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The Carbon Footprint of Indian Households

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Abstract

We estimate total emissions, which are attributed to the expenditure of single households in India during 2004/05 and 2009/10 to analyse the effect of income, household characteristics or changes in the composition of household consumption on household emissions. First, we apply input-output energy analysis in combination with household expenditure survey data to calculate the carbon footprint of households. Second, we analyse the respective emission drivers such as income and household characteristics in 2004/05. We further decompose the rise in household emissions between 2004/05 and 2009/10 to isolate the effect of income and changes in composition of household consumption. Finally we estimate income elasticities for a number of important consumption sub-categories, differentiating between households by income quintiles. By disaggregating household expenditure, we reveal how consumption patterns change when households become more affluent. We observe a disproportionately high increase in the demand for emission-intensive goods and services in comparison to less emission-intensive consumption categories.

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1.1 Introduction

Household income in India has increased considerably in line with economic growth over the last decades. The ministry of statistics and programme implementation (MOSPI) reports that wages have been rising between 2004/05 and 2009/10 by 187%.[1] In line with wages also household expenditure has been rising especially in the urban areas where richer households are located. We expect a large share of households to pass the critical income level of 2 Dollars per day and we expect that carbon emissions from Indian households will account for a significant share of global greenhouse gas emissions (GHG) in the future. This rise in carbon emissions will be correlated with increasing direct and indirect energy requirements of households. However, energy consumption and carbon footprints vary with what and how households consume. Therefore, we identify consumption patterns, their dynamics, and their respective carbon intensities for the different groups of households.

We apply input-output (IO) energy analysis in combination with household expenditure survey data from India for the year 2004/05 and 2009/10. For the analysis we calculate the carbon footprint of households and analyse the respective emission drivers. First we apply quantile regression analysis to explain the large differences within the household carbon footprint in 2004/05. Household income (total expenditure) appears to be the major driver but the elasticity of income is above one for households with a low, and below one for those with a high footprint. To analyse what drives the rise in emissions between the two years under observation we apply a Blinder-Oaxaca decomposition. We find that increased income (total expenditure) explains 47% of the rise in household emissions (57%) between 2004/05 and 2009/10. Second, we estimate income elasticities for a number of different consumption categories, differentiating between households by income quintiles. By disaggregating household expenditure, we reveal how consumption patterns change when households become more affluent. We observe a disproportionately high increase in the demand for emission-intensive goods and services in comparison to less emission-intensive consumption categories. Such a non-linear increase of carbon-intensive consumption is of great significance given that India has a large emerging middle class ready to spend its increasing discretionary income on a variety of emission-intensive consumption items.

[1] Urban wages were rising only by 173 % between 2004/05 and 2009/10.

The remainder of the paper is as follows. After the literature review we present the IO analysis as well as the expenditure analysis and clarify our definition of the middle class. In the results section we estimate the carbon footprint and determine the carbon intensive consumption items before we close with the conclusion.

1.2 Literature Review

For an excellent survey on recent literature concerning input-output analysis and the carbon footprint, see Minx et al. (2009). Although our particular focus is on India and developing countries, most studies focus on developed countries due to data availability.

Earlier carbon footprints for Indian households have been calculated by Parikh et al. (1997). Combining IO-data from 1989-90 and household data for the year 1987-88, their paper presents differences in consumption patterns across income groups and their carbon dioxide implications. A main finding is that the rich have a more carbon intensive lifestyle with the urban emission levels being 15 times as high as those of the rural poor. Apart from carbon footprints, closely related energy requirements of Indian households have been calculated by Pachauri & Spreng (2002) for the years 1983-84, 1989-90 and 1993-94. Based on IO-analysis, they find that household energy requirements have significantly increased over time identifying growing income, population and increasing energy intensity in the food and agricultural sectors as the main drivers. Based on this analysis, Pachauri & Spreng (2002) present cross-sectional variations in total household energy requirements. Using household consumption expenditure data for 1993-1994 matched with energy intensities calculated by Pachauri & Spreng (2002), an econometric estimation reveals income levels as the main factor determining variation in energy requirements across households.

Generally, carbon emissions, which are closely related to direct and indirect energy requirements of households, have been the subject of research since the 1970s. Herendeen and Tanaka (1976) use input-output and household expenditure data to calculate energy requirements of U.S. households. Additional to energy intensities, GHG intensities have been calculated by Lenzen (1998b) for Australian final consumption. Based on IO-analysis and including other GHGs than CO_2 such as CH_4, N_2O, CF_4 and C_2F_6. It is found that most of the GHG emissions are ultimately caused by household purchases.

Close to our approach, household expenditure data and IO derived carbon intensities have been used to calculate household carbon footprints for Australia Lenzen (1998a). Using IO derived carbon intensities from Lenzen (1998b) multiplied with expenditures on 376 commodities, it is one of the first studies calculating carbon footprints on a disaggregated household level. Among the finding that per capita income is the main determinant of household energy and carbon requirements, it is found that rural households spend their income on more energy intensive commodities than a person from a metropolitan area on average. Drawing on a similar methodology for energy, Lenzen et al. (2006) focus on the role of income growth in a cross-country analysis. Their motivation is to characterise household consumption patterns with respect to their environmental implications and hereby search for evidence on the Environmental Kuznets Curve (EKC). Their findings support previous research in the EKC energy literature, as energy requirements increase monotonically with household expenditure but no turning point is observed. Serrano & Roca (2007) apply IO analysis to estimate the emission content of Spanish household consumption from nine different atmospheric pollutants. They analyse the share of each income quintile in emissions and find, except for synthetic green house gases, declining emission intensities of household consumption with rising expenditure. Therewith they find an EKC at the country level.

In general there are several studies combining household expenditure data with IO derived carbon intensities to calculate household carbon footprints. Wier et. al (2001) analyse the carbon footprint of Danish households, identifying household characteristics with a significant influence on CO_2 emissions. Kerkhof et al. (2009) quantify CO_2 emissions of households in the Netherlands, UK, Sweden and Norway by combining a hybrid approach of process and input-output analysis with household expenditure data. Similar approaches recently published are Bin & Dowlatabadi (2005) and Weber & Matthews (2008), both focusing on US households. For the Netherlands, see Kerkhof et al. (2009).

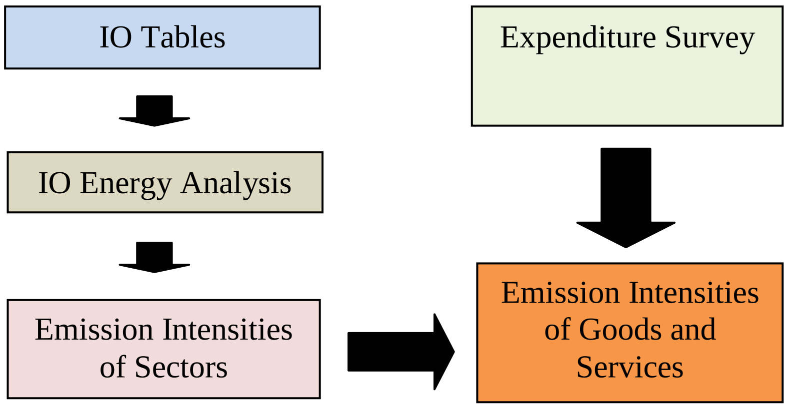
1.3 Methodology

1.3.1 Deriving the Carbon Footprint

We combine energy IO analysis with household demand structure to estimate the carbon footprint for Indian households. Therewith, we can trace the carbon content of each final consumption item back to its intermediates and account for the direct as well as indirect emissions from consumption. We focus on carbon emissions from fossil fuels[2] since CO_2 emissions represent the largest share of GHG emissions covert under the Kyoto Protocol. The method which has been applied is based on Leontief (1970) and we follow the approach of Lenzen (1998b) and Lenzen et al. (2004).

In a first step we estimate the CO_2 intensities (by local currency unit) of each sector of the Indian economy. We apply a single region IO model based on the Global Trade Analysis Project (GTAP). By using a single region IO model we account for direct and indirect emissions from goods produced and consumed in India as well as for emissions from imported goods.[3]

Figure 1: IO Energy Analysis with Expenditure Data



Source: After (Kok et al. 2006)

Figure 1 describes the process IO energy analysis. We use IO tables from the Indian Central Statistical Organisation (CSO) which provide us with an [jx1] vector of domestic output *x* by 130 industrial sectors *j*, a [jx1] vector of final demand *y* by 130 industrial sectors *j* (which includes imports). And a [jxj] matrix of the technical coefficients *A*, which reflect the input requirements of the *jth* sector of intermediates from other sectors measured in monetary units.[4] We apply the simple technology assumption and assume that imported goods are

[2] The CO2 emissions are derived from following energy sources: coal, crude oil, natural gas, petroleum products, gas, electricity and gas. The share of renewable and nuclear energy in India's electricity was considerably low in 2005 so that we can claim to estimate emissions from the use of fossil fuels.

