Carbon Footprints and Household Consumption Pattern in India: A SAM Based Analysis

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Abstract

In this study it is shown how the latest available Social Accounting Matrix of India (SAM) can be used to enumerate the direct and indirect carbon emissions required to satisfy a given consumption demand by the household sector. The 78 productive sector SAM is modified to 16 broad sectors on the basis of end use by the household sector and relative homogeneity along the technological lines. The emphasis has also been given to the manufacturing sector keeping in context with India's changed political ideology. In this study we derive the fixed price multipliers on the basis of the assumption of excess capacity which keeps the prices constant and compare them with the simple multiplier. The energy intensity of the productive sectors is compared through the composite energy intensity index. In the carbon footprint analysis of the household sector, the study finds that on increasing the endogeneity of the model, the sectors release higher emissions per unit of output demanded with the manufacturing sectors being the most carbon intensive. Also, in fixed price multiplier analysis, agriculture, construction and services sector climb up the ranking indicating the increasing importance of these sectors in the Indian household consumption basket.

Key Words: Carbon Emissions, Household Sector, Consumption, Social Accounting Matrix

1. Introduction

The discussions at the Paris Climate Summit to limit the temperature rise to 1.5^{o}C above pre industrial level makes it imperative for countries dependent on oil, coal and gas to find alternative sources of energy. At present, India shares lesser obligations for such a high target; however, it is not quite far when some stern measures would have to be taken by the political leadership. India, being one of the fastest growing developing economies, has recently opened its door to foreign investment in technology and infrastructure. Such measures necessitate actions to curtail the influx of carbon emissions. With growing need and demands of the household sector, there is ought to be increased energy consumption through services like transport, electricity, construction, agriculture and allied activities, durables amongst others. This aggravates the capacity of the carbon sink through increased carbon footprints. The situation has not been accounted for adequately in India's 12th Five Year Plan (2012-17).

Many country-wise empirical studies have been conducted inorder to estimate the amount of carbon emissions released due to some exogenous shocks in the demand structure. The Leontief Input Output Transactions table is the most frequently applied methodology. In studies by Mongelli et. al (2006) for Italy and Sanchez-Choliz and Duarte (2005) for Spain, Single Region Input-Output table (SRIO) was used to find out the countries carbon emissions. He and Fu (2014) took sixteen manufacturing sector and single country linked input output model to calculate the carbon emissions in trade for China. In India, a study by Sharma et al. estimated the carbon emissions for a few broad sectors for the year 1990, 1994 and 2000. Though input output tables is the commonly applied methodology, however, they fail to account for the indirect effects of the change in technology or elements of the production function on the household income distribution and factor demands. Social Accounting Matrix encompasses the input output tables along with factor demands and income distribution. They provide a complete representation of the economy in terms of the production sectors, households, private enterprises, governments, rest of the world, exports and imports, capital account, taxes, transfers and savings. In other words, SAM is a simplified general equilibrium model for a given time period. Using Social Accounting Matrix, Khan and Thorbecke (1988) carried a SAM analysis for the Indonesian energy sector. It looked at the energy content of the technologies within the SAM framework. In a study by Wiepke Wissema (2006) for Ireland, the country SAM for 1998 was disaggregated to include seven energy sectors. It was then aligned with the emissions data. Manresa and Sancho (2004) undertook a study for the Catalonian economy and estimated sectoral energy intensities and carbon emissions using SAM multiplier analysis. Using India's SAM of 2004, Parikh J et.al (2009) detailed the carbon emissions by sectors for the Indian economy. It carried a 25 sector level analysis along with the 10 household classes to find the emissions in India by various sectors and demand groups.

With limited number of empirical studies undertaken for India in this domain, this particular research paper tries to overcome the research gap and directs attention to pertinent policy questions. In this study it is shown how the latest available Social Accounting Matrix of India (SAM) for the year 2007-08 can be used to enumerate the direct and indirect carbon emissions required to satisfy a given consumption demand by the household sector which has been distinguished on the basis of urban and rural India. The 78 sector SAM has been aggregated to 16 broad sectors giving special attention to India's manufacturing sector.

