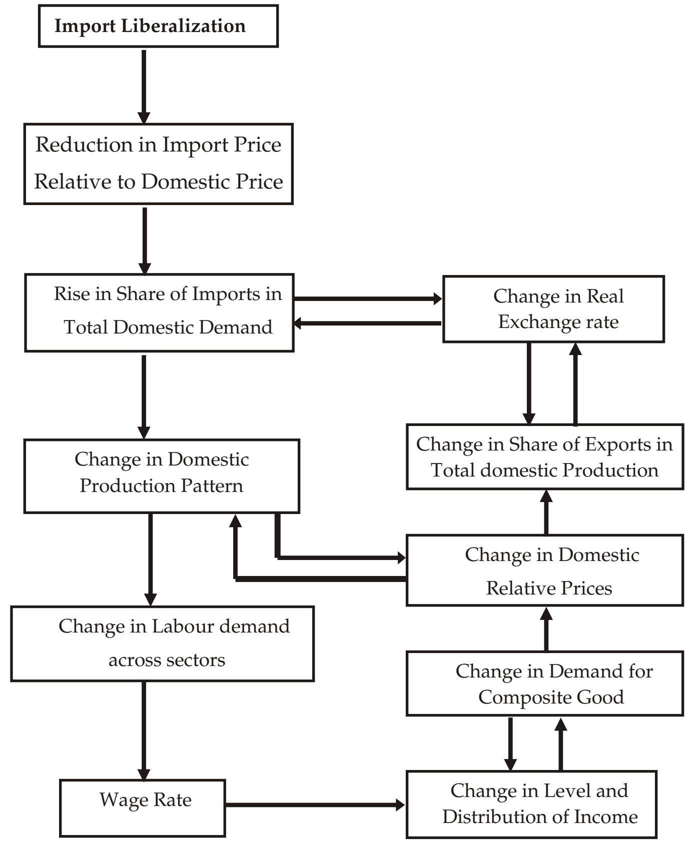

Figure 1: Major Interactions due to import liberalization

Only biomass consumption has been diminished. This is probably due to increased use of cleaner fuels like Kerosene, LPG, coal etc., for cooking purposes among rural households instead of biomass. Hence, all types of energy fuel consumption have increased except biomass consumption. Following table shows trade liberalization effects on energy consumption.

Table 4: Trade Liberalization Effects on Energy Consumption

Name of the Energy Source	Total Domestic Consumption	Tariff Reduction by 50%	Tariff Reduction by 100%	Foreign Capital Inflow	Energy Saving Technology
	Base run value (In Rs. Lakhs)	(% change)	(% change)	(% change)	(% change)
Electricity	1.3344E+7	0.587	1.4	0.080	-10.638
Coal	4.2001E+6	0.755	1.91	0.009	-13.056
Petroleum & Natural Gas	8.0741E+6	0.374	0.94	-0.023	-10.89
Biomass	3.6348E+6	-0.684	-1.649	0.056	-0.792

On environmental front, trade liberalization increases total CO_2 emission owing to higher consumption of energy fuels. Pollution embodied in exports has risen more than pollution embodied in imports leading to PTOT measure becoming greater than unity under benchmark scenario. With trade liberalization, PTOT have increased by 0.694 % and 2.092% in response to 50% and 100% of tariff reduction respectively. This also indicates evidence of 'Dirty Industry Migration' i.e. the Indian economy exports more pollution than it imports from rest of the world. Manifestation of 'Pollution Haven' in India gets stronger with trade liberalization as PTOT takes a value greater than unity and it increases with import liberalization. Simulation study reveals that, Indian exports in 2003-04 were 42% more pollution intensive than its imports and with gradual trade liberalization, pollution intensiveness of both exports and imports has increased over the corresponding base period values. Nevertheless, pollution intensiveness of exports have increased more as compared to imports leaving PTOT to be raised by 0.694 % and 2.092% over its base value on account of gradual tariff reduction by 50% and 100% respectively. On the whole, the Indian economy has been 'Pollution Haven' in 2003-04 and with trade liberalization 'Migration of Dirty Industries'[9] is confirmed through our simulation study.

