Courant Research Centre

'Poverty, Equity and Growth in Developing and Transition Countries: Statistical Methods and Empirical Analysis'

Georg-August-Universität Göttingen
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Discussion Papers

No. 161

Affluence and emission trade-offs: evidence from Indonesian household carbon footprint

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July 2014

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Affluence and emission trade-offs: evidence from Indonesian household carbon footprint

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Abstract

The objectives of this study are to analyze the household carbon footprint pattern in Indonesia and to analyze the determinants of the growing carbon footprint in this emerging economy. To measure the household emissions, we combine national input-output, emission database to generate sectoral CO2 emission intensities and matched these intensities with two waves of national expenditure surveys from 2005 and 2009. We then use this household CO2 emission for investigating the drivers of the rise in emissions from the micro perspective. Comparing CO2 intensities, the results show that transportation, fuel-light, are the two most intensive emitting sectors in Indonesia. We also found a significant difference of household carbon emission comparing between per capita expenditure level, region, and education. Regression analysis suggests that expenditure is the main determinant of household emission. Although other household characteristics determine the variation of emission, it is shown that varying affluent level differs significantly in term of carbon footprint. The decomposition analysis confirms that changes in emission are dominantly contributed by the rise of expenditure comparing between household level and over the two periods. Expenditure elasticities analysis suggest that the rise of household emission is mainly caused by general volume increase in overall household consumption, and not by shifting the share of expenditure amongst consumption basket.

Keywords: carbon footprint, household, Indonesia

JEL classification code: O120, O130, Q54, Q56, Q410

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1. Introduction

Climate change is one of the pressing challenges of the global world, including Indonesia. In this emerging economy, the middle income group has been growing and consuming more goods and services, causing households to directly and indirectly contribute to the rising emissions. However, a quick glance at the literatures on household carbon footprint were conducted in the developed countries compared to developing countries (e.g. Kenny & Gray (2009), Girod & de Haan (2010), Murthy *et al* (1997), Parikh *et al* (1997)). With that in regard, this study will fill in that gap by estimating the average household carbon footprint of Indonesia as one of emerging economies.

In order to calculate the environmental consequences of household activities, Lenzen (1998) analyses energy and green house gas (GHG) in the case of Australian household. It was found that the direct consumption of fuels and electricity accounts for about 30% of the total energy expenditure and 17% of the total GHG expenditure, the remainder of which was indirectly consumed through the purchasing of non-energy commodities. Bin & Dowlatabadi (2005), using the US Consumer Life Approach (CLA), estimates that more than 80% of the energy used and the CO_2 emitted in the US are a consequence of consumer demands and their supporting activities. Kenny & Gray (2009) show that 42% of the total CO_2 emissions of Irish households is related to home energy use, 35% to transportation, and 21% to air travel and other fuel intensive leisure activities. Moreover, using the Swiss household consumption database, Girod & de Haan (2010) found that the most important consumption categories are living (shelter), car driving, and foods, which together account for nearly 70% of total GHG emissions.

Apart from using computation, there are several studies that investigate the determinants of the household carbon footprint using a different method. For cross-country perspective, Lenzen *et al.* (2006) focused on the importance of income growth among the analyzed countries and investigated the evidence of the Environmental Kuznets Curve (EKC), which proposes an inverted U-shaped relationship between per capita income and environmental degradation. However, they found that the data does not support this hypothesis and argued that household energy requirements increases monotonically with expenditure where no turning point is observed.

From the micro perspective, consumption patterns and household emissions may differ due to differences in characteristics including household income. The 'aggregation theory', which proposes that aggregation over households with unequal incomes leads to rising emissions with rising incomes (Heerink, *et al*, 2001), could be a reason for this. Income portfolios and levels as well as the related patterns of consumption and production determine the carbon footprint of households. Findings show that income is the main driver of carbon footprints (Murthy *et al.*, 1997, Parikh *et al.*, 1997). Parikh *et al.* (1997), for the Indian case analyzed consumption patterns by income groups and what the carbon dioxide implications were. Their approach is based on an input-output (IO) model that uses consumption expenditure distribution data examining the direct and indirect carbon-dioxide emissions due to consumption of each of these income classes. Results showed that 62% of carbon emissions was due to private consumption, 12% was due to direct consumption by households and the remaining 50% was due to the indirect consumption of intermediates. The rich have a more carbon intensive lifestyle compared to the poor. Similarly, for Chinese case, Li & Wang (2010) found that besides income being the main determinant, household characteristics such as household size, education, age of household head and geographic factors also significantly influenced the carbon footprint both in rural and urban area.

This study will attempt to answer the following research questions. First, what are the characteristics of carbon consumption of households in Indonesia? How do they differ in terms of expenditure and other household characteristics? Second, what are the main determinants of the growing carbon footprint in fast growing emerging countries, and which consumption categories are the most and least carbon intensive? Third, how will carbon emissions develop over time when household incomes increase?

2. Methodology

We use the emissions database from the Global Trade Analysis Project-Environmental Account (GTAP-E), the Indonesian Input-Output table, and the Indonesian household expenditure survey (Susenas) from the 2005 and 2009 database. The GTAP-E includes CO_2 emissions from fossil fuels combustion (coal, oil, gas, petroleum products) and cement production, but does not include emissions from land use change which is also important in Indonesia (PEACE, 2007). We combine the IO analysis with GTAP-E and Susenas to calculate the indirect and direct carbon emissions of households. This method is convenient for describing and explaining the environmental impact of different household types (Kok *et al*. 2006). Expenditure amounts on consumption items found on the expenditure survey are multiplied with the corresponding value of the emission intensity. Each consumption item in the expenditure survey categorized into a specific economic sector.

2.1. Measuring emission intensities and deriving the household carbon footprint

To estimate an Indonesian household's carbon footprint, we follow Lenzen (1998)'s approach which computed carbon embedded in an Australian household's final consumption. We basically trace the carbon content of each final consumption item back to its intermediates and factor in the direct and indirect emissions that occur from consumption. We focus on CO_2 emissions since it represents the largest share of GHG emissions under the Kyoto Protocol. Applying the expenditure approach, Figure 1 shows how CO_2 intensities of goods and services in a given economy can be traced using IO analysis.[2]

In the first step, CO_2 intensities of each Indonesian IO sector (in the local currency unit) were estimated. We assume the Single Region Model which suggests that imported goods are produced with the same technology as domestic goods, which means that emissions of both imported and local products are not estimated differently[3]. One can argue that products in the developed world are produced more efficiently and may have lower emission intensities, however that matter is beyond the scope of this study. The CO_2 emission intensities were derived using the Leontif inverse of the IO table multiplied by the carbon intensities derived from GTAP.

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[2] There are three available methods in accounting the environmental load of GHG emission released by household consumption, including basic approach, expenditure approach and process approach (Kok et al, 2006). In this study, the expenditure approach is used since we will use national household expenditure data.

[3] There is also another version of input-output table called World Input Output (**http://www.wiod.org**) which has a set of harmonized supply and use tables, alongside with data on international trade in goods and services. However the dataset are very disaggregated and more focus on industry-level database.

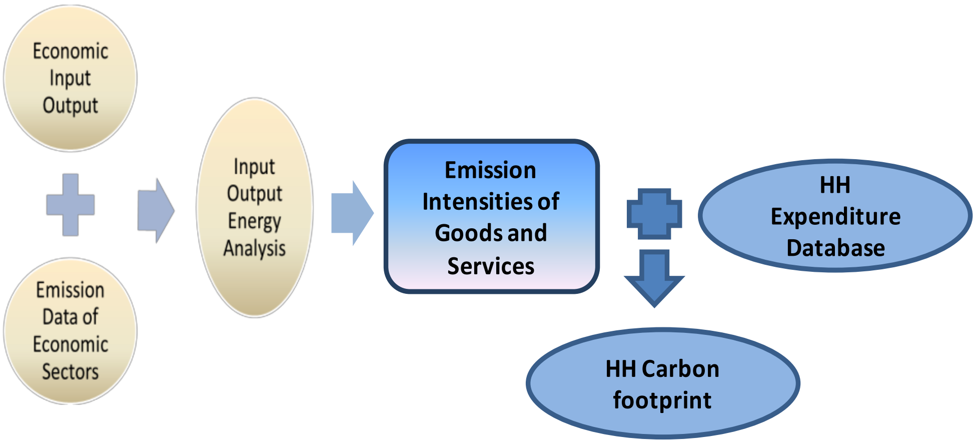


Figure 1. IO Energy Analysis with Household Expenditure Data
Source: modified from Kok *et al.* (2006)

In the second step, the CO_2 emission intensities of each economic sector were matched to their household expenditure category. We refer to the Susenas questionnaire and GTAP sector classification (Huff *et al* 2000) to match these sectors. Consumption expenditures from Susenas are then multiplied to the derived CO_2 emission intensity, then by summing them up we get the household carbon footprint[4]. The method used in deriving the household carbon footprint follows the concept of the consumer responsibility model (Suh, 2009).