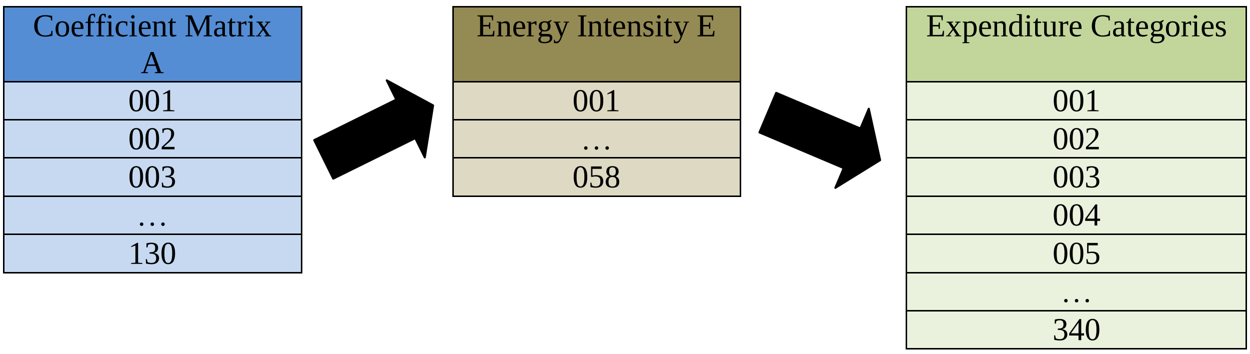
[3] The share of imported goods and services in the Indian GDP is constantly rising and accounted for 22% of GDP in 2005.

[4] All the values are in local currency units at 2004 producer prices.

produced with the same technology as local goods. Depending on the fuel type the CO_2 emissions per unit of fuel use are represented in the emission coefficient vector *c* [mx1]. The [mxj] energy use matrix E^{ind} represents the quantitative energy demand of the 58 sectors per monetary unit of intermediate output from other sectors. The energy use matrix E^{fd} represents the household's fuel quantitative use per monetary unit of final demand from 58 sectors.[5] Total emissions from consumption CO_2 would consist of direct CO_2^{fd} from final demand and indirect CO_2^{ind} emissions from energy use by each sector.

In Figure 2 the process of the data matching stages is outlined. In the first step we matched the 130 sectors of our IO tables with the energy use data, which is aggregated to 58 sectors in order to get the energy intensity matrix *E*. In a second step we match the 58 sector emission intensities with the corresponding expenditure categories from the household survey data. The data on household expenditure is rather disaggregated and we match all the 340 expenditure categories with the corresponding emission intensities.[6] Even though the IO tables contain information on monetary fossil fuel and electricity demand we still need to refer to the quantitative energy intensity data from GTAP to gain a more precise estimate on emissions per sector.

Figure 2: Data Matching Scheme



Source: Authors

In our model we consider a single region approach, which assumes that environmental and energy technology is the same as abroad. Therefore, we analyse the sum of direct and indirect emissions from industrial sectors. Direct emissions from final demand can be characterized as follows:

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[5] The data by the GTAB energy volume data is disaggregated into 58 sectors, which were matched with the 130 sectors from the Indian IO tables.

[6] For an overview on the emission intensities of each economic sector and our matched consumption category please refer to Appendix I

$$CO_2^{fd} = c'E^{fd}y \quad (1)$$

where *c'* represents the inverse emissions coefficient vector, E^{fd} is the energy use matrix and *y* is the final demand vector (Suh 2010).

Indirect emissions CO_2^{ind}, which are divided into emissions from domestic production for domestic final demand, emissions from imported intermediates and emissions from imported final demand (2).[7] The emissions by sector can be estimated by multiplying the demand of each sector represented as vector *y* with the transposed emissions coefficients vector *c* and the industrial energy use matrix E^{ind} as well as the with the domestic Leontief inverse $(I\text{-}A)^{-1}$:

$$CO_2^{ind} = c'E^{ind}\left[(I-A)^{-1}y_{\neq exp} + ((I-A_{tot})^{-1} - (I-A)^{-1})y_{\neq exp} + (I-A_{tot})^{-1}y_{imp_{\neq exp}}\right] \quad (2)$$

where $A_{tot}=A+A_{imp}$, $y_{tot}=y+y_{imp}$ and $y_{\neq exp}$ is domestic final demand and *I* represents an identity matrix and *A* is the technical coefficients matrix, which mirrors the contribution of the intermediates to one final output unit (Suh 2010).

Direct and indirect emissions from consumption can be estimated by:

$$CO_2 = CO_2^{fd} + CO_2^{ind} \quad (3)$$

$$CO_2 = c'\left[E^{fd}y_{hh} + E^{ind}\left((I-A)^{-1}y_{\neq exp} + ((I-A_{tot})^{-1} - (I-A)^{-1})y_{\neq exp} + I{-}Atot{-}1yimp{\neq}exp\right.\right. \quad (4)$$

In order to estimate the household carbon footprint we multiply the carbon intensity per local currency unit of each industrial sector with the household expenditure for the respective category and sum up over all consumption categories for each household.[8] Therewith we gain the household carbon footprint CO_2^{hh} for each household in 2004/05 in kg of CO_2.

$$CO_2{}^{hh}{}_i = \sum_{i=340}^{j}\left(CO_2^{ind}{}_j * Exp_{ij}\right) \quad (5)$$

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[7] Exports are excluded.

[8] For the consumption categories rice, wheat and kerosene we applied marked prices on those quantities, which households received at subsidized prices via the public distribution system (PDS).

where *i* represents the household and *j* the different expenditure category.

1.3.2 Determinants of the Household Carbon Footprint

Wier et al. (2001) show in a descriptive analysis that households have different CO_2 requirements depending on characteristics, which they subdivide in economic, demographic and socio-cultural variables. Namely they analyse expenditure, urbanity, household size, type of accommodation and age as well as education. We follow the approach of Wier et al. (2001) but apply a semi parametric regression analysis to explain the differences in the household carbon footprint. The regression model has the following form:

$$\log CO_{2_i}^{hh} = \alpha + \beta_1 Economic_i + \beta_2 Demographic_i + \beta_3 Socio\ Cultural_i + \beta_4 \text{Energy Source} + \beta_5 \text{SR} + e_i \quad (6)$$

where $logCO_2^{hh}$ represents the carbon footprint of household i in natural logs. The major driver of the household emissions is income, which is here proxied by total household expenditure in natural logs and which represents the economic variable, additionally we also control if a household is considered income poor and receives subsidized consumption goods such as kerosene from the public distribution system (PDS). Apart from income the location in either rural or urban areas, the household size and the age as well as gender of the household head explain the differences due to demographic variables. To control for socio-cultural impacts on consumption and therewith emission patterns we control for the education of the household head. One of the major direct energy needs arises from the energy source for cooking. These energy sources do not vary largely in industrialized countries, but in our sample some of the households use electricity, some kerosene and some dung cake as an energy source for cooking. Thus, we add control variables for the type of energy source for cooking of the household. Finally e_i represents the error term.

We apply quantile regression for the analysis for two reasons. First the distribution of the household carbon footprint is highly skewed and quantile regression analysis is more robust to outliers than ordinary least squares regression (OLS) since it does not assume the data to be normally distributed. Second, it allows us to study the impact of the regressors, such as income, on the location and the scale parameters of the model. The OLS estimator minimizes the sum of the squared error term $\sum_i e_i^2$ and quantile regression "minimizes a sum that gives the asymmetric penalties $(1-q)|e_i|$ for overprediction and $q|e_i|$ for underprediction" (Cameron & Trivedi 2010, 206).

We assume that the impact of an increase in income for households with a low carbon footprint is a different one than for households with a high carbon footprint. Quantile regression allows us to estimate the impact of a one-unit change in income on a specific quantile q of our response variable the household carbon footprint.

The q^{th} quantile regression estimator minimizes over β_q via linear programming

$$Q(\beta_q) = \sum_{i:y_i \geq x_i'\beta}^{N} q\left|y_i - x_i'\beta_q\right| + \sum_{i:y_i \leq x_i'\beta}^{N} (1-q)\left|y_i - x_i'\beta_q\right| \quad (7)$$

where $0 < q < 1$ and the choice of q (we choose 0.1 and 0.9 in our analysis) estimate different values of β. If $q=0.9$ then more weight is placed on prediction for observations with $y_i \geq x_i'\beta_q$ (Cameron & Trivedi 2010).

While the estimated relationship is useful to separate the different determinants of the household carbon footprint, it has two important drawbacks. The first originates from a theoretical standpoint. Households target their consumption at goods which fulfil their needs, while CO_2 emissions represent an externality that is neither explicitly taken into account nor is it an aim to maximize the carbon footprint.[9] To deal with this wrong behavioural assumption in equation (6), we adopt a real household consumption perspective by estimating the demand elasticities for various consumption items. The second drawback of this first approach is the missing information about the consumption categories driving the household carbon footprint. We expect some categories to drive the carbon footprint more than others, revealing valuable information for further energy and climate mitigation policies.