Table 5: Trade Liberalization Effects on Environmental Emission

Emission	Base Run Value	Tariff Reduction by 50% (% change)	Tariff Reduction by 10% (% change)	Foreign Capital Inflow (% change)	Energy Saving Technology (% change)
Total emission	1346.595 MT	0.65	1.393	0.017	-12.244
Pollution Embodied in Export	117.20895 MT	11.514	26.211	-4.326	-7.79
Pollution Embodied in Import	82.294 MT	10.745	23.626	5.450	-1.874
PTOT	1.42	0.694	2.092	-9.271	-6.034
PTOT*100	142.427	0.694	2.092	-9.271	-6.034
Social Welfare	5.164004E+7	0.056	0.304	0.428	1.020
Environmental Social Welfare	1.721445E+7	-0.025	-0.040	0.378	1.406

In addition, trade liberalization increases overall domestic consumption and aggregate social welfare. Since, environmental damage is caused by increasing air pollution and GHG emissions owing to greater uses of energy fuels, environmental social welfare that takes into account both consumption gains as well as environmental damage has reduced. Thus increasing consumption gains are completely outweighed by environmental damage caused by GHG emission. Table 5 depicts environmental impact of trade liberalization.

Experiment-2: Greater Inflow of Foreign Capital

We simulated higher foreign capital inflows to assess the impact over domestic energy consumption and GHG emissions. We increased foreign capital inflows up to the extent that the net capital account deficit became zero. Greater foreign capital inflow appreciates exchange rates and makes imports cheaper. This results in increase of imports in all sectors. Exchange becomes less profitable and so, sectoral domestic exports fall. Domestic saving is augmented by higher inflow of capital. Sectoral GDP increases in manufacturing sector along with overall expansion of GDP.

Energy consumption for almost all types of fuels increases with the expansion of secondary manufacturing sector, which is intensive in energy usage. On the environmental front, increased imports lead to higher pollution embodied in imports while, lower exports reduce pollution content of exports. PTOT has been reduced by 9.2%.[10] Although, Environmental social welfare increases by a small percentage, it is lower as compared to consumption based welfare. This is because of the environmental damage caused by GHG emissions.

Experiment-3: Greater Use of Energy Saving Technology

Trade liberalization brings forth the transfer of green technologies from the northern countries to the southern countries. Here, we have simulated a 10% increase of energy saving technology (i.e. per unit requirement of energy fuels as intermediate input reduces by 10% due to greater use of green technology). Immediate impact is quite obvious. Hence reduction in energy fuel consumption results in consequent fall of GHG emission. Utilization of electricity, coal, petroleum and natural gas diminishes by more than 10% while, total GHG emission reduces by 12.24%. However, PTOT falls by 6% due to lower exports of energy intensive products. At the Macro level, adoption of energy saving technology reduces 'Pollution Haven', producing an improvement in environmental social welfare owing to lower damage caused by reduced emissions.

Summary and Conclusions

The paper examines the impact of different trade related policy changes on macroeconomic variables and on the domestic physical environment, exhibited more specifically through energy consumption and consequent air pollution. We find that trade liberalization increases trade, GDP, social welfare, private consumption, gross investment and reduces composite commodity prices while, it causes deterioration in the environment through higher GHG emissions. Greater foreign capital inflows result in appreciation of exchange rates which lead to an increase in imports and reduction in exports. GDP, gross investment, welfare and private consumption all show an increase due to the negative effect of emissions. Thus, in general, we find that although liberalized trade policies encourage expansion of economic activities; they also promote the deterioration of domestic physical environment. Use of energy saving technology has helped in reducing GHG emissions.

'Pollution Haven' effect has been evaluated using PTOT which exhibits a value greater than unity for India in a benchmark scenario. This indicates India's exports contains higher pollution than pollution embodied in its imports and thus one could say that India has been a 'Pollution Haven' in the liberalized regime. With trade liberalization, 'Dirty Industry Migration' has been amplified which is confirmed through an increased value of PTOT[11].

Use of energy saving technologies through private-public-partnership (PPP), increase in investment in research and development of such technologies and transfer or purchase of green technology from developed countries are some options to reduce GHG emission in the globalised scenario[12]. Banking sector could play the pivotal role by providing Green Financing to the domestic households[13].