The Single Region Model approach assumes that the local environmental and energy technology used in the production is the same as it is abroad. Therefore, we measure the sum of direct and indirect emissions from industrial sectors. Direct emissions from final demand can be characterized as follows:

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

where c', E^{fd}, and y represent the inverse of emissions coefficient vector, the energy use matrix, and the final demand vector, respectively.

Indirect emissions CO_2^{ind}, are divided into three sources: (a) emissions from domestic production for domestic final demand, (b) emissions from imported intermediates; and (c) emissions from imported products for domestic final demand (excluding exports). 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 $(I-A)^{-1}$, the sectoral emissions can be estimated.

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

[4] The overview of data matching scheme of the input-ouput sectors with the household expenditure categories via the GTAP energy intensity is outlined as follows. There are 175 economic sectors in Indonesia, which were mapped using the GTAP sectors and aggregated into 57 sectors (Huff et al, 2010). The data on household expenditure is rather disaggregated, consists around 340 expenditure categories.

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

Direct and indirect emissions from consumption can be computed as follows:

$$CO_2 = CO_2^{fd} + CO_2^{ind} \tag{3}$$

$$CO_2 = c'\{E^{fd}y + E^{ind}[(I-A)^{-1}y_{\neq exp} + ((I-A_{tot})^{-1} - (I-A)^{-1})y_{\neq exp} + (I-A_{tot})^{-1}y_{imp\neq exp}\ ]\} \tag{4}$$

Finally, the above carbon intensities (in kg CO_2/Rp) of each sector are multiplied with the household consumption amount recorded from Susenas (in Rp) for the respective category and then the products from all categories are summed up for each household. The carbon footprint CO_2^{hh} (in kg of CO_2) for each household using the following equation:

$$CO_2{}^{hh}{}_i = \sum_i^j \left(CO_{2_j} * Exp_{ij}\right) \tag{5}$$

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

2.2. Drivers of the household carbon footprint

This section will investigate the emission implications, household characteristics and their consumption decisions. The linkage between the expenditure choices and the carbon footprints will be determined from the carbon intensity of particular items consumed in Indonesia. From the list of consumption items in Susenas, we will analyze the determinants of particular carbon-intensive consumption preference, including choices related to household operations such as fuel-light and transportation. The empirical analysis is postulated as follows.

$$lnCO_2^{hh}{}_i = \alpha + \beta_1 lnEXP_i + \beta_2 X_i + \varepsilon_i \tag{6}$$

The ordinary least square (OLS) method will first be employed to regress the household carbon footprint CO_2^{hh} on household expenditure, *EXP*, as a proxy for income, and a range of control variables X, including *region, household members, education, gender and age of household head.* To capture the nonlinearity effect on household carbon footprint, a squared term for the expenditure, household size, and age will be incorporated as well.

As we derive household CO2 emission from expenditure, one can argue that our expenditure variable is highly correlated with the carbon footprint. To deal with this issue, we can proxy it with income quintile dummies Q, which leads us to divide regression (6) into two stages, as follows

$$CO_2^{hh}{}_i = \alpha + \beta_q \sum_{q=1}^{5} Q_{qi} + \beta_{x_i} X_i + \varepsilon_i \tag{7}$$

and

$$\varepsilon_i = \alpha + \beta_1 X_i + \gamma_i \tag{8}$$

where ε_i is the residual from the regression (7).

By estimating the effect of the expenditure quintiles on the carbon footprint in (7) and then explaining the residuals with the control variables in (8), we reveal the true effect of the household characteristics on the carbon footprint. Of particular objectives are to understand the drivers of the heterogeneity of the carbon footprints of households, and to identify possible policy approaches which could be used to reduce emissions without compromising the well-being of households.

In addition, we will also apply an quantile regression in the analysis. We do this to account for the possibility that the distribution of the household emissions is highly skewed. In this case the quantile regression analysis will be more robust to outliers than the OLS regression, as it does not assume that the data are normally distributed. Another reason to use this regression is that we will be allowed to study the impact of the regressors, such as income, on the location and the scale parameters of the model. Technically, while the OLS estimator minimizes the sum of squared residuals, $\sum e_i^2$, the quintile regression minimizes the sum that gives penalties of about $(1-q)|ei|$ for over-prediction and of about $q|ei|$ for underprediction" (Cameron & Trivedi, 2010).

Our analysis assumes that the impact of income and control variables for lower carbon emitting households is different from the households with a high carbon footprint. With this in regard, the quintile regression estimates the impact of a one unit change in income on a specific quintile q of our response variable of the household carbon footprint. Technically, the q_{th} quintile regression estimator minimizes over βq via linear programming:

$$Q(\beta_q) = \sum_{i:y \geq x'\beta}^{N} q|y_i - x'_\beta| + \sum_{i:y \leq x'\beta}^{N} (1-q)|y_i - x'_\beta| \qquad (9)$$

where $0 < q < 1$ and the choice of q (here we choose q=0.1 and q=0.9) estimate different values of β. If $q=0.9$ then more weight is placed on the prediction for observations with $y_i \geq x'_i\beta_q$.

3. Decomposing the changes in the carbon footprint

Another important issue in comparing household emission changes from two periods is determining what the drivers are of these changes. If one considers emissions to be an output of the process, we could argue that it is product of driving forces. One theory is given Kaya (1990) who provides an intuitive approach to the interpretation of the historical trend of CO_2 emissions. This method, which is widely known as the Kaya Identity, suggests that the total emissions level can be found by calculating the changes in four inputs, i.e. population size, per capita income, energy use per unit of GDP, and CO_2 emissions per unit of energy used. Using this decomposition technique, we can then directly link CO_2 emission levels to the population effect, and level of economic affluence (measured by per capita expenditure), carbon emission intensity (per energy use) and energy intensity (per output)[5]. Finally we can find the main driving forces of changes in emission levels in the periods observed.

In macro analysis, the Kaya Identity suggests that CO_2 emission levels are the product of: (i) the carbon intensity of the energy supply (CO_2/E), (ii) the energy intensity of the economic

[5] In terms of policy, the carbon dioxide intensity of output generally focuses on the promotion of low (or zero) carbon sources of energy.

activity (E/GDP), (iii) the economic per capita output, and population. However, since we do not have the data for energy intensities, in our analysis the Kaya identity is modified as follows:

$$CO2_i = HHsize_i * \frac{EXP_i}{HHSize_i} * \frac{CO2_i}{EXP_i} \tag{10}$$

where the household CO_2 emissions level is a function of household size, *HHsize*, per capita expenditure, *EXP/HHsize*, and emission intensity, CO_2/EXP.

In other words, we set up emission equation to calculate and decompose the growth of CO_2 emissions into the population effect, per capita expenditure effect (Rp/capita), and carbon intensity effects (CO_2/Rp), and expresses the result as a percentage of the base line CO_2 emissions level. Following Ang (2005), our decomposition will be done using the Logarithmic Mean Divisia Index (LMDI), which has several advantages as it gives a perfect decomposition (the results do not contain unexplained residual term), and it is consistent in aggregation. The LMDI approach is modify from (10) to make the following formula

$$\Delta CO2_i = C^T - C^0 = \Delta CO2_{HHsize} + \Delta CO2_{EXP/HHsize} + \Delta CO2_{CO2/EXP} \tag{11}$$

where

$$\Delta CO2_{HHsize} = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} \ln\left(\frac{HHsize_i^T}{HHsize_i^0}\right)$$

$$\Delta CO2_{EXP/HHSize} = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} \ln\left(\frac{(\frac{EXP}{HHsize})_i^T}{(\frac{EXP}{HHsize})_i^0}\right)$$

$$\Delta CO2_{CO2/Y} = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} \ln\left(\frac{(\frac{CO2}{EXP})_i^T}{(\frac{CO2}{EXP})_i^0}\right)$$

where $\Delta CO2_{HHsize}$, $\Delta CO2_{EXP/HHSize}$, and $\Delta CO2_{CO2/Y}$ represent changes in CO_2 emissions because of population, expenditure, and the carbon intensity effect, respectively.

4. Expenditure elasticites of emission

The demand analysis is generally used to measure the change in demand for any particular good due to the change in income. This demand function is derived from the utility maximization equation of the consumer, which depends on the prices of goods and income of the individuals (Deaton & Muellbauer, 1980). We modify this demand theory by replacing the demand for goods with CO_2 emissions given the consumption of the respective goods. By applying this, we can analyze the responsiveness of CO_2 emissions of any household consumption category to a change in household affluence, which is proxied by household expenditure.