1.3.3 Demand Analysis

Based on the Theory of Consumption by Deaton & Muellbauer (1980) demand functions derived from the utility maximization of the consumer depend on prices and income of these individuals. Since we do not have the data on prices of the household expenditure items we estimate these engel curves without prices, only dependent on income and socio-economic

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[9] To some extent carbon emission are taken into account via energy prices leading to different prices of goods.

characteristics of the households.[10] Having no prices available, there is no necessity to meet the homogeneity restriction, with the adding-up restriction leading to linear budget constraints as the necessary requirement left for the equation to estimate. The model to be estimated has the following form:

$$w_{ij} = \beta_0 + \beta_{1_{ij}} \log y_i + \beta_{2_{ij}} X_i + \varepsilon_{ij} \tag{8}$$

where w_{ij} represents the share of total expenditures allocated to the *jth* consumption category by the *ith* household, $\log y_i$ the income of household i in logs, X_i a vector with household characteristics and the error term ε_{ij}. With no income information available in the data, we follow the standard approach and use total expenditures per household as a proxy for income. The engel curves should preferably be estimated in a complete demand system to secure efficient estimates. However, our specification is in line with the adding-up restriction even if we estimate equation by equation by ordinary least squares.

Besides the choice of functional form, which is a discussion on its own in the literature we are facing a couple of econometric problems, caused by the data and the estimated specification under consideration. The first problem, present in most household surveys is measurement error. A second problem is the potential endogeneity of our main explanatory variable. These common problems in demand estimation can be solved with instrumental variable techniques, but the data hardly offers many candidates for valid instruments.

Deaton (1997) points to another source of potential simultaneity bias, which is caused by richer household buying high quality products, which are more expensive. In other words as households get richer they do not consume more of a certain good and cause more carbon emissions but they consume higher quality goods, which may not have to be related with higher carbon emissions than the lower quality items of the same consumption category. To control for this quality bias we split the sample for the analysis in rural and urban since we find that the majority of the urban households are living of less than 2 dollars a day. We further split our sample into income quintiles. Following Easterly (2001) we take this relative definition of different income classes instead of taking an absolute approach such as the number of households living of less than two dollars a day. Banerjee & Duflo (2008) point out

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[10] We derived prices by dividing the household expenditure on a certain item through the number of items bought, but we received very unreliable results. The variance in the derived unit price was too large to be reliable.

that relative measures draw the wrong image of the society and the low-income class or the people living in poverty underrepresented. Nevertheless, we do not intend to define who is poor and who is not, we try to reveal what happens to consumption patterns and therewith the carbon footprint when household income is rising.

1.3.4 Decomposing the Changes in the Carbon Footprint

As a last step of the analysis we apply a Blinder-Oaxaca decomposition to analyse to the changes in the carbon footprint between 2004/05 and 2009/10. Blinder (1973) and Oaxaca (1973) explain the gap in the mean of an outcome variable between two groups, which will be applied to two time periods in our case. The gap is decomposed into the part due to the differences in the magnitudes of the explanatory variables and the differences in the coefficients of these variables. Hence the increase in the carbon footprint between 2004/05 and 2009/10 could be due to higher overall expenditure or to different expenditure patterns.

O'Donnell et al. (2008) display the method as follows. The gap between the mean carbon footprint in the first period $CO_2^{hh'}$ and the second period $CO_2^{hh''}$ is equal to

$$CO_2^{hh''} - CO_2^{hh'} = \beta''x'' - \beta'x' \quad (9)$$

where x'' and x' are vectors of explanatory variables evaluated at the means in period two and one while assuming the error term to be zero.

$$CO_2^{hh''} - CO_2^{hh'} = \Delta x\beta'' + \Delta\beta x'' + \Delta x\Delta\beta = E + C + CE \quad (10)$$

where the gap between the mean household carbon footprints in the first and second period is decomposed into the gap in the endowments *E*, the gap in the coefficients and the interaction of endowments C and coefficients *CE*.

1.4 Data

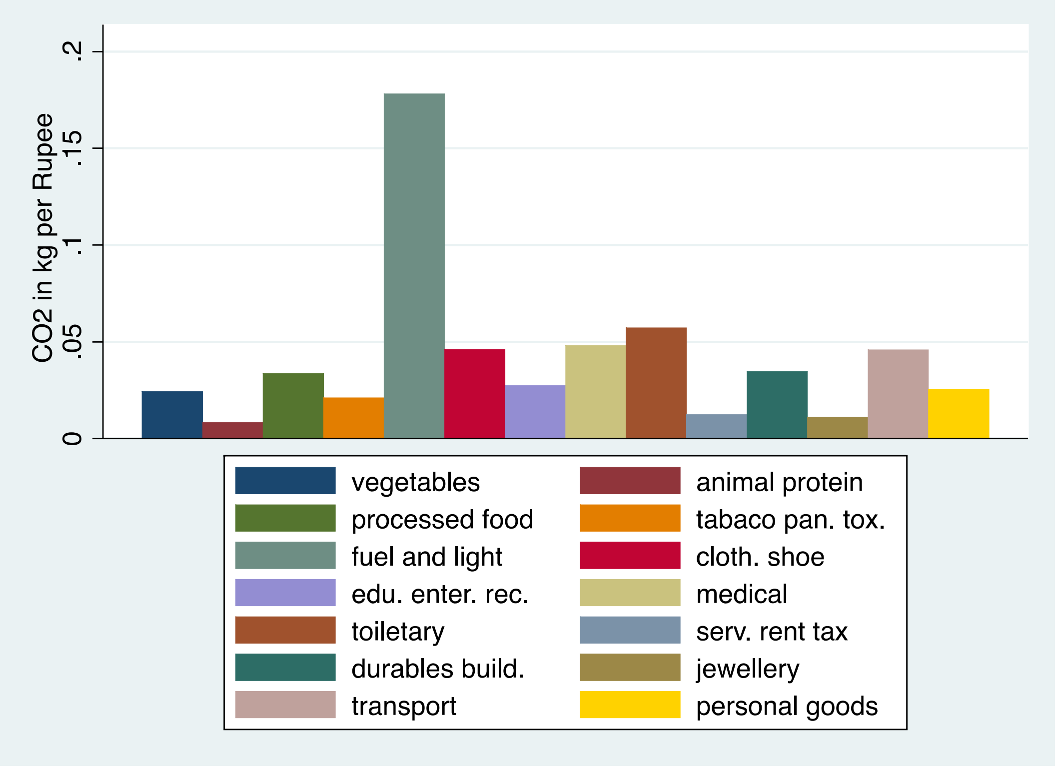
We apply IO data for 2004 from the Central Statistical Organisation in India. The IO tables are disaggregated into 130 economic sectors.[11] The data on energy demand per sector and the conversion into CO_2 emissions is derived from GTAP.[12] We estimated the emission

[11] For a list of the sectors and the corresponding emission intensities refer to Appendix I.

[12] The data on energy demand and CO_2 emissions by sectors is available upon request.

intensities for 58 economic sectors, which were matched with the household expenditure categories and are displayed in Figure 3. Emission intensities vary strongly between the consumption categories with the highest emission intensity per currency unit for toiletry items as well as light and fuel. We observe the lowest emission intensities for vegetables and fruits as well as expenses on education.[13]

Figure 3: Emission Intensities of Expenditure Sub-Groups



Source: CSO (2005) and NSS (2006).

The household expenditure analysis is based on data from the National Sample Survey, which consists of data on expenditure of about 125000 households, which is disaggregated to around 340 consumption categories and 40 sub-categories.[14] The survey is a representative sample of the Indian economy and we apply the waves, which were conducted in 2004/05 and 2009/10.[15] The households are to 64% located in urban areas and 69% of the households live of less than 2 dollars per person each day. The poor households are concentrated in rural areas. There are 11% of the households, which are headed by a woman. The average household size

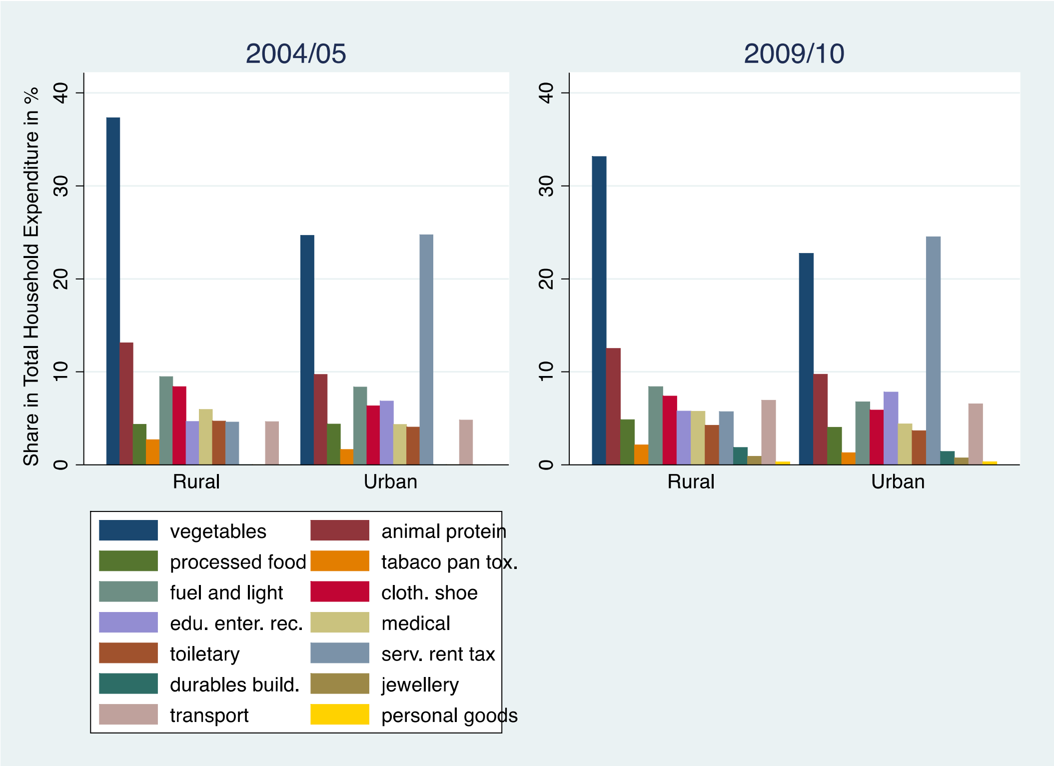
[13] Our Carbon Intensities by sector are much higher than the data by (N. Murthy et al. 1997)

[14] For an overview on household expenditure categories refer to Appendix II.