Notes

1. This is pointed out by Dr. K. Parikh committee report on behalf of planning commission in July, 2011.
2. Schematic structure of SAM is presented at the end of the body of this paper.
3. In India I/O table is published by Central Statistical Office (CSO after every five years. Saluja et al (2006) constructed SAM for India using I/O matrix for the year 1999.
4. In India Biomass is responsible for more than 25% supply of primary energy.
5. Net indirect tax mentioned in the SAM has been classified into domestic indirect tax and import tariff.
6. In India government savings in most of the cases are negative that constitutes large part of country's fiscal deficit. Expenditure of the government is usually determined in annual budget.
7. Here m represents primary fuels like a) Coal b) Petroleum and Gas c) Biomass. n represents 7 different sectors of the economy.
8. See Mukhopadhyay and Forssell (2005).
9. Fall of average cost with the increase of domestic production.
10. This is also called Pollution Haven effect.
11. This indicates country is gaining environmentally through foreign capital inflow as its exported pollution has been declining as compared to imported pollution. However PTOT has remained greater than unity.
12. In this regard see the interim report on Low Carbon strategies for inclusive growth by the Planning commission, Government of India in May 2011.
13. Banks like NABARD, SIDBI usually provide loans to the households for using solar lantern, generators, solar pump set etc. These are the prominent examples of green financing and investment in energy saving technologies on PPP basis.

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Appendices

Appendix 1: Mathematical Structure of the Model

Production Block:

$$Y_j = b_j \cdot \left[\prod_h F_{h,j}^{\beta_{j,h}} \right] \quad (1)$$

$$X_{i,j} = ax_{i,j} \cdot Z_j \quad (2)$$

$$Y_j = ay_j \cdot Z_j \quad (3)$$

$$F_{h,j} = \beta_{h,j} \cdot py_j \cdot Y_j / pf_h \quad (4)$$

$$pz_j = ay_j \cdot py_j + \sum_i ax_{i,j} \cdot pq_i + \frac{FC_j}{Z_j} \quad (5)$$

Government Behaviors:

$$GINC = Td + Tdc + TInd + NCAT + ENT + TARR - Ts \quad (6)$$

$$Td = \sum_b taud_b \cdot \left[\sum_h pf_h \cdot FF_h \cdot r_{h,b} + GT_b + NCUT_b \right] \quad (7)$$

$$Tdc = tcorp \cdot (OPR + IND) \quad (8)$$

$$OPR = sop \cdot \left[\sum_h pf_h \cdot FF_h + NF_1 + NF_2 \right] \quad (9)$$

$$TInd = \sum_b tauz_j \cdot pz_j \cdot Z_j \quad (10)$$

$$TARR = \sum_i taum_i \cdot pm_i \cdot M_i \quad (11)$$

$$Ts = taus \cdot \sum_i pe_i \cdot E_i \quad (12)$$

$$Xg_i = mu \times GDP / pq_i \quad (13)$$

$$GT_b = gt_b \cdot GINC \quad (14)$$

$$GEXP = \sum_i Xg_i + \sum_b GT_b + Ts \quad (15)$$

$$S_G = GINC - GEXP \quad (16)$$

Investment Behaviors:

$$Xv_i = lamda_i \cdot \left[Dep + \sum_b Sp_b + Sg + Sc + Sf \cdot epsilon \right] \Big/ pq_i \quad (17)$$

Savings:

$$HHIN_b = \sum_h \left[\sum_h FF_h \cdot pf_h + NF_1 + NF_2 \right] \cdot r_{h,b} + NCUT_b + GT_b \quad (18)$$

$$HHIN_b = \left[\sum_h FF_h \cdot pf_h + NF_1 + NF_2 \right] \cdot r_b + NCUT_b + GT_b \quad (18.a)$$

Where $r_b = \sum_h r_{h,b}$

$$Sp_b = ssp_b \cdot HHIN_b \quad (19)$$

$$Sc = ssc \cdot (OPR + IND) \quad (20)$$

Household Consumption:

$$Xp_{i,b} = alpha_{i,b} \cdot [HHIN_b - Td_b - Sp_b] / pq_i \quad (21)$$

International Trade:

$$pm_i = epsilon * pWm_i * (1 + taum_i) \quad (22)$$

$$pe_i = epsilon * pWe_i * (1 + taus) \quad (23)$$

$$\sum_i pWe_i * E_i + Sf + \sum_b NCUT_b + NF_1 + NF_2 + NCAT + Ts = \sum_i pWm_i * M_i \quad (24)$$