The following paper describes the Social Accounting Matrix Framework in Section 2. Section 3 details the methodology applied in the paper. Section 4 discusses the results and analysis. Section 5 gives the conclusion of the paper and policy implications.

2. Social Accounting Matrix Framework

The Social Accounting Matrix provides a conceptual and data intense framework within which the technology structure of the entire economy can be incorporated in a simple network of rows and columns. It provides a strong base to explore major macroeconomic effects of policy changes on the production function of an economy. As a general equilibrium framework, it incorporates the input output matrix along with the interrelation of the production structure with the factorial income distribution and the income distribution between various socio-economic classes. It goes a step ahead of the IO model to incorporate institutions like households and corporate, capital account, net indirect taxes, savings and factors of production apart from government and rest of the world.

SAM is a square matrix with the columns representing the expenditure outlays and the rows representing the receipts under each sub head of the variables under study. For any given account or variable of study, the sum of the expenditure outlays, given by the column, is equal to the sum of the receipts, given by the rows.

India's most recent 2007-08 SAM as prepared by Pradhan et. al (2013) includes 78 production sectors and 9 household classes which are distinguished on the basis of urban and rural boundaries and occupation. There are three factors of production namely labour, capital and land where labour has been disaggregated into skilled, semi-skilled and unskilled labour. The values stated in the SAM are given in lakh rupees.

For this paper, the 78 production sectors have been aggregated to 16 broad sectors on the basis of end use of the product by the household sector and relative homogeneity along the technological lines. Emphasis has been given to keep the manufacturing sectors more disaggregated than agriculture and services sector to understand the flow of carbon footprints from and to the manufacturing sector which has received the Indian governments focus in the recent past. The energy sectors are kept disaggregated to focus on the carbon footprints as released by a unit consumption of the product which intakes such energy intensive inputs. In this study coal, natural gas and petroleum have been considered as the energy sectors.

Inorder to estimate the carbon emissions, instead of taking direct sector-wise emission coefficients, the study takes emission coefficient by fuels. The fuel coefficients for India have been taken from Parikh et.al (2009). It is assumed that the fuel coefficients listed for 2003-04 in Parikh et.al study have remained the same till 2007-08 which is the year of study in this paper.

3. Methodology

In the modified 36 X 36 SAM undertaken for study in this paper there are three endogenous accounts: 1) sixteen production sectors; 2) labour and non labour (capital and land) components; and 3) household sector as represented by nine household classes. The private corporation, public enterprises, government, indirect taxes, capital account and rest of the world are taken as exogenous.

An important assumption maintained in this study is that there is excess capacity in the Indian economy. This allows the prices to remain constant when there is an external shock in terms of increase in demand for the output. This assumption does not invalidate the results of the study as the Indian economy does have excess capacity in terms of increasing the efficiency of the factors of production and better utilization of resources at hand. Using the SAM multiplier analysis, the assumption gives us the fixed price multiplier which helps in the estimation of the effect of an exogenous shock in the general equilibrium model. The methodology followed in this paper has been adapted from Pyatt and Round (1979), Manresa and Sancho (2004) and Pradhan et.al (2006).

Linearity in the transaction accounts of SAM has been assumed like in the IO model. In an N X N sector economy, where N equals 36 in this study, we assume that the economy satisfies the budget constraint. This implies the total receipts equal the total outlays.

This implies, if each component in the transactions account matrix is taken as Xij where the outflows are from account i to account j then,

$Xj = \Sigma^{n}_{i=1} Xij$ where $j= 1,.., n$ (1)

$Xi = \Sigma^{n}_{j=1} Xij$ where $i= 1,.., n$ (2)

where eq. (1) represents the total receipts by account j over each of account i and eq. (2) represents the total expenditure by account i over each of account j. By the budget constraint, Xj= Xi.