[15] For summary statistics refer to Appendix III and V.

consists of 5 members, 46% of the households consist of 3 to 6 members and 39% are households with up 43 members.[16] The household heads are to 76% of Hindu, 12% of Muslim or 7% of Christian religion. The average years of schooling of the household head is 4 years and 30% of the household heads received only 1 year of schooling. The mean monthly per capita expenditure equals 3880 Rupee in 2004/05 and 5831 Rupee in 2009/10.

Figure 4: Expenditure per Consumption Category



Source: CSO (2005) and NSS (2006).

Figure 4 gives an overview on what households spent their income on in 2004/05 and 2009/10. Overall expenditure has been rising by 67%. The structure of the expenditure shares varies largely between rural and urban households in Figure 4 und changes further over time. Rural households spent a larger fraction of their income on food items and a much smaller share on services, rent and taxes than urban households. Expenditure shares for education, entertainment and recreation were increasing between the two time periods.

When turning to the household carbon footprint, which consists of the sum of all expenses from the 40 sub expenditure categories multiplied with the respective emission intensities, we

[16] A household is defined as people sharing one kitchen.

find large differences between the household carbon footprint of different income quintiles as displayed in Figure 5. Apparently, the carbon footprint of the 20% richest households 4.5t CO_2 is about four times as high as the carbon footprint of the 20% poorest households with 0.75t CO_2 and still three times as high as the one of the median. The gap between urban and rural households is only 1.2t CO_2 per year. Considering these large differences we want to analyse the drivers of the strong rise in the household emissions between the middle and high-income class. Therefore we analyse various carbon intensive consumption categories and estimate the income and carbon elasticities.

Figure 5: Household Carbon Footprint by Income and Location 2004/05

Source: CSO (2005) and NSS (2006).

1.5 Results

First we will present the results from the analysis, which attempts to reveal the effect of changes in major determinants of the household carbon footprint such as income, demographic as well as socio-cultural variables and the major energy source of the household. Second we present how much of the rise in the household carbon footprint between 2004/05 and 2009/10 was due to changes in total expenditure. Last but not least we present the results on how much the composition of household expenditure changes when total expenditure is rising.

1.5.1 Determinants of the Household Carbon Footprint

Table 1 displays the results from the analysis of the household carbon footprint and its main determinants. Column 1 presents the results from OLS regression and a model specification containing the same variables as analysed in Wier et al. (2001).

Table 1: Determinants of the household carbon footprint

VARIABLES	(1) OLS $\log(CO_2^{hh})$	(2) QR (q=0.1) $\log(CO_2^{hh})$	(3) QR (q=0.9) $\log(CO_2^{hh})$	(4) QR (q=0.1) $\log(CO_2^{hh})$	(5) QR (q=0.9) $\log(CO_2^{hh})$
Log(Income)	1.008***	1.077***	0.897***	1.045***	0.869***
PDS Dummy	-0.0803***	-0.0857***	-0.0715***	-0.0700***	-0.0590***
Urban Dummy	0.154***	0.103***	0.143***	0.0817***	0.119***
Income*Urban	1.30e-07*	3.91e-07***	6.98e-07***	5.14e-08	5.88e-07***
HH-Size	-0.00389**	0.0168***	-0.0301***	0.0260***	-0.0243***
HH-Size^2	7.73e-05	-0.000770***	0.00181***	-0.00113***	0.00163***
HH-Size^3	-2.11e-06	1.98e-05***	-4.51e-05***	2.42e-05***	-4.28e-05***
Income*HH-Size	8.89e-09	-6.04e-08***	4.86e-08***	-5.81e-08***	4.77e-08***
Age-Head	-0.00869***	-0.00758***	0.00147	-0.0105***	0.00131
Age-Head^2	0.000233***	0.000185***	2.83e-05	0.000239***	2.68e-05
Age-Head^3	-1.51e-06***	-1.19e-06***	-1.88e-07	-1.53e-06***	-1.82e-07
Female Dummy	0.0445***	0.0163***	0.0623***	0.00934***	0.0543***
Edu.-Head	0.0403***	0.0287***	0.0332***	0.0251***	0.0271***
Edu.-Head^2	-0.00110***	0.000117	-0.00131***	3.29e-05	-0.00117***
Income*Edu.	-2.36e-07***	-3.60e-07***	-8.73e-08***	-3.64e-07***	-7.16e-08***
LPG				0.163***	0.0963***
Gas				0.0653***	-0.00593
Dung				-0.0105*	-0.0430***
Charcoal				0.205***	-0.0220
Kerosene				0.0640***	0.0123*
Electricity				0.251***	0.491***
Constant	-3.178***	-4.559***	-1.723***	-4.212***	-1.458***
Observations	124,589	124,589	124,589	124,589	124,589
R-squared	0.860				

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$, state dummies are included.

In column 2 and 3 we display the results from the quantile regression. Column 2 presents the effect of a unit change of the explanatory variables on the 10th quantile of the predicted variable household carbon footprint and column 2 the effect on the 90th quantile respectively. In column 2 an increase in income by 1% is related to a rise of the carbon footprint by about 1.1% for the 10th quantile and a rise by about 0.9% for the 90th quantile. This implies that at the positive effect of a rise in income is higher for lower percentiles of the carbon footprint. When comparing those results with the OLS results in column 1 the OLS estimator underestimates the effect of an increase in income for the 10th quantile and overestimates it for the 90th quantile of the household carbon footprint. The coefficients of the demographic and socio-cultural control variables do not vary as much for the different quantiles in column 2 and 3. Being eligible for goods form the public distribution system (PDS) has a small negative impact on the household carbon footprint. Being located in an urban area explains slightly higher emissions and higher income accelerates this effect. Concerning the household size an increase by another household member leads to rising emissions with a turning point at 13 members. Female-headed households cause on average slightly higher emissions, which is stronger for households with a higher level of emissions. The more educated the household head the higher the emissions with a turning point of 12 years of education for households in the 10th quantile of the carbon footprint distribution. Higher income and higher education contribute to a slight decrease in emissions.

In Table 1 column 4 and 5 we add the major energy sources used for cooking to the analysis again differentiating for the effects on the 10th and 90th quantile. The results on income, demographic and socio-cultural variables remain but using electricity or liquid pressured gas (LPG) leads to higher carbon footprints. The positive effect of kerosene is smaller and using dung cake leads to a smaller carbon footprint as one might expect.

1.5.2 Changes in the Household Carbon Footprint over Time

Table 2: Results from the Blinder-Oaxaca Decomposition

VARIABLES	(1) Differential	(2) Endowments	(3) Coefficients	(4) Interaction
Prediction 09/10	2351.469***			
Prediction 04/05	1502.936***			
Difference	1.564583***			
Total		1.557128***	1.038254***	0.9677669***
Log(Income)		1.471259***	0.8336551***	0.99278***
PDS Dummy		0.9978685***	1.017076***	1.00101***
Urban Dummy		1.006609***	0.9876895***	0.998296***
HH-Size		0.9989425***	0.9891407***	1.00055***
Age Head		1.000942***	1.01923***	1.000209***
Sex Head		1.0000	0.9996	1.0000
Edu. Head		1.026392***	0.9800202***	0.9901009***
LPG		1.011776***	1.0005	1.0002
Gas		1.0000	1.0000	1.0000
Dung		1.00035***	0.9998	1.0001
Charcoal		1.0000	1.0000	1.0000
Kerosene		0.9995399***	0.9997	1.0001
Electricity		1.000381***	0.9998663***	0.9998842***
Constant			1.2102	

Observations	225440	225440	225440	225440

Note: *** p<0.01, ** p<0.05, * p<0.1, state dummies are included. The dependent variable is CO_2^{hh} in kg per Rupee.