Armington (1969) Function:

$$Q_i = gamma_i \left[deltam_i \cdot M_i^{eta_i} + deltad_i \cdot D_i^{eta_i} \right]^{\frac{1}{eta_i}} \quad (25)$$

$$\frac{M_i}{Q_i} = \left[gamma_i^{eta_i} \cdot deltam_i \cdot \frac{pq_i}{pm_i} \right]^{\frac{1}{1-eta_i}} \quad (26)$$

$$\frac{D_i}{Q_i} = \left[gamma_i^{eta_i} \cdot deltad_i \cdot \frac{pq_i}{pd_i} \right]^{\frac{1}{1-eta_i}} \quad (27)$$

Transformation Function:

$$Z_i = theta_i \cdot \left[xie_i \cdot E_i^{phi_i} + xid_i \cdot D_i^{phi_i} \right]^{\frac{1}{phi_i}} \quad (28)$$

$$\frac{E_i}{Z_i} = \left[theta_i^{phi_i} \cdot xie_i \cdot (1 + tind) \frac{pz_i}{\cdot pe_i} \right]^{\frac{1}{1-phi_i}} \quad (29)$$

$$\frac{D_i}{Z_i} = \left[theta_i^{phi_i} \cdot xid_i \cdot (1 + tind) \cdot \frac{pz_i}{pd_i} \right]^{\frac{1}{1-phi_i}} \quad (30)$$

Market Clearing Condition:

$$Q_i = \sum_b Xp_{i,b} + Xg_i + Xv_i + \sum_j X_{i,j} \quad (31)$$

$$FF_h = \sum_j F_{h,j} \quad (32)$$

Fictitious Objective Function:

$$UU = \sum_b \prod_i Xp_{i,b}^{\alpha_{i,b}} \quad (33)$$

Appendix-1.A: List of Endogenous Variables

Y_j	= Combined input used in j^{th} activity.
$F_{h,j}$	= Demand for basic input h in j^{th} activity.
Z_j	= Output of j^{th} activity.
PY_j	= Price of combined input in j^{th} activity.
PF_h	= Price of basic input h.
PQ_i	= Price of the i^{th} commodity.
$GINC$	= Total Government income.
TD	= Household income tax.
TDc	= Corporate tax.
$TInd$	= Indirect tax.
Pf_h	= Factor price of the h^{th} factor.
FF_h	= Factor demand of the h^{th} factor.
GT_b	= Government transfer to the b^{th} household.
gt_b	= Government income share transferred to b^{th} household.
$Xp_{i,b}$	= b^{th} household consumption of the i^{th} good.
Xg_i	= Government consumption of the i^{th} good.
$X_{i,j}$	= i^{th} sector's output goes to j^{th} sector as intermediate input.
Xv_i	= i^{th} commodity used as investment good.
PQ_i	= Price of the i^{th} commodity.
pe_i	= Price of export.
Sg	= Government savings.
Sp_b	= Private savings of the b^{th} household.
Sg	= Government savings.

Sc = Corporate savings.
epsilon = Exchange rate.
$HHIN_b$ = Income of the b[th] household.
pe_i = Export price of good i.in domestic currency.
pm_i = Imports price of good i in domestic currency.
pd_i = Price of domestic good.
pz_i = Supply price of the i[th] good.
pWe_i = World export price.
pWm_i = World import price.
E_i = Export of good i.
M_i = Import of good i.
epsilon = Exchange rate.
Q_i = Output composite good.
D_i = Output domestic good.
UU = Social welfare function.

Appendix 1.B: List of Exogenous Variables

b_j = Production function shift parameter.
$\beta_{h,j}$ = Share of h[th] input within combined input in j[th] activity.
$ax_{i,j}$ = Per unit requirement of i[th] commodity in j[th] activity as intermediate input.
ay_j = Per unit requirement of combined input in j[th] activity.
$r_{h,b}$ = h[th] factor income share of b[th] household.
ENT = Income of the government from entrepreneurial activity.
$taud_b$ = Share of total household income paid as income tax by b[th] household.
mu_i = Share of government expenditure on i[th] commodity.
NCAT = Net transfer to government.
Sf = Foreign savings at world prices.
$lamda_i$ = Proportion of savings converted into investment.
Dep = Depreciation of capital.
FF_h = Total factor demand of the h[th] factor.
$gamma_i$ = Scale parameter in Armington function.
$deltad_i$ = Share coefficient of domestic good in Armington function.
$deltam_i$ = Share coefficient of import good in function.
eta_i = Constant determining elasticity of substitution in Armington function.
$theta_i$ = Scale parameter transformation function.
xie_i = Share parameter of export in Transformation function.
xid_i = Share parameter of domestic good in transformation function.
phi_i = Constant determining elasticity of substitution in Transformation function.
tind = Indirect tax rate.
$taum_i$ = Import tariff rate.
taus = Export subsidy rate.
$NCUT_b$ = Net current transfer to b[th] household.
tcorp = Share of corporate income to tax.
OPR = Operating profit.
IND = Interest on debt.
sop = Share of operating profit to total factor income.
NF_1 = Net labor income earned abroad.
NF_2 = Net capital income earned abroad.
Tpurhh = b[th] household purchase tax.
Tpurg = Government purchase tax.
Ting = Taxes on intermediate.
Tinv = Taxes on investment good.
Ts = Taxes on export.
$tpurhh_b$ = Share of household purchase paid as purchase tax by b[th] household.
tpurg = Share of government purchase paid as purchase tax.
ting = Share of intermediate good purchase to tax.
tinv = Share of investment to tax.
taus = Share of export paid as tax.
FC_j = Fixed cost in the j[th] sector.