Because of the assumption of linearity, the Average Expenditure Coefficient (aij) can be written as,

$aij = Xij / Xj$ for all i and j. (3)

Here aij represents the amount paid to account i per unit of income spent by account j.

On dividing eq. (2) by Xj on both the sides,

$Xi = (\Sigma^{n}_{j=1} Xij / Xj) (Xj)$ (4)

Substituting eq. (4),

$Xi = \Sigma^{m}_{j=1} aij Xj + \Sigma^{m+k}_{j=m+1} aij Xj$ (5)

where n=m+k. Here m represents the endogenous accounts and k represents the exogenous accounts. This partitions the SAM into four sub matrices.

I. Matrix of transactions between endogenous accounts:
   Zmm = (aij); i =1,.., m ;j =1,.., m

II. Matrix of leakages from endogenous accounts to exogenous accounts:
   Zmk = (aij); i =1,.., m ; j = m+1,.., m+k

III. Matrix of injections from exogenous accounts to endogenous accounts:
   Zkm = (aij) = X; i = m+1,.., m+k; j = 1,.., m

IV. Matrix of transactions between exogenous accounts:
   Zkk = (aij); i = m+1,.., m+k; j =m+1,.., m+k

Using the total income for the endogenous and exogenous accounts, Xm and Xk respectively, and eq. (5), we get,

$Xm = Zmm * Xm + Zmk * Xk$ (6)

$$Xm - Zmm * Xm = Zmk * Xk \quad (7)$$

$$Xm (I - Zmm) = Zmk * Xk \quad (8)$$

$$Xm = (I-Zmm)^{-1} * Zmk * Xk \quad (9)$$

$$Xm = (I-Zmm)^{-1} * W \quad (10)$$

The matrix $(I\text{-}Zmm)^{-1}$ is the matrix of SAM fixed price multiplier or the extended multiplier as against the simple Leontief multiplier of the IO model. W represents the vector of exogenous flows in the model. Leontief inverse is a special case of the extended SAM multiplier in which the number of endogenous accounts equals the productive sectors and W equals the final demand vector. In SAM multiplier analysis, we increase the endogeneity of the model by including more inter and intra account transactions. This increase in endogeneity gives larger multiplier values as against the simple multiplier.

With fixed prices and endogenous income for some accounts and constant income for others, the incremental income distribution will differ across accounts according to the income elasticities. Therefore, marginal propensities should be replaced with average propensities or average expenditure coefficient. However, we assume that income elasticities are unity in the SAM and hence average and marginal propensities are equal (Pyatt and Round 1979, Pradhan et. al 2006). We also assume that there is only one type of labour in SAM and they provide the same type of service. An incremental demand affects all the households within that type of labour equally (Graham Pyatt, 1988).

The carbon footprints, which is the amount of direct and indirect carbon emissions required to satisfy a given consumption demand by the household sector, is calculated by multiplying the sub matrix of fuel taken from the SAM fixed multiplier and the carbon emission by fuel. As stated there are three fuels considered in this study. The carbon emission coefficient by fuel is given in Appendix A.1. It is taken from Parikh et. al (2009). It is assumed that the fuel coefficients taken from Parikh et. al (2009) for the year 2003-04 have remained constant till 2007-08.

4. Results and Analysis

The inclusion of only the sixteen productive sectors as the endogenous variables in the SAM matrix, like in the IO model, gives the petroleum sector - crude petroleum and petroleum products - as the most energy intensive output. This is followed by metals, coal, natural gas, construction sector and the services sector. Within the services sector, trade and transport, are the most energy intensive accounts. The composite energy intensity index, in Table 1 below, is the aggregate of all the entries in each row. It gives the net energy intensity associated with per unit of output produced. The net composite energy intensity associated with the petroleum sector is 2.23 units. For metals and coal, the composite energy intensity is 1.18 units and 1.07 units. Table 1 details the composite energy intensity for sixteen endogenous accounts in case of the simple multiplier.