Table 2 presents the results from the Blinder-Oaxaca decomposition. Column 1 presents the mean prediction for the household carbon footprint in 2009/10, which represents 2351.5kg CO_2 and 1503kg in 2004/05. There is an increase of about 0.7 tons CO_2, hence mean emissions increased by 57%, which is represented by the coefficient for Difference 1.57 in column 1. In column 2 to 4 this rise in emissions is divided into three parts. Column 2 reflects the mean increase in emissions if the households in period one would have had the same characteristics such as income, household size, age or education as in period two. The coefficient of Total endowments 1.56 indicates that the change in endowments accounts almost for the entire rise (56%) in emissions between the two periods. More precisely income accounts for 47% and the education of the household head for 3% of rise in emissions. As confirmed above, changes in household income are the major driver of differences in household emissions between households and over time. Column 3 quantifies the rise in emissions when applying the coefficients from the second period to the characteristics from the first period. The coefficients play a minor role when explaining the rise in emissions only 4% of the difference is attributed to the total coefficients. Column 4 presents the interaction terms, which measure the simultaneous effect of differences in endowments and coefficients.

1.5.3 Income and Carbon Elasticities

The analysis of income elasticities reveals some interesting results. Due to potential endogeneity, one could use a 2SLS procedure with an instrument for total expenditures. However, the data doesn't offer many candidates as valid instruments for total expenditures. Therefore we present in Table 3 the OLS results for urban, rural and all India. Negative income elasticities represent a declining expenditure share of the respective expenditure category with rising income. These inferior good categories such as vegetables are in opposition to luxury goods such as medical goods or services and rent. It shows that one of the main priorities when households get richer appears to be housing. When doubling income, the share of total expenditures spent for rent would rise by about 10%. However, it has to be stressed that differences between different income classes can be significant, which can be shown by distinguishing between urban and rural households. Decreases in the spending for vegetables with rising income is stronger for rural households, urban households show smaller spending responses towards lower vegetable consumption. The classification into inferior, necessities and luxury goods holds for rural and urban households for the same consumption category. While households generally decrease vegetables consumption relative to their total expenditures when income rises, animal products gain weight in their consumption basket.

Table 3: Income elasticities expenditure categories

	All India		Rural		Urban	
	coeff	se	coeff	se	coeff	se
Vegetables	-0.161***	(0.000736)	-0.151***	(0.00111)	-0.105***	-0.00113
Animal protein	0.0175***	(0.000402)	0.0491***	(0.000667)	0.0114***	-0.000502
Processed food	0.0173***	(0.000546)	0.0133***	(0.000655)	0.0192***	-0.000981
Tobacco, pan, tox	-0.000844***	(0.000232)	0.00235***	(0.000360)	0.00201***	-0.000331
Fuel, light	-0.0324***	(0.000268)	-0.0306***	(0.000398)	-0.0258***	-0.000408
Clothing, shoes	-0.0166***	(0.000322)	-0.00970***	(0.000520)	-0.00861***	-0.000514
Education	0.0214***	(0.000424)	0.0207***	(0.000543)	0.0257***	-0.000797
Entertainment	0.00722***	(9.72e-05)	0.00564***	(0.000143)	0.00667***	-0.000175
Medical goods	0.0277***	(0.000619)	0.0477***	(0.00101)	0.0241***	-0.0009
Toiletary	-0.0114***	(0.000191)	-0.00849***	(0.000306)	-0.00844***	-0.00026
Services, rent	0.108***	(0.000695)	0.0282***	(0.000424)	0.0299***	-0.00121
Durables, building	1.74e-05***	(3.58e-06)	0.000219***	(2.05e-05)	0.000124***	-1.20E-05
Transport	0.0232***	(0.000338)	0.0324***	(0.000491)	0.0283***	-0.00059
Personal goods	5.92e-05***	(4.28e-06)	0.000211***	(2.22e-05)	0.000117***	-1.40E-05

Source: NSS 2006 and CSO 2005. Note: Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

In general most of the estimated coefficients are very small, implying that the big change in carbon footprints is caused by a general volume increase in consumption and not by shifts within the consumption basket. Besides the coefficients shown in Table 3 and the above discussion of their signs, their magnitude can be better understood by showing how a change in income affects the composition of the consumption basket.

In Table 4, it is shown that a 10% income rise only marginally affects the composition of the consumption basket. The biggest change can be observed in the consumption of vegetables, a 10% income rise changes the share of vegetables in total expenditures by 1.6 %. Other consumption shares change in way less dramatic way.

Looking at the mean of the income distribution like in the first column in Table 3, average effects for the whole population can be an interesting starting point. If one is additionally interested in carbon footprint changes of different income groups, greater heterogeneity in consumption behaviour can be revealed.[17] The poorest group of the population significantly

[17] Results for income quintiles are shown in table Appendix VII and VIII.

reduces the share of vegetable food in total expenditures and increases consumption in most other categories. In general, no shift towards a sustainable consumption with low emission goods can be observed. With the exception of services and rent as low emission intensity consumption categories, high emission intensity consumption increases with income. By moving up the income ladder, a considerable part of the additional income is spent on carbon intensive goods such as transport.

Table 4: Consumption Shares and Changes when Income Rises

consumption category	share of total exp (%); before income rise	change in share (% points), 10% income rise	share of total exp (%); after income rise
Vegetables	35.4876	-1.6100	33.8776
Animal protein	10.5664	0.1750	10.7414
Processed food	5.1714	0.1730	5.3444
Tobacco, pan, intoxicants	2.5964	-0.0084	2.5879
Fuel, light	10.4598	-0.3240	10.1358
Clothing, shoes	7.6268	-0.1660	7.4608
Education	3.3132	0.2140	3.5272
Entertainment	0.8401	0.0722	0.9123
Medical goods	4.4001	0.2770	4.6771
Toiletary	5.0000	-0.1140	4.8860
Services, rent, tax	10.8620	1.0800	11.9420
Durables, building	0.0164	0.0002	0.0165
Transport	3.6547	0.2320	3.8867
Personal goods	0.0053	0.0006	0.0059
Sum	100	0	100

Source: NSS 2006

1.6 Conclusion

In a first step we applied input output analysis matched with Indian household expenditure data to estimate the carbon footprint for Indian households. In a second step we analysed the effect of differences in income and household characteristics on the household carbon footprint in 2004/05. Therefore we analysed the determinants of the variation in the carbon footprints trying to find out what besides income is the major driver of Indian CO_2 emissions from consumption. We further examined the effect of income and household characteristics by analysing changes over time. Finally we estimated the income elasticity of major consumption subgroups to be able to investigate the effect of changes in the composition of household consumption and to point to consumption items, which are declared as luxury goods and which exhibit a high carbon intensity.

We find that income is indeed the major driver of household emissions but fuel types, which are used for cooking, have an impact on carbon footprints as well as age, gender and education of the household head. The effect of a rise in income affects households differently. Households with a currently low carbon footprint tend to observe a stronger rise in emissions as income is increasing with an elasticity of income greater than one. Households with currently high carbon footprint reveal an income elasticity lower than one. Hence, they might have passed a point of saturation and therefore increased consumption is less carbon intense. When looking at changes over time we find that the rise in the mean carbon footprint by 57% is mostly due to increased household income (total expenditure), which explains 47% of the rise in emissions. With the analysis of income elasticities of each consumption category we find that those categories, which are classified as luxury goods such as transport, medical goods, entertainment or services do not exhibit the highest carbon intensities, which leads us to the conclusion that the strong rise in the carbon footprint between the fourth and fifth income quintile is mainly due to the overall income increase. To give more insight on this matter one would have to have a look at the emission elasticities.

1.7 References

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1.8 Appendix

Appendix I – Emission Intensities by IO Sector

IO Code	IO Description	kt CO2/100000 Rupee (Rs. Lakhs)
1	Paddy	0.004112514
2	Wheat	0.005150024
3	Jowar	0.001998897
4	Bajra	0.001521553
5	Maize	0.001716166
6	Gram	0.001352482
7	Pulses	0.001843026
8	Sugarcane	0.00199567
9	Groundnut	0.000933164
10	Coconut	0.001094785
11	Other oilseeds	0.001688505
12	Jute	0.000767761
13	Cotton	0.002064095
14	Tea	0.000488243
15	Coffee	0.001506113
16	Rubber	0.00116961
17	Tobacco	0.00088182
18	Fruits	0.000312899
19	Vegetables	0.000373043
20	Other crops	0.002218529
21	Milk and milk products	0.000723386
22	Animal services(agricultural)	0.002240727
23	Poultry & Eggs	0.00038531
24	Other liv.st. produ. & Gobar Gas	0.001052826
25	Forestry and logging	0.000397309
26	Fishing	0.000606924
27	Coal and lignite	0.003316245
28	Natural gas	0.005760873
29	Crude petroleum	0.00079371
30	Iron ore	0.003675439
31	Manganese ore	0.001162252
32	Bauxite	0.00655872
33	Copper ore	0.000977475
34	Other metallic minerals	0.003819088
35	Lime stone	0.003384801
36	Mica	0.001313169
37	Other non metallic minerals	0.000753466
38	Sugar	0.002909385
39	Khandsari, boora	0.002914822
40	Hydrogenated oil(vanaspati)	0.002583513
41	Edible oils other than vanaspati	0.001830671
42	Tea and coffee processing	0.005209347
43	Miscellaneous food products	0.004666592
44	Beverages	0.004290131
45	Tobacco products	0.001895663
46	Khadi, cotton textiles(handlooms)	0.005402276
47	Cotton textiles	0.006461528
48	Woolen textiles	0.004257129
49	Silk textiles	0.0027169