As suggested by the conventional Engel curves, we should include price as one of the independent variables. However, as that there is no price data in Susenas, we will estimate the expenditure elasticites of emission without using prices, meaning that the response of CO_2 emissions will only be dependent on the expenditure amount and socio-economic level of the households. There is no necessity to address the homogeneity restriction, with the adding-up restriction leading to linear budget constraints as the necessary requirement left for the equation to estimate. We will estimate the following model:

$$sCO2_{ij} = \beta_0 + \beta_{1_{ij}} \ln EXP_i + \beta_{2_{ij}} X_i + \varepsilon_{ij} \quad (12)$$

where $sCO2_{ij}$ represents the share of CO_2 emissions of jth consumption category to total household CO_2 emission by the i-*th* household, $lnEXP_i$ is the total expenditure of household i in natural logs, X_i is a vector with household characteristics and the error term ε_{ij}[6].

5. Results and discussions

5.1. Descriptive analysis

Susenas 2005 and 2009 consist of data on household expenditures of more than 257,000 and 291,753 Indonesian households, respectively[7]. **Figure 2** provides an overview on what households spent their income on in 2005 and 2009. In general expenditure increased by 72.27% (nominal) and 24.83% (deflated). In addition, the structure of the expenditure shares varies largely between rural and urban households, changing further over time. Compared to urban households, rural households spent a larger fraction of their income on food items and a much smaller share on recreation, services, rent and taxes. In general, comparing two surveys we find that food expenditure declined as expected. Moreover, the share of telecommunication, transportation, health, education, and taxes have been increasing both in the rural and urban areas. The share of beverage goods has been increasing in urban areas as oppose to in rural areas where it has been decreasing. In contrast, the share of income that has been spent on housing and durable expenditures has been increasing for households in rural areas as oppose to household in urban areas where it has indeed been decreasing.

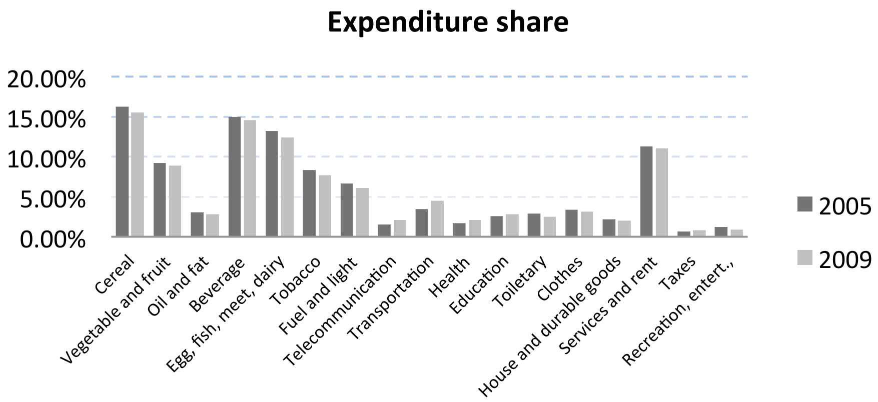


Figure 2. Expenditure share per consumption category
Source: Susenas (2005 and 2009)

[6] One might argue that there is a potential endogeneity problem due to the fact that our CO2 emissions are derived from expenditure. We could apply the instrumental variables estimation using (for instance) the households‘ asset index as an instrument for household expenditure. However, due to data limitation this is beyond of our scope of study.

[7] For both surveys, the consumption is disaggregated to around 300 consumption items. In 2005 (and 2009), about 62.57% (64.64%) of households were located in rural areas. There are about 12.12% (13.61%) of households were headed by a woman. The households consisted of about 4.08 (3.96) members which 81.36% (83.30%) of them had a maximum 5 household members. The average years of schooling of the household head was 6.1 (6.49) years. The annual household expenditure equaled to Rp 11.90 million (Rp 20.50 million). Urban households spent about Rp 16.50 million/year (Rp 27.70 million/year) compare to Rp 9.13 million/year (Rp 16.60 million/year) in urban area.

Before we begin the computation of the carbon footprint, it is very important to point out the coverage of Susenas compared to the private consumption database based on the macro perspective. If we compare the two databases, we see that the expenditure computation from Susenas will be significantly less than the national account (this underestimated measure can be also found in other studies e.g. Yusuf, 2006; Mishra, 2009). The deviation between the two measures is partly because of the computations in the national accounts that were constructed mainly from the supply side's economy while Susenas expenditures were taken from representative sample surveys[8].

Table 1. Estimate Private Consumption: Susenas vs National Account (Rupiah)

Year	Susenas	National Account	Percentage of Susenas to National Accounts
1996	210,507	460,297	45.73
1999	499,435	1,051,483	47.50
2002	760,003	1,557,099	48.81
2005	983,032	2,167,979	45.34
2009	1,695,220	4,031,541	42.05

Source: Our own computation is based on the monthly household expenditure (Susenas, BPS) and the monthly private (household) consumption (World Development Indicators, World Bank), various series.

The calculations found using the national account and Susenas can be seen in Table 1. Given the difference in the measurements from Susenas, which accounted for around 42-49% of the national account measurements, we scaled up the computation of household emissions by dividing household consumption by the percentage of Susenas to total expenditure based on national accounts when we computed the carbon emissions (Mishra, 2009). However, the fact that the aggregate from Susenas expenditures falls short from the national account (including in our calculation with the scaled up household emission) does not imply anything about the distribution of the expenditures across households, meaning that the discrepancy between expenditure items are more or less at the same amount.

In the next step, by incorporating the Indonesia input-output table and GTAP's energy use matrix, we extract the CO_2 emission intensity level of the 175 economic sectors[9]. The CO_2 emission intensity is measured in terms of kilotons per Million rupiah (or gram CO_2/Rupiah), which captures the amount of CO_2 released in the production of goods and services in the Indonesia economy. Table 2 presents the 10 most and least CO_2 intensive sectors. It can be seen that sectors which emit CO_2 intensively include: electricity, gas, cement, non-metallic minerals, glasses and their products, ceramics and clay products. In addition to those electric and manufacturing sectors, all transportation services are also very carbon intensive.

The least CO_2 intensive sector in the Indonesian economy involves the production of agricultural crops, including fiber crops, grains, sweet potato, fruits, and bean. These figures reflect the fact that these products do not use much energy in production compared to manufacturing and transportation sectors. In addition to the agricultural sectors, service sectors also have a lower CO_2 intensity, which include such industries as film and distribution

[8] Yusuf (2006) argue that the aggregate food expenditures (particularly staple food such as rice) are relatively closer to national accounts than non-food expenditures. In other words, non-food expenditure from Susenas is more under-estimated relative to food expenditure. One of the possible reasons is partly because that the higher-income households are under-represented in the Susenas sample. In addition, under-reporting of non-food expenditure by the higher income groups are commonly occur.

[9] We follow Huff e*t al* (2000) using concordance matrix between GTAP's emission data and all economic IO sectors, using MATLAB® software.

services, building and land rent. In general, agricultural related activities emit less CO_2 compared to manufacturing sectors.

Table 2. CO_2 intensity of economic sectors: top 10 and bottom 10

Number on list	Sectors	gr CO2/Rupiah
Top 10		
1	Electricity and gas	1.04962
2	Cement	0.44619
3	Other items of non-metallic materials	0.39552
4	Glass and glass products	0.38542
5	Ceramics and building materials from clay	0.37331
6	Ceramics and items made of clay	0.36825
7	Air transport services	0.20421
8	Railway services	0.17156
9	Marine transportation services	0.16338
10	River and lake transport services	0.16153
Bottom 10		
10	Other nuts	0.00380
9	Other animal products	0.00374
8	Soybean	0.00287
7	Cassava	0.00280
6	Vegetables	0.00266
5	Bean	0.00218
4	Fruits	0.00185
3	Sweet potato	0.00102
2	Grains and other foodstuffs	0.00078
1	Fiber crops	0.00031

Source: author's computation, based on GTAP-E and Indonesian IO. For detail sectors, see Appendix

The derived CO_2 emission intensities were then matched with the consumption categories in the Susenas 2005 and 2009. There are more than 300 consumption categories in the expenditure survey and this was aggregated to represent the major household expenditures. Figure 2 shows the average CO_2 emissions (in kg) from major expenditure categories. It is observed that CO_2 emissions vary based on the consumption item. The lowest CO_2 emissions were observed from the consumption of cereals, medical services, telecommunication services and recreation. On the other hand, the highest CO_2 emissions were observed from the consumption of transportation, fuel and light.