Table 1: Composite Energy Intensity in case of Simple Multiplier

Sectors	Coal	Natural Gas	Petroleum	Composite Energy Intensity Index
Petroleum	0.017422	0.547777	1.667885	2.233084
Metals	0.718228	0.395644	0.068749	1.182621
Coal	1.037646	0.019529	0.014428	1.071603

Natural Gas	0.000778	1.001182	0.000622	1.002582
Construction	0.461602	0.229906	0.108443	0.799951
Services	0.137891	0.240757	0.408438	0.787086
Machinery	0.256432	0.17381	0.056322	0.486564
Chemicals	0.057041	0.284537	0.089453	0.431031
Electricity	0.200872	0.151148	0.04124	0.393259
Agriculture	0.062014	0.103731	0.095345	0.261091
Textiles	0.037755	0.076402	0.037635	0.151792
Durables	0.047814	0.065027	0.033022	0.145863
Cement	0.058308	0.066001	0.012583	0.136892
Non Metals	0.034441	0.030609	0.022341	0.087392
Other Manufacturing	0.028969	0.022229	0.01349	0.064688
Mining	0.002187	0.002803	0.003003	0.007993

Source: Author's estimates

On increasing the endogeneity of the model by including the skilled, semi-skilled and unskilled labour; capital and land; and nine household classes segregated on the basis of rural and urban, higher multiplier values are noted. According to the composite energy intensity index, in case of such an extended multiplier analysis or the fixed multiplier, petroleum sector leads with 2.29 units, followed by services (1.79 units), metals (1.29 units), construction (1.10 units) and coal (1.09 units). Within services the transport and trade sector are the most energy intensive. Table 2 below details the composite energy intensity index for the productive accounts in case of fixed price multipliers.

Table 2: Composite Energy intensity in case of Fixed Price Multipliers

Sectors	Coal	Natural Gas	Petroleum	Composite energy intensity
Petroleum	0.027681	0.56664	1.694822	2.289142
Services	0.322666	0.579344	0.890395	1.792405
Metals	0.73851	0.432876	0.121838	1.293224
Construction	0.517581	0.332339	0.254055	1.103975
Coal	1.040635	0.025018	0.022258	1.087911
Natural Gas	0.001546	1.00259	0.002631	1.006767
Agriculture	0.157688	0.27899	0.34384	0.780518
Machinery	0.280538	0.218037	0.119352	0.617927
Chemicals	0.070644	0.309503	0.125031	0.505178
Electricity	0.209749	0.167381	0.064306	0.441437
Textiles	0.055219	0.10841	0.083183	0.246812
Durables	0.062314	0.091621	0.070882	0.224817
Cement	0.06055	0.070116	0.018451	0.149117
Other Manufacturing	0.036707	0.036426	0.033725	0.106858
Non Metals	0.03784	0.03685	0.031241	0.105931
Mining	0.004834	0.007663	0.009934	0.022432

Source: Author's Estimates

The carbon footprints associated with simple and extended multipliers indicate that petroleum is not only the most energy intensive sector but also the most carbon intensive one. The direct and indirect emissions caused because of the petroleum sector when there is a unit increase in output demand[1] is 6.35 tonnes in the case of simple multiplier and 6.49 tonnes in case of extended SAM multiplier. This is because a major fraction of the petroleum is used within the sector itself to produce petroleum products apart from being used in the production of non - electrical machinery, transport and trade. In addition to this, the fuel emission coefficient for petroleum in India is relatively high. It is approximately 3. 1 tonne of CO_2 per tonne of fuel. On increasing the endogeneity in the model, it is interesting to note that the services, construction and agriculture sector become more carbon intensive than in case of simple multiplier. This is because of the high consumption value of these sector products by the household sector. Table 3 and Table 4 show the carbon footprints (in tonnes) per unit of output demanded by the household sector for both Simple and Extended Multipliers.