50	Art silk, synthetic fiber textiles	0.006005325
51	Jute, hemp, mesta textiles	0.005337591
52	Carpet weaving	0.003882589
53	Readymade garments	0.004105045
54	Miscellaneous textile products	0.004905571
55	Furniture and fixtures-wooden	0.002889844
56	Wood and wood products	0.002280736
57	Paper, paper prods. & newsprint	0.00732061
58	Printing and publishing	0.006650471
59	Leather footwear	0.002680479
60	Leather and leather products	0.002693471
61	Rubber products	0.005867202
62	Plastic products	0.00669696
63	Petroleum products	0.005068154
64	Coal tar products	0.006296996
65	Inorganic heavy chemicals	0.00644006
66	Organic heavy chemicals	0.005079818
67	Fertilizers	0.006147752
68	Pesticides	0.005936411
69	Paints, varnishes and lacquers	0.006142738
70	Drugs and medicines	0.005415864
71	Soaps, cosmetics & glycerin	0.005408317
72	Synthetic fibers, resin	0.005061084
73	Other chemicals	0.005631599
74	Structural clay products	0.013650674
75	Cement	0.016108776
76	Other non-metallic mineral prods.	0.012805394
77	Iron, steel and ferro alloys	0.00931503
78	Iron and steel casting & forging	0.010505635
79	Iron and steel foundries	0.008489451
80	Non-ferrous basic metals	0.003302273
81	Hand tools, hardware	0.004930313
82	Miscellaneous metal products	0.006259155
83	Tractors and agri. implements	0.005557207
84	Industrial machinery(F & T)	0.00385153
85	Industrial machinery(others)	0.003714747
86	Machine tools	0.004202782
87	Other non-electrical machinery	0.004237429
88	Electrical industrial Machinery	0.005155655
89	Electrical wires & cables	0.004981934
90	Batteries	0.005836697
91	Electrical appliances	0.005199852
92	Communication equipments	0.004088944
93	Other electrical Machinery	0.004878112
94	Electronic equipments(incl.TV)	0.003260319
95	Ships and boats	0.000670547
96	Rail equipments	0.005507866
97	Motor vehicles	0.005184593
98	Motor cycles and scooters	0.006261721
99	Bicycles, cycle-rickshaw	0.005540685
100	Other transport equipments	0.005560586
101	Watches and clocks	0.00238502
102	Medical, precision&optical instru.s	0.003419611
103	Jems & jewelry	0.001112014
104	Aircraft & spacecraft	0.000173823
105	Miscellaneous manufacturing	0.001335668
106	Construction	0.005032379
107	Electricity	0.060437653
108	Water supply	0.003468475

109	Railway transport services	0.010466244
110	Land tpt including via pipeline	0.004600846
111	Water transport	0.017015131
112	Air transport	0.006523075
113	Supporting and aux. tpt activities	0.005900578
114	Storage and warehousing	0.013685152
115	Communication	0.00236796
116	Trade	0.001434421
117	Hotels and restaurants	0.003031951
118	Banking	0.001128398
119	Insurance	0.002280669
120	Ownership of dwellings	0.000341209
121	Education and research	0.000411614
122	Medical and health	0.001798426
123	Business services	0.002431687
124	Computer & related activities	0.000885475
125	Legal services	0.000430641
126	Real estate activities	0.000745064
127	Renting of machinery & equipment	0.000271409
128	O.com, social&personal services	0.001008876
129	Other services	0.001450611
130	Public administration	4.00E-06

Source: Authors estimation based on data from GTAP and CSO (2005)

Appendix II – Matched Carbon Emission Intensities with Consumption Categories

NSS Code	NSS Description	IO Code	WIOD Code
101	rice - PDS	1	1
102	rice - other sources	1	1
103	chira	1	1
104	khoi, lawa	1	1
105	muri	1	1
106	other rice products	1	1
107	wheat/atta - PDS	2	1
108	wheat/atta - other sources	2	1
110	maida	2	1
111	suji, rawa	2	1
112	sewai, noodles	1	1
113	bread: bakery	2	1
114	other wheat products	2	1
115	jowar & products	3	1
116	bajra & products	4	1
117	maize & products	5	1
118	barley & products	2	1
120	small millets & products	4	1
121	ragi & products	7	1
122	other cereals	20	1
129	cereal: s.t. (101-122)		
139	**cereal substitutes: tapioca, jackfruit, etc.**	**20**	**1**
140	arhar, tur	6	1
141	gram: split	6	1
142	gram: whole	6	1
143	moong	6	1
144	masur	6	1
145	urd	6	1
146	peas	6	1
147	soyabean	7	1
148	khesari	7	1
150	other pulses	7	1
151	gram products	6	1
152	besan	6	1
153	other pulse products	7	1
159	pulses & pulse products: s.t. (140-153)		
160	milk: liquid (litre)	21	3
161	baby food	21	3
162	milk: condensed/ powder	21	3
163	curd	21	3
164	ghee	21	3
165	butter	21	3
166	ice-cream	21	3
167	other milk products	21	3
169	milk & milk products: s.t.(160-167)		3
170	vanaspati, margarine	40	3
171	mustard oil	11	3
172	groundnut oil	9	3
173	coconut oil	10	3
174	edible oil: others	41	3
179	edible oil: s.t. (170-174)		
180	eggs (no.)	23	3
181	fish, prawn	26	3
182	goat meat/mutton	22	3
183	beef/ buffalo meat	22	3
184	pork	22	3
185	chicken	23	3
186	others: birds, crab, oyster, tortoise, etc.	23	3
189	egg, fish & meat: s.t. (180-186)		
190	potato	19	3
191	onion	19	3
192	radish	19	3
193	carrot	19	3
194	turnip	19	3

195	beet	19	3
196	sweet potato	19	3
197	arum	19	3
198	pumpkin	19	3
200	gourd	19	3
201	bitter gourd	19	3
202	cucumber	19	3
203	parwal, patal	19	3
204	jhinga, torai	19	3
205	snake gourd	19	3
206	papaya: green	19	3
207	cauliflower	19	3
208	cabbage	19	3
210	brinjal	19	3
211	lady's finger	19	3
212	palak/other leafy vegetables	19	3
213	french beans, barbati	19	3
214	tomato	19	3
215	peas	19	3
216	chillis: green	19	3
217	capsicum	19	3
218	plantain: green	19	3
220	jackfruit: green	18	3
221	lemon (no.)	18	3
222	garlic (gm)	19	3
223	ginger (gm)	19	3
224	other vegetables	19	3
229	vegetables: s.t. (190- 224)		
230	banana (no.)	18	3
231	jackfruit	18	3
232	watermelon	18	3
233	pineapple (no.)	18	3
234	coconut (no.)	18	3
235	guava	18	3
236	singara	18	3
237	orange, mausami (no.)	18	3
238	papaya	18	3
240	mango	18	3
241	kharbooza	18	3
242	pears, naspati	18	3
243	berries	18	3
244	leechi	18	3
245	apple	18	3
246	grapes	18	3
247	other fresh fruits	18	3
249	fruits (fresh): s.t.(230-247)		
250	coconut: copra	10	3
251	groundnut	9	3
252	dates	18	3
253	cashewnut	9	3
254	walnut	9	3
255	other nuts	9	3
256	raisin, kishmish, monacca, etc.	18	3
257	other dry fruits	18	3
259	fruits (dry): s.t. (250-257)		
260	sugar - PDS	38	3
261	sugar - other sources	38	3
262	gur	8	3
263	candy, misri	39	3
264	honey	38	3
269	sugar: s.t. (260-264)		
279	**salt**	**37**	**3**
280	turmeric (gm)	20	3
281	black pepper (gm)	20	3
282	dry chillies (gm)	20	3
283	tamarind (gm)	20	3
284	curry powder (gm)	20	3
285	oilseeds (gm)	20	3
286	other spices (gm)	20	3
289	spices: s.t. (280-286)		
290	tea: cups (no.)	42	3