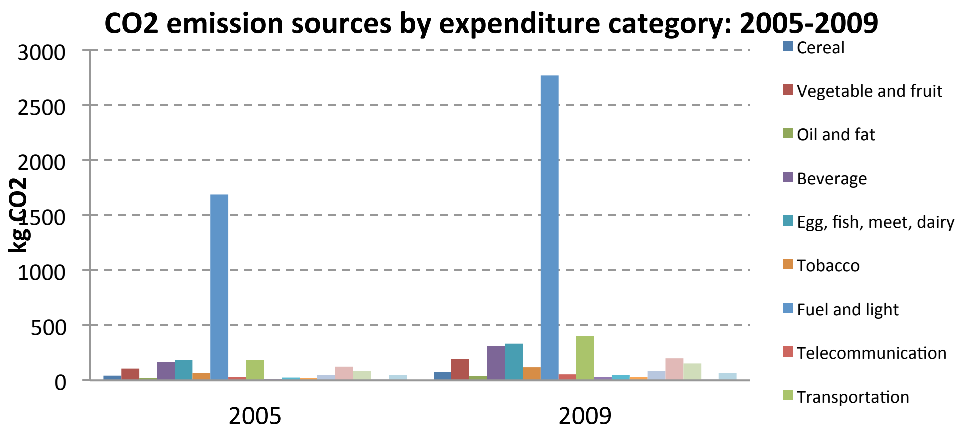


Figure 2. Emission in Expenditure Subgroup (2005 and 2009)
Source: own computation, based on GTAP-E, IO and SUSENAS

The disaggregation of the CO_2 emissions into regions and income levels is shown in Figure 3. We find large differences between the household carbon footprint of every income level. Additionally, we found a variations in the carbon emission levels of households of different educational attainments. In more detail, the carbon footprint of households from the 5th quintile income group is almost seven times as high as the carbon footprint of households from the 1st quintile, and still about three times as high as the level from households in the third quintile (middle income group). Considering these large differences, in the next step we analyze the drivers of the strong rise in household emissions of the middle and high-income classes. Also, we analyze various carbon intensive consumption categories and estimate the expenditure elasticities.

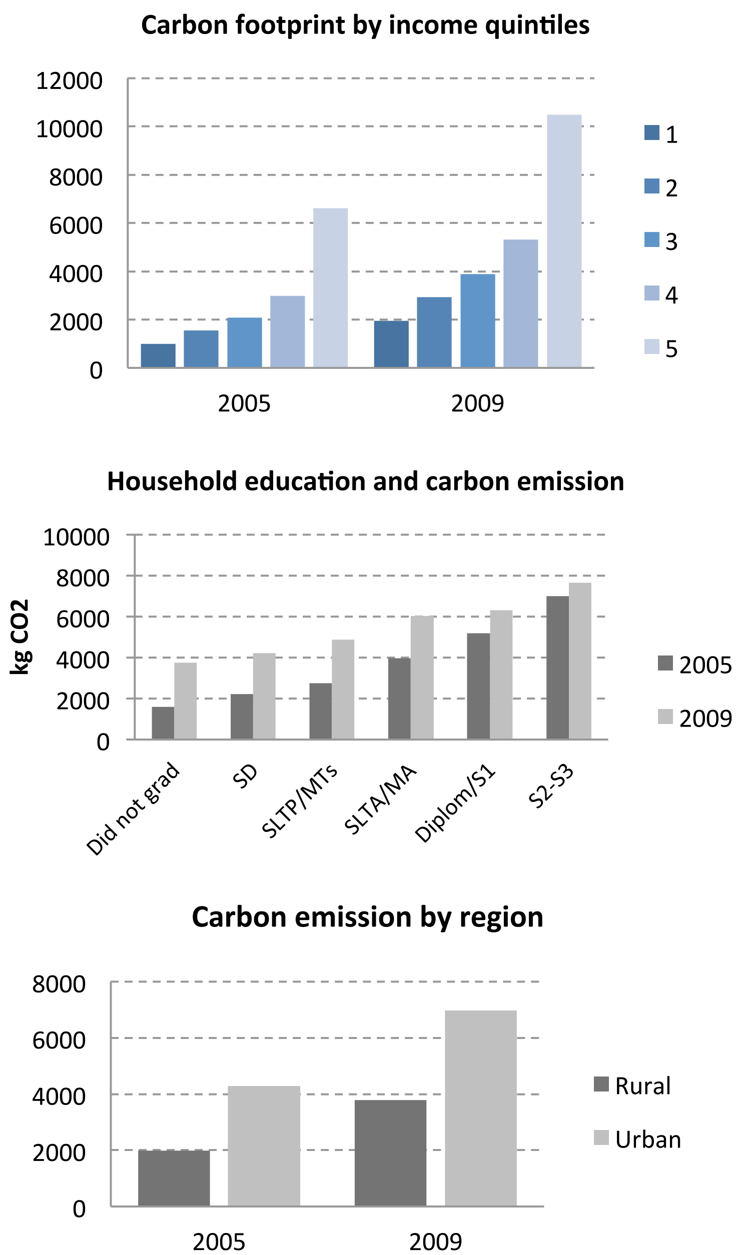
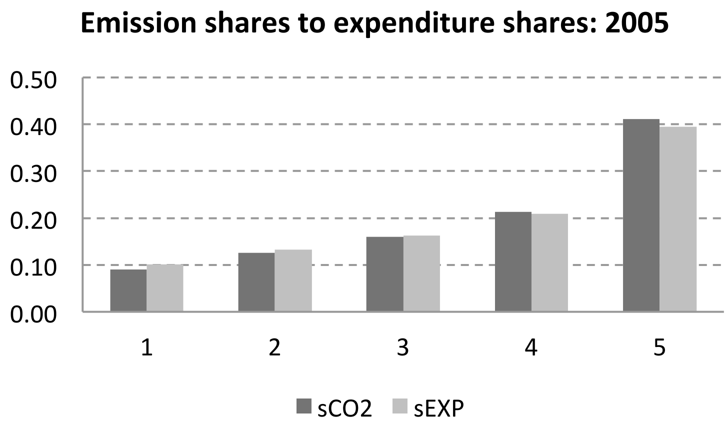


Figure 3. Carbon footprint by household affluence quintile, education attainment, and region (2005 and 2009)
Source: own computation, based on GTAP-E, IO and Susenas



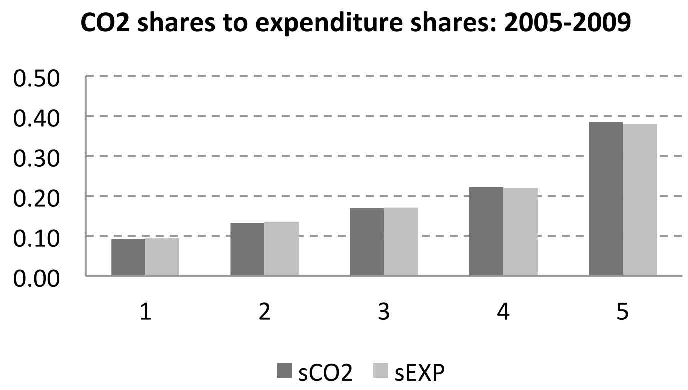


Figure 3b. CO2 emission shares to expenditure shares by quintile (2005 and 2009)

The emission profile of urban and rural households shows the huge disparity in the carbon footprint between the two locations. Urban household emissions are about twice the amount of rural households. Looking at fuel, light and transportation expenditures, on average urban households emits two times of the amount of CO_2 that is emitted by the rural households.

Comparing emission shares to expenditure shares, it can be seen that the emission shares are lower than expenditure shares from the first to the third quintile. In contrast, CO_2 emission shares of households in the top two quintiles are higher than their emission shares. This picture indicates that affluent households in the top two quintiles have a more carbon intensive lifestyle than households in the first three quintiles.

5.2. The determinants of household carbon footprint

Table 3 displays the results from the regression analysis of the household carbon footprint and its main determinants. Several model specifications were carried out to understand what drives the variation in CO_2 emission. In the first regression, the log of CO_2 emission was regressed on the log of expenditure and other control variables. In the second regression, the squared log of expenditure and dummies for different household characteristics were included. In the third regression, we regress the carbon footprint with only income quintiles. Regression IV, V and VI use the residual from the Regression III as the dependent variable and household characteristics as control variables.

From Regressions I and II, we find that all independent variables are statistically significant. In addition, expenditure has a nonlinear effect on the CO_2 emissions as the coefficient of squared household expenditure has a negative sign. This implies an inverted U shaped behavior of the carbon footprint towards income. This means, holding other factors constant, as income increases CO_2 emissions also increase, eventually reaching a turning point where the household carbon footprint starts to decline as household expenditure increases even farther. Furthermore, the more household members, the greater the age (of the household head), if the gender was female, and if the region was the urban area, the more carbon that was emitted. Moreover, number of household members and age of the household head both have non-linear relationships with the carbon footprint.