Appendix 2: Simulation Experiment Results

Table 6: Simulation Experiment Results

ECONOMIC VARIABLES	BASE RUN	EXP-1	EXP-2	EXP-3	EXP-4
Macro Indicators	(In Rs. lakhs)	(in %form)	(in %form)	(in %form)	(in %form)
GDP	4.75E+08	0.238	0.612	-0.017	-0.592
Gross Investment	67692335	1.26	2.48	6.8	18.24
Private consumption	462304387	0.179	0.143	0.92	-0.286
External accounts					
Export	45206080	10.8	24.34	-4.32	7
Import	4.97E+07	12.46	28.08	5.28	8.031
Exchange Rate	1	2.97	6.22	-1.811	-9.51
Govt. Account					
Govt. Income	23776038	-15.02	-36.08	1.187	-1.316
Govt. Expenditure	40437165	-6.49	-15.41	0.459	-9.64
Govt. Savings	-16661127	-0.65	-1.3	-0.04	-15.346

Household Consumption					
RHH1	40413419	0.432	0.739	0.142	12.064
RHH2	5.44E+07	0.063	-0.152	0.162	12.52
UHH1	3.58E+08	0.114	.005	1.869	-15.841
UHH2	9490968	0.332	0.569	0.064	16.045
Sectoral output					
Primary Sectors	7.846715 E+7	-1.964	-4.511	-0.552	-3.478
Industrial Manufacturing	1.914785 E+8	0.953	2.467	-0.035	1.769
Tertiary sector	9.858651 E+7	0.477	0.997	0.242	1.68
Electricity	8.471178 E+7	0.587	1.41	0.080	-10.638
Coal	3298805.2	-0.687	0.995	-0.513	-14.614
Gas & Oil	1272807.1	0.345	-1.244	-0.358	-13.64
Biomass	1.674169 E+7	-0.684	-1.64	0.056	-0.792
Composite Prices					
Primary Sectors	1	-1.617	-3.64	-0.177	-2.61
Industrial Manufacturing	1	-2.475	-5.4	-0.131	-6.93
Tertiary sector	1	-1.053	-2.3	0.085	-17.648
Electricity	1	-1.3	2.85	-0.072	-10.196
Coal	1	-1.45	-2.49	-0.21	-3.792
Gas &Oil	1	-2.255	-4.96	-0.16	6.739
Biomass	1	-0.307	-0.684	-0.009	-2.258
Sectoral Export					
Primary Sectors	2978019	6.79	14.14	-4.92	-21.12
Industrial Manufacturing	25376947	12.44	28.69	-4.345	-5.412
Tertiary sector	10605075	9.54	20.92	-4.21	26.58
Electricity	4824222	0	0	0	0
Coal	15711	8.314	18.34	-4.91	-42.305
Gas & Oil	7551	13.32	30.87	-4.5	-42.3
Biomass	1398547	0	0	0	0
Sectoral Import					
Primary Sectors	12756258	21.53	51.8	4.32	19.514
Industrial Manufacturing	28730550	9.44	20.279	5.568	11.374
Tertiary services	3326565	12.58	27.94	5.77	-22.25
Electricity	413424	0	0	4.56	-12.32
Coal	500866	13	29.77	4.13	-0.421
Gas & Oil	8608702	9.53	20.56	4.32	31.751
Biomass	2111355	0	0	0	0