291	tea: leaf (gm)	14	3
292	coffee: cups (no.)	42	3
293	coffee: powder (gm)	15	3
294	ice	44	3
295	cold beverages: bottled/canned (litre)	44	3
296	fruit juice and shake (litre)	44	3
297	coconut: green (no.)	44	3
298	other beverages: cocoa, chocolate, etc.	44	3
300	biscuits	43	3
301	salted refreshments	43	3
302	prepared sweets	43	3
303	cooked meals (no.)	43	3
304	cake, pastry	43	3
305	pickles (gm)	43	3
306	sauce (gm)	43	3
307	jam, jelly (gm)	43	3
308	other processed food	43	3
309	beverages etc.: s.t. (290- 308)		
310	pan: leaf	17	3
311	pan: finished (no.)	45	3
312	supari (gm)	45	3
313	lime (gm)	45	3
314	katha (gm)	45	3
315	other ingredients for pan (gm)	45	3
319	pan: s.t. (310-315)		
320	bidi (no.)	45	3
321	cigarettes (no.)	45	3
322	leaf tobacco (gm)	17	3
323	snuff (gm)	45	3
324	hookah tobacco (gm)	45	3
325	cheroot (no.)	45	3
326	zarda, kimam, surti (gm)	45	3
327	other tobacco products	45	3
329	tobacco: s.t. (320-327)		
330	ganja (gm)	44	3
331	toddy (litre)	44	3
332	country liquor (litre)	44	3
333	beer (litre)	44	3
334	foreign liquor or refined liquor (litre)	44	3
335	other intoxicants	44	3
339	intoxicants: s.t. (330-335)		
340	coke	64	8
341	firewood and chips	56	6
342	electricity (std. unit)	107	17
343	dung cake	24	1
344	kerosene-PDS(litre)	63	8
345	kerosene - other sources (litre)	63	8
346	matches (box)	56	6
347	coal	64	8
348	LPG	63	8
350	charcoal	64	8
351	candle (no.)	73	9
352	gobar gas	28	8
353	other fuel	63	8
359	fuel and light: s.t. (340-353)		
360	dhoti (metre)	54	4
361	sari (metre)	54	4
362	cloth for shirt, pyjama, salwar, etc. (metre)	54	4
363	cloth for coat, trousers, overcoat, etc. (metre)	54	4
364	chaddar, dupatta, shawl, etc. (no.)	54	4
365	lungi (no.)	54	4
366	gamchha, towel, handkerchief (no.)	54	4
367	hosiery articles, stockings, under- garments, etc. (no.)	54	4
368	ready-made garments (no.)	53	4
370	headwear (no.)	54	4
371	knitted garments, sweater, pullover, cardigan, muffler, scarf, etc. (no.)	54	4
372	knitting wool, cotton yarn (gm)	54	4
373	clothing: others	54	4
374	clothing: second-hand	54	4
379	clothing: s.t. (360-374)		

380	bed sheet, bed cover (no.)	54	4
381	rug, blanket (no.)	52	4
382	pillow, quilt, mattress (no.)	54	4
383	cloth for upholstery, curtain, table- cloth, etc. (metre)	54	4
384	mosquito net (no.)	54	4
385	mats and matting (no.)	54	4
386	cotton (gm)	47	4
387	bedding: others	54	4
389	bedding, etc.: s.t. (380-387)		
390	leather boots, shoes	59	5
391	leather sandals, chappals, etc.	59	5
392	other leather footwear	59	5
393	rubber/ PVC footwear	61	10
394	other footwear	59	5
399	footwear: s.t. (390-394)		
400	books, journals	58	7
401	newspapers, periodicals	57	7
402	library charges	121	32
403	stationery	123	32
404	tuition and other fees (school, college, etc.)	121	32
405	private tutor/ coaching centre	121	32
406	other educational expenses	121	32
409	education: s.t. (400-406)		
410	medicine	70	33
411	X-ray, ECG, pathological test, etc.	122	33
412	doctor's/surgeon's fee	122	33
413	hospital & nursing home charges	122	33
414	other medical expenses	122	33
419	medical - institutional: s.t. (410-414)		
420	medicine	70	33
421	X-ray, ECG, pathological test, etc.	122	33
422	doctor's/surgeon's fee	122	33
423	family planning	122	33
424	other medical expenses	122	33
429	medical - non-institutional: s.t. (420-424)		
430	cinema, theatre	129	34
431	mela, fair, picnic	129	34
432	sports goods, toys, etc.	105	34
433	club fees	129	34
434	goods for recreation and hobbies	105	34
435	photography	94	34
436	video cassette/ VCR/ VCP(hire)	94	34
437	cable TV connection	94	34
438	other entertainment	129	34
439	entertainment: s.t. (430-438)		
440	spectacles	105	16
441	torch	105	16
442	lock	105	16
443	umbrella, raincoat	105	16
444	lighter (bidi/ cigarette/ gas stove)	105	16
445	other goods for personal care and effects	105	16
449	goods for personal care and effects: s.t. (440-445)		
450	toilet soap	71	9
451	toothbrush, toothpaste, etc.	62	9
452	powder, snow, cream, lotion	71	9
453	hair oil, shampoo, hair cream	71	9
454	comb	62	9
455	shaving blades, shaving stick, razor	82	9
456	shaving cream	71	9
457	sanitary napkins 00 458 other toilet articles	57	9
459	toilet articles: s.t. (450-458)		
460	electric bulb, tubelight	91	14
461	batteries	90	14
462	other non-durable electric goods	91	14
463	earthenware	76	16
464	glassware	76	16
465	bucket, water bottle/ feeding bottle & other plastic goods	62	10
466	coir, rope, etc.	53	10
467	washing soap/soda	71	9
468	other washing requisites	71	9
470	agarbati	71	9

471	flowers (fresh): all purposes	20	9
472	insecticide, acid, etc.	68	9
473	other petty articles	76	9
479	sundry articles: s.t. (460-473)		
480	domestic servant/cook	123	34
481	sweeper	123	34
482	barber, beautician, etc.	123	34
483	washerman, laundry, ironing	123	34
484	tailor	123	34
485	priest	128	34
486	legal expenses	130	34
487	postage & telegram	128	34
488	telephone charges	128	34
490	repair charges for non-durables	123	34
491	grinding charges	128	34
492	miscellaneous expenses	129	34
493	pet animals (incl. birds, fish)	129	34
494	other consumer services excluding conveyance	129	34
499	consumer services excluding conveyance: s.t. (480-494)		
500	air fare	112	25
501	railway fare	109	23
502	bus/tram fare	97	23
503	taxi, auto-rickshaw fare	97	23
504	steamer, boat fare	111	24
505	rickshaw (hand drawn & cycle) fare	99	23
506	horse cart fare	22	23
507	porter charges	128	23
508	petrol	29	8
510	diesel	29	8
511	lubricating oil	29	8
512	school bus/van	97	23
513	other conveyance expenses	98	26
519	conveyance : s.t. (500-513)		
520	house rent, garage rent (actual)	120	29
521	residential land rent	120	29
522	other consumer rent	120	29
529	rent: s.t. (520-522)		
539	**house rent, garage rent (imputed- urban only)**	**120**	**29**
540	water charges	108	17
541	other consumer taxes & cesses 549	130	34
549	consumer taxes and cesses: s.t. (540-541)		
550	bedstead	54	4
551	almirah, dressing table	54	4
552	chair, stool, bench, table	55	5
553	suitcase, trunk, box, handbag and other travel goods	63	5
554	foam, rubber cushion (dunlopillo type)	61	10
555	carpet, daree & other floor mattings	52	4
556	paintings, drawings, engravings, etc.	69	7
557	other furniture & fixtures (couch, sofa, etc.)	55	6
559	furniture & fixtures: s.t. (550-557)		
560	gramophone & record player	94	14
561	radio	94	14
562	television	94	14
563	VCR/VCP/DVD	94	14
564	camera & photographic equipment	94	14
565	tape recorder, CD player	94	14
566	gramophone record, audio/video cassette, etc.	94	14
567	musical instruments	105	14
568	other goods for recreation	105	14
569	goods for recreation: s.t. (560-568)		
570	gold ornaments	103	12
571	silver ornaments	103	12
572	jewels, pearls	103	11
573	other ornaments	103	11
579	jewellery & ornaments: s.t. (570-573)		
580	stainless steel utensils	82	16
581	other metal utensils	82	16
582	casseroles, thermos, thermoware	82	16
583	other crockery & utensils	82	16
589	crockery & utensils: s.t. (580-583)		
590	electric fan	91	13

591	air conditioner	91	13
592	air cooler	91	13
593	lantern, lamp, electric lampshade	91	13
594	sewing machine	91	13
595	washing machine	91	13
596	stove	91	13
597	pressure cooker/pressure pan	91	13
598	refrigerator	91	13
600	electric iron, heater, toaster, oven & other electric heating appliances	91	13
601	other cooking/household appliances	91	13
609	cooking and household appliances: s.t. (590-601)		
610	bicycle	99	19
611	motor cycle, scooter	98	19
612	motor car, jeep	97	19
613	tyres & tubes	61	19
614	other transport equipment	100	19
619	personal transport equipment: s.t. (610-614)		
620	hearing aids & orthopaedic equipment	102	14
621	other medical equipment	102	14
629	therapeutic appliances : s.t. (620-621)		
630	clock, watch	101	14
631	other machines for household work	91	14
632	personal computer	115	14
633	mobile phone handset	115	14
634	any other personal goods	93	14
639	other personal goods: s.t. (630-634)		
640	bathroom and sanitary equipment	87	16
641	plugs, switches & other electrical fittings	89	16
642	residential building & land (cost of repairs only)	129	16
643	other durables (specify)	105	16
649	residential building, land and other durables : s.t. (640-643)		
659	**durable goods : total (559+569+579+589+609+619+629+639+649)**		