In the Regression III, we regress household emission with expenditure quintiles, which divide household into 5 equal parts by sorting the per capita expenditure out from lowest to highest. It is observed that households in the higher quintiles have a larger carbon footprint and the coefficients are statistically significant. Moving from the lowest quintile to the second lowest quintile increases the carbon footprint by 35% while moving from the lowest to the highest income quintile increases the household's carbon footprint by 125%.

Table 3. The Determinants of Household Carbon Footprint, 2005-2009

	I	II	III	IV Dep var: Residuals III	VI Dep var: Residuals III	VI Dep var: Residuals III
lnexp	1.045***	1.029***				
lnexp^2	-0.002***	-0.001**				
Expenditure quintile						
2			0.351***			
3			0.579***			
4			0.825***			
5			1.251***			
hhsize	0.004***	0.036***		0.345***	0.494***	
hhsizesq	-0.001***	-0.008***		-0.019***	-0.050***	
hhsizecub		0.000***			0.002***	
age	0.005***	0.013***		0.008***	0.011***	
agesq	-0.000***	-0.000***		-0.000***	-0.000***	
agecub		0.000***			0.000***	
HH size (#)						
2						0.424***
3						0.700***
4						0.903***
5						1.054***
6						1.176***
7+						1.325***
HH-head age						
25-44						0.081***
44-64						0.133***
65+						0.148***
Urbanity	0.108***	0.109***		0.240***	0.240***	0.242***
Education						
Elementary	0.020***	0.020***		0.076***	0.073***	0.069***
Secondary	0.039***	0.039***		0.125***	0.121***	0.115***
High school	0.068***	0.067***		0.200***	0.196***	0.191***
At least college	0.068***	0.068***		0.298***	0.299***	0.298***
Married HH-head	0.044***	0.037***		0.055***	0.027***	0.010***
Female HH-head	0.053***	0.052***		0.036***	0.031***	0.030***
Survey year 2009	0.067***	0.067***	0.625***	0.019***	0.018***	0.019***
_cons	-9.139***	-9.158***	6.833***	-1.512***	-1.730***	-1.145***
Number of observations	549,659	549,659	549,659	549,659	549,659	549,659
R2	0.828	0.828	0.505	0.417	0.422	0.420
Including province dummy	Yes	Yes	Yes	Yes	Yes	Yes

Note: Regression I-III and quantile regression, dependent variable: total household carbon footprint. Regression 4 and 5, dependent variable is residual from Regression III. ***, **, and * denote $p<0.01$, $p<0.05$, $p<0.1$ respectively.

We then use the residual from the Regression III as the dependent variable of Regression IV, V, and VI, and household characteristics as control variables. The idea is to drop the income interventions and would reveal the effect of certain household characteristics on their carbon footprint without compromising the households' well-being. As indicated, it is not surprising that the coefficients of household characteristics (the control variables) are statistically significant and consistent with the previous specifications. In other words, household characteristics are some of the determinants of the household's carbon footprint.

From all regressions, we include dummies for all of the provinces. The estimated coefficients for all control variables with and without dummies do not change significantly. However, from the province fixed effects regression it can be seen that the emissions of provinces in Java and Bali islands, as well as South Sulawesi. The CO_2 emissions in East Kalimantan, South Kalimantan were higher than the amount in other provinces. The detailed estimations of the dummy coefficients are mentioned in the Appendix.

Table 4 presents quantile regression estimates using q=0.25; 0.50 (median regression); 0.75; and 0.90. Apart from theoretical background that quantile regression fits prediction over quintile which avoid sensitivity of the outliers with can dominate the regression if we just employ OLS, quintile regression will also estimate an equation expressing a quintile of conditional distribution as well as allow as to investigate the effects of the independent variables to differ over quintiles. In our case, this might be sensible since that household affluence effect might have different effect for any different household groups.

We found some interesting findings. It can be seen that low emitter household group seems to be more responsive (elastic) than the higher affluence household groups. In addition, we can see that expenditure square is no longer negative if we apply q=0.50 onward. Other control variables (household characteristics) are also behaving consistently as the OLS regression.

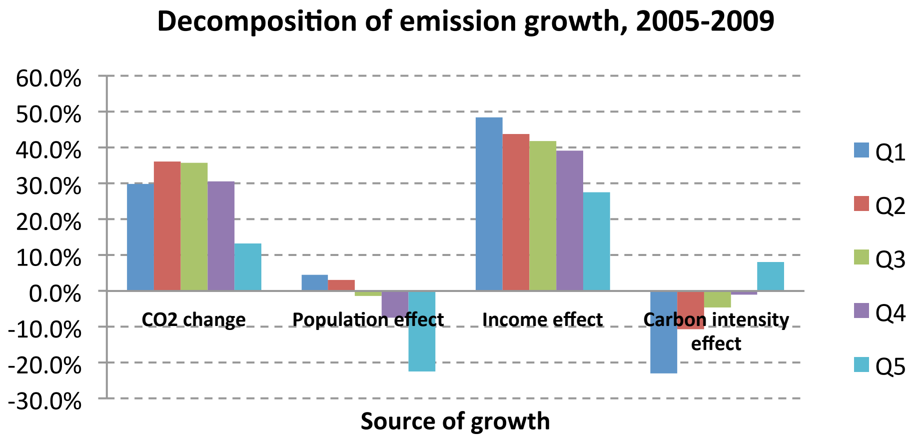
Table 4. Quantile Regression Estimates

	OLS		Q(0.1)		Q(0.25)		Q(0.50)		Q(0.75)		Q(0.90)	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
lnexp	1.045***	*0.024*	1.967***	*0.039*	1.525***	*0.03*	0.908***	*0.025*	0.358***	*0.025*	0.180***	*0.033*
lnexpsq	-0.002***	*0.001*	-0.028***	*0.001*	-0.016***	*0.001*	0.001*	*0.001*	0.017***	*0.001*	0.021***	*0.001*
hhsize	0.004***	*0.001*	0.067***	*0.005*	0.061***	*0.003*	0.051***	*0.003*	0.037***	*0.002*	0.025***	*0.003*
hhsizesq	-0.001***	*0.000*	-0.014***	*0.001*	-0.013***	*0.001*	-0.012***	*0.000*	-0.009***	*0.000*	-0.007***	*0.001*
hhsizecub	0.000***	*0.000*	0.001***	*0.000*	0.001***	*0.000*	0.001***	*0.000*	0.000***	*0.000*	0.000***	*0.000*
age	0.005***	*0.000*	0.022***	*0.001*	0.022***	*0.001*	0.021***	*0.001*	0.017***	*0.001*	0.014***	*0.001*
agesq	-0.000***	*0.000*	-0.000***	*0.000*	-0.000***	*0.000*	-0.000***	*0.000*	-0.000***	*0.000*	-0.000***	*0.000*
agecub	0.000***	*0.000*	0.000***	*0.000*	0.000***	*0.000*	0.000***	*0.000*	0.000***	*0.000*	0.000***	*0.000*
Urbanity	0.108***	*0.001*	0.210***	*0.002*	0.207***	*0.001*	0.177***	*0.001*	0.143***	*0.001*	0.122***	*0.002*
Married HH-head	0.044***	*0.002*	0.048***	*0.004*	0.053***	*0.003*	0.052***	*0.003*	0.045***	*0.002*	0.033***	*0.003*
Female HH-head	0.053***	*0.002*	0.055***	*0.004*	0.055***	*0.003*	0.050***	*0.003*	0.044***	*0.003*	0.031***	*0.003*
SD	0.020***	*0.002*	0.044***	*0.003*	0.029***	*0.002*	0.018***	*0.002*	0.014***	*0.002*	0.005*	*0.003*
SLTP	0.039***	*0.002*	0.051***	*0.004*	0.032***	*0.003*	0.019***	*0.002*	0.014***	*0.002*	0.004	*0.003*
SLTA	0.068***	*0.002*	0.081***	*0.004*	0.062***	*0.003*	0.047***	*0.002*	0.039***	*0.002*	0.029***	*0.003*
at least college	0.068***	*0.002*	0.086***	*0.005*	0.074***	*0.004*	0.065***	*0.003*	0.057***	*0.003*	0.042***	*0.004*
Survey year 2009	0.067***	*0.001*	0.045***	*0.002*	0.047***	*0.001*	0.048***	*0.001*	0.061***	*0.001*	0.079***	*0.002*
_cons	-9.139***	*0.197*	-17.869***	*0.324*	-13.654***	*0.246*	-7.905***	*0.207*	-2.702***	*0.208*	-0.716***	*0.268*
#Obs	549,659		549,659		549,659		549,659		549,659		549,659	
(pseudo) R2	0.828		0.5538		0.55893		0.5639		0.5732		0.576	

5.3. Decomposition analysis

The result of the decomposition of the growth of per capita CO_2 emissions from 2005 to 2009 can be seen in Figure 4. From the perspective of contributors to CO_2 emissions, we can clearly show that rising expenditures is the largest contributor to the rise in CO_2 emissions in all quintiles. This rise in expenditures has the largest effect in the lowest quintile, which means that rising the per capita expenditure of households in this quintile will more greatly increase CO_2 emission than the same rise in per capita expenditures of household in the upper quintiles would. Moving to affluent households, the expenditure effect then decrease gradually, but the effects in all quintile remain positive.