Table 3: Carbon Footprints in case of Simple Multipliers

Sectors	Carbon Footprints (in tonnes)
Petroleum	6.354323
Metals	2.262146
Natural Gas	2.105732
Services	2.006571
Coal	1.845465
Construction	1.602044
Machinery	0.974605
Chemicals	0.971781
Electricity	0.786
Agriculture	0.618801
Textiles	0.341231
Durables	0.32009
Cement	0.276521
Non Metals	0.191997
Other Manufacturing	0.137659
Mining	0.018912

Source: Author's estimates

Table 4: Carbon Footprints in case of Fixed Price Multipliers

Sectors	Carbon Footprints (in tonnes)
Petroleum	6.4949
Services	4.526177
Metals	2.53943
Construction	2.363833

[1] Note: The SAM matrix is in lakh rupees. If one unit of agricultural output is demanded (here unit can be kg's/tonnes/million tonnes of rice etc.) then the worth of that unit is one lakh rupees. The SAM matrix indicates how much monetary expenditure has to be incurred to produce a unit of output whose worth is one lakh rupees.

Natural Gas	2.116223
Agriculture	1.920023
Coal	1.886352
Machinery	1.303905
Chemicals	1.157654
Electricity	0.906707
Textiles	0.57937
Durables	0.517983
Cement	0.307169
Other Manufacturing	0.243373
Non Metals	0.238478
Mining	0.055111

Source: Author's Estimates

Textiles, durables, cement, other manufacturing, non metals and mining have remained down the list of carbon intensive products in both the simple and extended multiplier scenarios. This is because textiles and durables though form an important part of the household consumption basket they are low in terms of value when compared with heavy machinery, metals etc and also their energy intensity is less when seen from Table 1 and Table 2. Cement production is not quite a lot in India and it being used largely in the construction sector.

5. Conclusion and Policy Implications

In this paper the carbon footprints of the Indian economy have been estimated using the most recent SAM matrix of India for the year 2003-04. The SAM matrix was modified to a 36 X 36 matrix from a 98 X 98 matrix after aggregating the productive sectors of the economy. The energy sectors and the manufacturing sectors were kept at a more disaggregated level than the agriculture and services sector. The sectors included in the analysis were agriculture and allied activities, coal, natural gas, petroleum, mining, textiles, durables, chemicals and fertilizers, cement, non metallic products, metals, machinery (capital goods), other manufacturing, construction, electricity and services. The simple and fixed price multipliers were estimated for the study which then were used, along with the literature based carbon emission coefficients of fuel, to give the carbon footprints. As expected, petroleum, coal, metals, construction were high carbon intensive sectors. It was intriguing to note that on increasing the endogeneity of the model in case of fixed price multiplier the construction, services and agriculture sector become more carbon intensive. It shows the importance of these sectors in the household consumption basket. It points that as the households enter the general equilibrium model, as in this case, there are more carbon footprints per unit of a consumption unit demanded by the households. Table 3 and Table 4 reflect this fact accurately. Textiles, durables, cement, non metals are the least carbon intensive as they are low in energy intensity as well as in terms of value.

Though the government's attention has recently been on the manufacturing sector but it has become imperative to take some stern measures with regard to carbon emissions in this sector. As shown by the estimates of this study, petroleum, coal, metals and construction are high carbon intensive products. With an increase in demand for the manufacturing products by the household sectors there is ought to be an alarming increase in the level of carbon emissions. With India's stand to reduce emissions during the Paris Conference in December 2015 some strict policy measures are required in the upcoming Five Year Plan.

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Appendix

A1. Emission Coefficient by Fuel

Fuel	Units	India Emission coefficient in desired units
Coal	Tons of CO_2/Ton of Fuel	1.69585
Natural Gas	Tons of CO_2/ 1000 cubic metre	2.1
Petroleum	Tons of Co2/Ton of fuel	3.1024

Source: J. Parikh et. al (2009)