Source: NSS (2006) WIOD (2012)

Appendix III: Summary Statistics 2004/05

Variable	Obs	Mean	Std. Dev.	Min	Max
HH CO_2	124644	2025.848	1861.983	7.323413	110981.5
Income	124644	46560.8	38017.33	171.6717	920746.8
PDS Dummy	124644	0.5576682	0.4966652	0	1
Urban Dummy	124644	0.3638041	0.4810951	0	1
HH-Size	124644	4.89182	2.522365	1	43
Age Head	124642	45.71692	13.57614	0	108
Sex Head	124644	0.1123921	0.3158495	0	1
Edu. Head	124591	4.165983	2.785832	1	11
LPG	124644	0.2830541	0.4504843	0	1
Gas	124644	0.0018372	0.0428237	0	1
Dung	124644	0.0511617	0.2203283	0	1
Charcoal	124644	0.0009868	0.0313982	0	1
Kerosene	124644	0.0399217	0.1957761	0	1
Electricity	124644	0.0011312	0.0336147	0	1

Source: NSS (2006) and CSO (2005)

AppendixV: Summary Statistics 2009/10

Variable	Obs	Mean	Std. Dev.	Min	Max
HH CO2	100855	3078.101	2917.591	45.03134	124513.3
Income	100855	69973.31	59234.38	288.9851	2089375
PDS Dummy	100855	0.5909771	0.4916559	0	1
Urban Dummy	100855	0.4138218	0.4925198	0	1
HH-Size	100855	4.645789	2.338262	1	35
Age Head	100855	46.22093	13.46178	2	105
Sex Head	100855	0.1122304	0.3156513	0	1
Edu. Head	100851	6.219611	3.665076	1	13
LPG	100855	0.3877646	0.4872428	0	1
Gas	100855	0.0014278	0.0377593	0	1
Dung	100855	0.0334837	0.1798968	0	1
Charcoal	100855	0.0010213	0.0319411	0	1
Kerosene	100855	0.0271776	0.1626016	0	1
Electricity	100855	0.0021119	0.0459076	0	1

Source: NSS (2012) and CSO (2005)

Appendix VI: Cross Correlations 2004/05

	HH CO2	Income	PDS D.	Urban D.	HH-Size	Age Head	Sex Head	Edu. Head	LPG	Gas	Dung	Charcoal	Kerosene	Electricity
HH CO2	1													
Income	0.8240*	1												
PDS D.	-0.2517*	-0.1845*	1											
Urban D.	0.2930*	0.1877*	-0.2884*	1										
HH-Size	0.2816*	0.3653*	0.1254*	-0.1011*	1									
Age Head	0.1877*	0.1931*	0.0798*	-0.0426*	0.2140*	1								
Sex Head	-0.0711*	-0.0936*	0.0113*	0.0209*	-0.1742*	0.0862*	1							
Edu. Head	0.3723*	0.3626*	-0.2334*	0.2576*	-0.0891*	-0.1408*	-0.1773*	1						
LPG	0.4754*	0.4129*	-0.3537*	0.4368*	-0.0538*	0.0689*	-0.0101*	0.4568*	1					
Gas	0.0211*	0.0306*	0.0088*	-0.0285*	0.0168*	0.0207*	-0.0093*	0.0157*	-0.0270*	1				
Dung	-0.0329*	-0.0079*	0.0587*	-0.1194*	0.1020*	0.0057*	-0.0290*	-0.0693*	-0.1459*	-0.0100*	1			
Charcoal	-0.0015	-0.0038*	-0.0209*	0.0240*	-0.0034*	-0.0087*	0.0115*	-0.0008	-0.0197*	-0.0013	-0.0073*	1		
Kerosene	-0.0461*	-0.0645*	0.0117*	0.1950*	-0.0949*	-0.0732*	0.0129*	-0.0070*	-0.1281*	-0.0087*	-0.0474*	-0.0064*	1	
Electricity	0.0186*	0.0022*	-0.0210*	0.0276*	-0.0132*	-0.0057*	-0.0014	0.0211*	-0.0211*	-0.0014	-0.0078*	-0.0011	-0.0069*	1

Source: NSS (2006) and CSO (2005), Note: * indicates 5% significance level.

Appendix VII: Cross Correlations 2009/10

	HH CO2	Income	PDS D.	Urban D.	HH-Size	Age Head	Sex Head	Edu. Head	LPG	Gas	Dung	Charcoal	Kerosene	Electricity
HH CO2	1													
Income	0.8750*	1												
PDS D.	-0.2811*	-0.2369*	1											
Urban D.	0.2546*	0.1756*	-0.3480*	1										
HH-Size	0.2445*	0.3136*	0.1316*	-0.1075*	1									
Age Head	0.1793*	0.1698*	0.0712*	-0.0319*	0.2190*	1								
Sex Head	-0.0633*	-0.0787*	0.0174*	0.0233*	-0.1637*	0.1024*	1							
Edu. Head	0.3076*	0.3004*	-0.2841*	0.2530*	-0.1156*	-0.1708*	-0.1921*	1						
LPG	0.4076*	0.3614*	-0.4165*	0.4477*	-0.0555*	0.0774*	-0.0120*	0.4354*	1					
Gas	0.0357*	0.0420*	0.001	-0.0264*	0.0215*	0.0148*	-0.0085*	0.0053*	-0.0301*	1				
Dung	-0.0334*	-0.0188*	0.0551*	-0.0970*	0.0759*	0.0009	-0.0189*	-0.0779*	-0.1481*	-0.0070*	1			
Charcoal	-0.0013	-0.0040*	-0.0176*	0.0305*	0.001	0.0008	0.0122*	0.0003	-0.0254*	-0.0012	-0.0060*	1		
Kerosene	-0.0443*	-0.0527*	0.0106*	0.1290*	-0.0781*	-0.0619*	0.0032*	-0.0262*	-0.1330*	-0.0063*	-0.0311*	-0.0053*	1	
Electricity	0.0160*	0.0025*	-0.0311*	0.0350*	-0.0122*	-0.0102*	0.0028*	0.0060*	-0.0366*	-0.0017	-0.0086*	-0.0015	-0.0077*	1

Source: NSS (2012) and CSO (2005), Note: * indicates 5% significance level.

Appendix VIII: Income Elasticities per Income Quintiles

	Quint 1		Quint 2		Quint 3		Quint 4		Quint 5	
	coeff	se	coeff	se	coeff	se	coeff	se	coeff	se
Vegetables	-0.0674***	(0.00702)	-0.189***	(0.00665)	-0.207***	(0.00608)	-0.178***	(0.00399)	-0.114***	(0.00128)
Animal protein	0.0718***	(0.00176)	0.0740***	(0.00494)	0.0377***	(0.00535)	0.00501	(0.00369)	-0.0403***	(0.000901)
Processed fod	0.00480	(0.00294)	0.00360	(0.00413)	0.0241***	(0.00428)	0.0136***	(0.00394)	0.00883***	(0.00177)
Tobacco, pan, tox	0.00207	(0.00172)	0.00756***	(0.00273)	-0.00344	(0.00292)	-0.00489**	(0.00196)	-0.00244***	(0.000652)
Fuel, light	-0.0110***	(0.00206)	-0.0240***	(0.00334)	-0.0281***	(0.00317)	-0.0384***	(0.00206)	-0.0328***	(0.000571)
Clothing, shoes	-0.0436***	(0.00409)	-0.00905***	(0.00249)	-0.00880***	(0.00248)	-0.0167***	(0.00168)	-0.0195***	(0.000519)
Education	0.00449***	(0.00109)	0.0235***	(0.00248)	0.0246***	(0.00303)	0.0268***	(0.00254)	0.0275***	(0.00206)
Entertainment	0.00308***	(0.000355)	0.00723***	(0.000907)	0.00909***	(0.00110)	0.0106***	(0.000846)	0.00217***	(0.000365)
Medical goods	0.0175***	(0.00143)	0.0255***	(0.00450)	0.0327***	(0.00536)	0.0388***	(0.00441)	0.0294***	(0.00257)
Toiletary	-0.0135***	(0.00245)	-0.00627***	(0.00158)	-0.0105***	(0.00153)	-0.0120***	(0.00105)	-0.0144***	(0.000325)
Services, rent, tax	0.0260***	(0.00181)	0.0609***	(0.00550)	0.0968***	(0.00684)	0.131***	(0.00558)	0.135***	(0.00293)
Durables, building	-4.13e-05*	(2.27e-05)	-8.85e-06	(3.58e-05)	5.00e-05	(5.30e-05)	4.52e-05*	(2.65e-05)	1.59e-05	(1.17e-05)
Transport	0.00584***	(0.00128)	0.0265***	(0.00249)	0.0325***	(0.00301)	0.0244***	(0.00242)	0.0207***	(0.00160)
Personal goods	1.11e-05**	(5.00e-06)	2.35e-05	(2.02e-05)	7.17e-05***	(2.37e-05)	7.95e-05***	(2.67e-05)	5.06e-05***	(1.91e-05)

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1