Moreover, the population effect (change in household size) has a positive effect on the first two quintiles, and has a negative effect on the third to the highest quintile. Moving from the lowest to highest household, we can clearly identify that the population effect has decreasing pattern. Finally, CO_2 intensity effect (measure as kg CO_2/Rp) has the largest negative contribution to CO_2 emission risings in the lowest quintile. This effect has negative sign from the first until third quintile and has a positive sign in the highest quintile. Moving from the lowest to highest quintile, we can say that households in the lowest quintile have a less carbon intensive lifestyle than more affluent households[10].



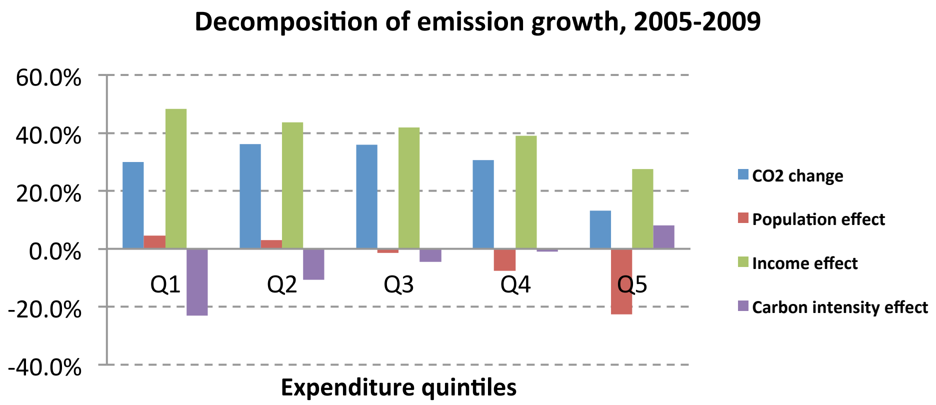


Figure 4. Decomposition of contribution of CO_2 emission growth[11]
Source: own computation, Susenas 2005-2006, IO 2005, GTAP-E 2005

From the quintile perspective, it can be seen that the rise in CO_2 emissions between 2005 and 2009 in the first and second quintiles is mostly a result of the (positive) per capita expenditure effect, followed by the (negative) CO_2 intensity effect and (positive) population effect. In the third and fourth quintiles, the rise of CO2 emissions is a result of the (positive) effect of rising per capita expenditures, but the effect is not as strong as it was in the first two quintiles. They are also affected by the negative contribution from carbon intensity and population effect. In the highest quintile, the expenditure is not as strong as it was in the lower quintiles, however it is still the largest contributor to the change in household

[10] Our results seems mirror of the figure from macro level analysis. For instance, of the EIA's (2012) International Energy Outlook 2011 reports that for non OECD countries rising affluence (output per capita) is the largest contributor to the change in CO2 emission, while emission intensities and energy intensities have a negative contribution to the change in CO2 emissions.

[11] Note: CO2 emissions and total expenditure are deflated

emissions. This effect was strengthen by the carbon intensity effect which only had a positive contribution in this quintile, but was weakened by the larger negative population effect.

6. Expenditure elasticities of emission

Due to the fact that expenditure is the main determinant of the household carbon footprint increases in the findings, we conduct an analysis of expenditure elasticities of CO_2 emissions that measure the responsiveness of CO_2 emissions (as a share of total household emissions) to a change in expenditure. There are some important issues to be taken into consideration for our analysis. First, dealing with the potential endogeneity problem, one could have a valid instrument for total expenditures, say for the instance asset index, and employ the instrument in a 2SLS procedure. However, our database unfortunately does not provide sufficient candidates as valid instruments for total expenditure, as we do not have sufficient database in Susenas. Second, in addition to the national estimation, we will also analyze expenditure elasticities for both rural and urban areas, as well as computing expenditure elasticities by household quintiles.

As the demand theory suggests, the negative coefficient of expenditure elasticities accounts for a declining share of any particular expenditure category due to rising income, and vice versa. Our results on expenditure elasticities on CO_2 emissions generally have the same direction as conventional Engle curve. **Table 5** reveals some important findings. We found that inferior goods, such as vegetables and cereals, have negative signs which mean that rising expenditure will reduce their share of CO_2 emissions of these consumption category. In the opposite direction, luxury goods such as health expenditures, housing, durable goods, transportation, services and rent have positive value, meaning that the rising of household affluence tends to contribute a higher share of CO_2 emissions to the total household emissions. Specifically, the transportation expenditure is so carbon intensive that an 1% increase of household expenditure will increase the share of CO_2 emissions from transportation by about 0.03%. Fuel and light consumption, another carbon intensive category, has a negative elasticity which means an increase in household expenditures will reduce the share of CO_2 emissions from these consumption items by about 0.07%.

Table 5. Expenditure elasticities of emission

Share of CO_2 emission	All Indonesia		Rural		Urban	
	2005	2009	2005	2009	2005	2009
Cereal	-0.0169	-0.0095	-0.0185	-0.0076	-0.0080	-0.0052
Vegetable and fruit	-0.0088	-0.0066	-0.0084	-0.0060	-0.0095	-0.0074
Oil and fat	-0.0044	-0.0029	-0.0054	-0.0032	-0.0033	-0.0024
Beverage	0.0045	-0.0006	0.0070	0.0023	0.0021	-0.0048
Egg, fish, meat, dairy	0.0033	0.0143	0.0074	0.0159	-0.0011	0.0122
Tobacco	0.0023	0.0046	0.0048	0.0089	-0.0005	-0.0011
Fuel and light	-0.0686	-0.0916	-0.0740	-0.1045	-0.0639	-0.0741
Telecommunication	0.0065	0.0068	0.0041	0.0064	0.0091	0.0073
Transportation	0.0277	0.0334	0.0304	0.0379	0.0250	0.0272
Health	0.0022	0.0021	0.0023	0.0019	0.0021	0.0024
Education	-0.0011	0.0047	-0.0004	0.0045	-0.0019	0.0048
Toiletry	-0.0012	-0.0007	-0.0014	-0.0008	-0.0009	-0.0007
Clothes	0.0000	0.0024	0.0003	0.0031	-0.0003	0.0013
House and durable goods	0.0349	0.0263	0.0391	0.0282	0.0306	0.0240
Services and rent	0.0087	0.0077	0.0045	0.0056	0.0136	0.0105
Taxes	0.0007	0.0010	0.0005	0.0008	0.0009	0.0012
Recreation, ceremony	0.0071	0.0057	0.0079	0.0066	0.0062	0.0047

$sCO2_{ij} = \beta_0 + \beta_{1_{ij}} \ln EXP_i + \beta_{2_{ij}} X_i + \varepsilon_{ij}$

Note: all coefficients are significant at 1%, estimations for different quintiles are mentioned in Appendix.

Conducting a simulation of a 10% increase in income (**Table 6**), we find that some of the priorities of households, if they were more affluent, would be to have more housing and durable goods, transportation, and services and rents. For instance, in the hypothetical case where a household has double total expenditure, i.e. a rise of about 100%, (double expenditure) the CO_2 emission for consuming durable goods and transportation increase by 3.4% and 2.7%, respectively.

Table 6: CO_2 emission shares and changes when total expenditure rises

CO2 emission of consumption category	Share from total emission (%) before expenditure rise		Change is share (% points), once 10% expenditure increase		Share (%) of CO2 emission to total CO2 after expenditure rise	
	2005	2009	2005	2009	2005	2009
Cereals	2.468	2.317	*-0.169*	*-0.095*	2.299	2.222
Vegetables and fruits	4.956	4.855	*-0.088*	*-0.066*	4.867	4.789
Oil and fat	1.108	1.003	*-0.044*	*-0.029*	1.064	0.974
Beverage	6.545	6.801	*0.045*	*-0.006*	6.590	6.794
Egg, fish, meat, dairy	7.603	7.290	*0.033*	*0.143*	7.636	7.433
Tobacco	3.249	3.052	*0.023*	*0.046*	3.272	3.098
Fuel and light	57.330	55.927	*-0.686*	*-0.916*	56.644	55.011
Telecommunication	0.572	0.903	*0.065*	*0.068*	0.637	0.971
Transportation	5.028	7.011	*0.277*	*0.334*	5.305	7.345
Health	0.466	0.579	*0.022*	*0.021*	0.488	0.600
Education	0.702	0.893	*-0.011*	*0.047*	0.691	0.940
Toiletry	0.759	0.672	*-0.012*	*-0.007*	0.747	0.664
Clothes	1.862	1.826	*0.000*	*0.024*	1.862	1.849
House and durable goods	2.837	2.683	*0.349*	*0.263*	3.186	2.946
Services and rent	2.833	2.880	*0.087*	*0.077*	2.920	2.957
Taxes	0.089	0.117	*0.007*	*0.010*	0.096	0.126
Recreation, ceremony	1.593	1.194	*0.071*	*0.057*	1.664	1.252

Source: own computation from Susenas 2005 and 2009.

However, it is important to note that there could be a different response to expenditure rises in different regions and income levels. For instance, how much CO_2 emissions from durable goods decrease due to rises in expenditure for rural households is higher than urban households, and vice versa. Finally, in general most of the estimated coefficients of expenditure elasticities are very small, but generally the directions of these expenditure elasticities to CO_2 emissions have the same signs as the conventional Engle curve. However, they have different sensitivities due to the different CO_2 intensities of the consumption categories. The small size of the expenditure elasticites indicates that the change in household emissions is mainly caused by a general volume increase in overall consumption, not by shifting the share of expenditures within the consumption basket.

7. Summary and policy implications

The objectives of this study are to analyze the household carbon footprint pattern in Indonesia and to analyze the determinants of the growing carbon footprint in this emerging economy. Of particular relevance is identifying possible trade-offs between increasing incomes (which are in line with poverty reduction) and the carbon intensive behavioral choices of households from the consumption side. In the transition economy, household (particularly energy related) consumption is an important element.

This study combines national input-output, and an emission intensities database to compute sectoral CO_2 emission intensities for Indonesia. These intensities were then matched with two waves of national expenditure surveys from 2005 and 2009 to calculate the carbon footprint for every household in the surveys. We further use this household CO_2 emissions information in investigating the drivers of the rise in emissions from a micro-cross sectional perspective.

Comparing CO_2 intensities, the results show that the transportation and fuel and light consumption categories are the two most CO_2intensive emitting sectors in Indonesia. These expenditures are also the main sources of overall household emission. In contrast, food or agriculture-related expenditures post the lowest CO_2 intensities as well as carbon emission levels. In terms of numbers, we found that there is an increase of households' carbon footprint from 2005 to 2009 by about 72.36% (or 24.90% if we deflate CO_2 and expenditure). Dividing households into per capita expenditure quintiles, we showed emission inequalities between quintiles as household from the middle quintiles (3^{rd} and 4^{th} quintile) and the highest quintile (5^{th} quintile) emit 2, 3 and 6 times the CO_2 that the first quintile emits. In addition, we found there is a significant difference of household carbon emissions between different income levels, regions, and education levels.

To understand the driver(s) of the variations in the household carbon footprint, we apply various regressions of household CO_2 emissions on household characteristics such as income, education, region, household population, as well as age and gender of the household head. We found that rising household expenditures is the main determinant of rising household emissions. It is clearly shown that varying income levels differ significantly in terms of their carbon footprint. Other household characteristics also contribute to the variation in emission levels. Urbanity, large household size, more educated, older and female household head, as well as households in Java provinces, all have a higher profile of CO_2 emissions.

The results of the decomposition analyses also show that changes in household emission levels are due primarily to the rise in per capita expenditures between household levels and over the two periods. Expenditure elasticities analysis suggested that the rise in household emissions is mainly caused by general increases in overall household consumption, and not by shifts in the consumption basket.

Our study raised some possible policy implications. First, as Indonesian per capita income (expenditure) grows, the future emissions will definitely rise. However, there would be a turning point where the household carbon emission would grow more slowly. Second, changes in the consumption habits toward less intensive emission goods would also reduce emissions. Finally, the above findings suggest comprehensive policies have to be taken into account in order to promote poverty reduction while controlling for the climate change that will result from the change in consumption patterns. Through policies that will make technological shifts, better and accurate energy subsidies and taxes, better infrastructure for mass and low carbon transportation, and clean technology, renewable-clean energy sectors and changes in consumption patterns, this issue could successfully managed. All of above issues have significant relevance to Indonesian as well as to global debates on how to reduce the carbon intensity of development paths.

Acknowledgements

The author would like to thank to Prof Stephan Klasen. J-Prof. Jann Lay for the supervision, and to EXPERTS - Erasmus Mundus Partnership in South and South-East Asia, EntdeKen Project, and GGG Göttingen for financial supports.

References

Ang, 2005. The LMDI approach to decomposition analysis: a practical guide, *Energy Policy* 32:1131-1139.

Banerjee, A.V. and Duflo, E., 2008. What is middle class about the middle classes around the world? *The Journal of Economic Perspectives: a Journal of the American Economic Association*, 22(2), p.3.

Bin, S. and Dowlatabadi, H., 2005. Consumer lifestyle approach to US energy use and the related CO2 emissions. *Energy Policy*, 33(2), pp.197–208.

Blinder, A.S. 2009. Wage Discrimination: Reduced form and structural estimates. *Journal of Human Resource, VIII 4.*

Carbon Dioxide Information Analysis Center (CDIAC). 2012. Ranking of the world's countries by 2009 per capita fossil-fuel CO2 emission rates. http://cdiac.ornl.gov/trends/emis/top2009.cap

Carbon Dioxide Information Analysis Center (CDIAC). 2013. Global Carbon Project - Full Global Carbon Budget (1959-2011). http://cdiac.ornl.gov/trends/emis/meth_reg.html

Deaton, A. and Muellbauer, J., 1980. *Economics and Consumer Behavior*, Cambridge University Press.

Deaton, A., 1997. The analysis of household surveys: a microeconometric approach to development policy, *World Bank Publications*.

Girod, B., and P. de Haan, 2009. GHG reduction potential of changes in consumption patterns and higher quality levels: Evidence from Swiss household consumption survey. *Energy Policy* 37 (12),5650-5661.

Grunewald, N. *et al.* 2012. The carbon footprint of the rising Indian middle class. *Chair of Development Economics Working Paper*. University of Goettingen (unpublished manuscript).

Heerink, N., Mulato, A. and Bulte, E. 2001. Income inequality and the environment: aggregation bias in environmental Kuznets curves, *Ecological Economics* 38 pp 359–367.

Huff, K., R. McDougall, T. Walmsley, 2000. Contributing Input-Output Tables to the GTAP Data Base. *GTAP Technical Paper*, No. 1 Release 4.2, January 2000.

Jann, B. 2008. The Blinder-Oaxaca decomposition for linear regression models. *The Stata Journal* 8(4): 453-479

Kaya, Y. 1990. *Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios* Paris: IPCC Energy and Industry Subgroup - Response Strategies Working Group

Kenny, T and Gray, N.F. 2009. A preliminary survey of household and personal carbon dioxide emissions in Ireland. *Environment InterTotal expenditure*, **35**, 259-272.

Kerkhof, N. S. and Moll, H., 2009. Relating the environmental impact of consumption to household expenditures: An input–output analysis. *Ecological Economics*, 68(4), pp.1160–1170.

Kok, R., Benders, R.M.J. and Moll, H.C., 2006. Measuring the environmental load of household consumption using some methods based on input–output energy analysis: A comparison of methods and a discussion of results. *Energy Policy*, 34(17), pp.2744–2761.

Lenzen, M. 1998. Energy and greenhouse gas cost of living for Australia during 1993/94. *Energy* Vol. 23, No. 6, pp. 497–516.

Lenzen, M., 1998a. Energy and greenhouse gas cost of living for Australia during 1993/94. *Energy*, 23(6), pp.497–516.

Lenzen, M., 1998b. Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis. *Energy Policy* 26(6), pp.495–506.

Lenzen, M., Pade, L.-L. and Munksgaard, J., 2004. CO2 multipliers in multi-region Input-Output models. *Economic Systems Research*, 16, pp.391–412.

Lenzen, M., M. Wier, C. Cohen, H. Hayami, S. Pachauri, R. Schaeffer. 2006. A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan. *Energy* 31 (2006) 181–207.

Leontief, W., 1970. Environmental Repercussions and the Economic Structure: An Input-Output Approach. *The Review of Economics and Statistics*, 52(3), pp.262–271.

Li, J. and Wang, Y. 2010. Income, lifestyle and household carbon footprints (carbon-income relationship), a micro-level analysis on China's urban and rural household surveys, *Environmental Economics* Vol. 1 (2).

Mishra, S. C. 2009. Economic Inequality in Indonesia: trend causes and policy responses. *Strategic Asia,* March 2009.

Murthy, N., Panda, M. and Parikh, J., 1997. Economic development, poverty reduction and carbon emissions in India. *Energy Economics*, 19(3), pp.327–354.

Oaxaca, R. 1973. Male-female wage differenctials in urban labor markets. *International Economic Review,* Vol 14, Issue 3 (Oct. 1973), 693-709

Pachauri, S. and D. Spreng. 2002. Direct and indirect energy requirements of households in India. *Energy policy*, 30(6), pp.511–523.

Parikh, J., M. Panda, and N.S. Murthy. 1997. Consumption patterns by income groups and carbon-dioxide implications for India: 1990-2010. *International Journal of Global Energy Issues*, 9(4-6), pp.237–255.

Peters, G.P., J. C. Minx, C. L. Weber, O. Edenhofer. 2011. Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences 108, 8903-8908. http://www.pnas.org/content/108/21/8903.abstract

Suh, S. 2009. *Handbook of Input-Output Economics in Industrial Ecology*. Springer. USA.

U.S. Energy Information Administration (EIA). 2012. International Energy Outlook 2011.

PEACE, 2007. Indonesia and Climate Charge: Current Status and Policies. http://siteresources.worldbank.org/INTINDONESIA/Resources/Environment/ClimateChange_Full_EN.pdf

Weber, C. L. and Matthews, H.S., 2008. Quantifying the global and distributional aspects of American household carbon footprint. *Ecological Economics*, 66(2-3), pp.379–391.

Wier, M. *et al*., 2001. Effects of household consumption patterns on CO2 requirements. *Economic Systems Research*, 13, pp.259–274.

Yusuf, A.A. 2006. On the re-assesment of inequality in Indonesia: household survey or national account? *MPRA Paper* No 1728, February 2007.

Appendices

1. Expenditure category: description

	Notes
Cereal	Rice, grains, and cereals
Vegetable and fruit	Vegetable and fruit
Oil and fat	Oil and fat ingredients
Beverage	Drink material, season, noodles, chips, alcohol drink
Egg, fish, meat, and dairy	Egg, fish, meat, dairy products
Tobacco	Tobacco
Fuel and light	Electricity bill, fuel
Telecommunication	Telephone bill, other telecommunication
Transportation	Transportation cost
Health	Health costs, health insurance
Education	Education costs
Toiletry	Soap, cosmetic, etc
Clothes	Clothes
House and durable goods	House and durable goods
Services and rent	Services
Taxes	Taxes, retribution, other taxes
Recreation, entertainment, ceremony	Recreation, entertainment, ceremony

2. Expenditure: share to total expenditure (%)

	2005			2009		
	National	**Rural**	**Urban**	**National**	**Rural**	**Urban**
Cereal	16.24	19.68	10.49	15.51	18.67	9.72
Vegetable and fruit	9.20	9.72	8.34	8.89	9.37	8.01
Oil and fat	3.08	3.51	2.35	2.81	3.21	2.09
Beverage	14.99	14.32	16.12	14.54	13.62	16.23
Egg, fish, meat, dairy	13.21	13.44	12.83	12.38	12.60	11.98
Tobacco	8.30	9.08	6.99	7.72	8.42	6.42
Fuel and light	6.62	6.08	7.54	6.12	5.87	6.58
Telecommunication	1.50	0.55	3.09	2.11	1.53	3.18
Transportation	3.49	2.64	4.91	4.50	3.86	5.68
Health	1.71	1.61	1.89	2.06	1.89	2.36
Education	2.58	1.93	3.65	2.84	2.41	3.62
Toiletry	2.94	2.84	3.11	2.49	2.46	2.54
Clothes	3.38	3.42	3.31	3.17	3.21	3.10
House and durable goods	2.15	2.13	2.17	2.02	2.02	2.02
Services and rent	11.26	9.11	14.86	11.07	9.17	14.53
Taxes	0.68	0.53	0.93	0.84	0.67	1.16
Recreation, entert'n, ceremony.	1.25	1.34	1.09	0.93	1.01	0.78

3. Elasticities to CO2 emission sources by quintiles, pooled estimation

	Q1	Q2	Q3	Q4	Q5	Overall
Cereal	-0.010	-0.011	-0.010	-0.008	-0.005	-0.009
Vegetable and fruit	-0.004	-0.006	-0.007	-0.009	-0.009	-0.007
Oil and fat	-0.003	-0.004	-0.004	-0.004	-0.003	-0.003
Beverage	0.003	0.004	0.001	0.003	-0.009	0.001
Egg, fish, meat, dairy	0.016	0.025	0.020	0.013	-0.006	0.011
Tobacco	0.016	0.010	0.006	-0.001	-0.006	0.004
Fuel and light	-0.061	-0.083	-0.084	-0.090	-0.076	-0.082
Telecommunication	0.004	0.005	0.007	0.009	0.006	0.007
Transportation	0.029	0.034	0.032	0.033	0.017	0.031
Health	0.000	0.001	0.002	0.003	0.005	0.002
Education	0.003	0.002	0.002	0.002	0.001	0.003
Toiletry	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Clothes	0.004	0.002	0.001	0.001	-0.001	0.002
House and durable goods	0.008	0.015	0.022	0.034	0.051	0.029
Services and rent	-0.004	0.002	0.005	0.008	0.021	0.007
Taxes	0.000	0.001	0.001	0.001	0.001	0.001
Recreation, ceremony	0.001	0.004	0.007	0.006	0.010	0.006
No of observations						549,659

$$sCO2_{ij} = \beta_0 + \beta_{1_{ij}} \ln EXP_i + \beta_{2_{ij}} X_i + \varepsilon_{ij}$$

4. Expenditure elasticites to CO2 emission shares, 2005 and 2009 estimation

	I		II		III		IV		V	
Share of CO2 emission	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Cereal	-0.0298	-0.0036	-0.0113	-0.0114	-0.0089	-0.0138	-0.0090	-0.0135	-0.0046	-0.0084
Vegetable and fruit	-0.0086	-0.0030	-0.0073	-0.0049	-0.0079	-0.0072	-0.0064	-0.0088	-0.0079	-0.0094
Oil and fat	-0.0065	-0.0017	-0.0043	-0.0030	-0.0047	-0.0038	-0.0041	-0.0041	-0.0025	-0.0028
Beverage	0.0099	-0.0007	-0.0014	0.0057	-0.0075	0.0056	-0.0130	0.0000	-0.0102	-0.0079
Egg, fish, meat, dairy	0.0087	0.0184	0.0096	0.0221	0.0128	0.0146	0.0075	0.0073	-0.0145	-0.0017
Tobacco	0.0088	0.0202	0.0138	0.0144	0.0116	0.0080	0.0068	0.0005	-0.0052	-0.0072
Fuel and light	-0.0026	-0.0911	-0.0459	-0.1007	-0.0548	-0.0956	-0.0565	-0.0857	-0.0690	-0.0776
Telecommunication	0.0006	0.0050	0.0010	0.0070	0.0024	0.0076	0.0051	0.0083	0.0062	0.0059
Transportation	0.0198	0.0349	0.0270	0.0445	0.0301	0.0467	0.0314	0.0375	0.0144	0.0195
Health	0.0001	-0.0002	-0.0006	0.0002	0.0000	0.0008	0.0010	0.0021	0.0043	0.0047
Education	-0.0011	0.0061	0.0039	0.0056	0.0034	0.0061	0.0011	0.0055	-0.0024	0.0037
Toiletry	-0.0018	-0.0006	-0.0008	-0.0011	-0.0006	-0.0012	-0.0009	-0.0012	-0.0010	-0.0006
Clothes	0.0021	0.0057	0.0036	0.0054	0.0027	0.0024	0.0016	0.0022	-0.0010	-0.0008
House and durable goods	0.0076	0.0078	0.0140	0.0104	0.0156	0.0184	0.0285	0.0320	0.0565	0.0487
Services and rent	-0.0083	-0.0019	-0.0046	-0.0005	-0.0040	0.0019	-0.0009	0.0064	0.0215	0.0216
Taxes	-0.0002	0.0003	0.0004	0.0005	0.0003	0.0007	0.0004	0.0010	0.0014	0.0016
Recreation, ceremony	-0.0009	0.0028	0.0011	0.0029	0.0074	0.0057	0.0055	0.0072	0.0129	0.0083

$$sCO2_{ij} = \beta_0 + \beta_{1_{ij}} \ln EXP_i + \beta_{2_{ij}} X_i + \varepsilon_{ij}$$